PENNSYLVANIA STATE PLAN FOR ELECTRIC VEHICLE MOBILITY

July 2022

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List of Abbreviations

AC	Alternating current
AFC	Alternative fuel corridor
AFDC	Alternative Fuel Data Center
AFIG	Alternative Fuels Incentive Grant
AFLEET	Alternative fuel life-cycle environmental and economic transportation
ADA	Americans with Disabilities Act
AV	Automated vehicle
AADT	Average annual daily traffic
BEV	Battery electric vehicle
BIL	Bipartisan Infrastructure Law
CO_2	Carbon dioxide
CCS	Combined Charging System
CMAQ	Congestion mitigation and air quality
DEP	Department of Environmental Protection
DCFC	Direct current fast charger
DCNR	Department of Conservation and Natural Resources
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
EIA	Energy Information Administration
EJ	Environmental justice
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FCEV	Fuel cell electric vehicle
GHG	Greenhouse gas
HDV	Heavy-duty vehicle
HEV	Hybrid electric vehicle
IIJA	Infrastructure Investment and Jobs Act
ICE	Internal combustion engine
ICCT	International Council on Clean Transportation
L2	Level 2 (charger)
LDV	Light-duty vehicle
LEV	Low emission vehicle
MDV	Medium-duty vehicle
MCS	Megawatt charging system
MOU	Memorandum of understanding
MPGGE	Miles per gasoline gallon equivalent
NEVI	National electric vehicle infrastructure
NHS	National highway system
NREL	National Renewable Energy Lab
NERC	North American Electric Reliability Corporation
PennDOT	Pennsylvania Department of Transportation
PEV	Plug-in electric vehicle
PHEV	Plug-in hybrid electric vehicle
P3	Public-private partnership
REEV	Range extending electric vehicle
ROP	Regional operations plan
RFC	ReliabilityFirst Corporation

RFP	Request for proposals
RoS	Routes of significance
SES	Socio-economic status
TNC	Transportation network company
TSMO	Transportation systems management and operation
USDOT	United States Department of Transportation
ZEV	Zero-emission vehicle

Definitions

Alternative fuel corridor
FHWA has established a formal designation for alternative fuel corridors. The original corridors were designated over five rounds by FHWA and include segments of 134 Interstates and 125 US and state highways. The NEVI formula program, part of the Bipartisan Infrastructure Law (BIL), prescribes new requirements on Interstate highways (directly transcribed from NEVI formula program guidance):

- Electric vehicle (EV) charging infrastructure is installed every 50 miles along the State's portions of the Interstate Highway System within 1 travel mile of the Interstate, unless a discretionary exception has been granted,
- EV charging infrastructure includes at least four 150kW Direct Current (DC) Fast Chargers with Combined Charging System (CCS) ports capable of simultaneously DC charging four EVs,
- EV charging infrastructure has minimum station power capability at or above 600kW and supports at least 150kW per port simultaneously across four ports for charging, and
- Such additional considerations deemed necessary and appropriate by the Secretary of Transportation.

EV Charging terminology

- Chargers or charging stations – Single charging units that generally are placed at one parking stall or between stalls; may have multiple ports
- EVSE (Electric vehicle supply equipment) – The equipment used to deliver electrical energy from an electricity source to an EV battery
- Charging locations – General places (e.g., I-80 interchange 299) where EV charging is being discussed
- Charging sites – Precise places (e.g., park and ride parking lot) where EV charging is being discussed
- Ports – One CCS or other port where an EV can plug in to receive charge
- Publicly-available – Chargers that are open to any person to use to charge their EV; may be on public or private sites, but are accessible to anyone

Direct current fast charging (DCFC)
DC fast chargers are the fastest chargers currently available for charging light-duty vehicles. This type of charging can be provided at a range of power levels from 50-350+ kW. There are two standard plug types for DCFC including CHAdeMO and SAE J1772 Combo (CCS), although industry has recently coalesced around CCS. Support for legacy vehicles using CHAdeMO can be considered as needed. Note that this study does not include Tesla chargers as they are currently proprietary and can only be used by Tesla vehicles.

Environmental Protection Agency (EPA) Emissions Classifications

- Light-duty passenger vehicles have a max gross vehicle weight rating of 8,500 lbs. This encompasses sedans, SUVs, pickup trucks, and minivans.
- Medium-duty passenger vehicles have a gross vehicle weight rating from 8,500-10,000 lbs.
- Heavy-duty trucks have a gross vehicle weight rating above 8,500 lbs. The EPA has many sub-categories that separate this group, with the largest being Heavy Duty Vehicle 8b, which includes trucks over 60,000 lbs.

Interstate look-alike
In Pennsylvania, an Interstate look-alike is defined as a controlled-access freeway that operates similarly to an Interstate highway but is a US or state highway. These do not include limited-access arterials that have at-grade crossings.

Level 2 (L2) charger
AC (alternating current) Level 2 charging is the standard for lower-speed charging for most EVs. These systems utilize a 240 V plug (typical of those used for heavy equipment such as clothes dryers) to provide faster charging than Level 1, which uses a typical 120 V residential outlet. The standard plug for L2 charging is a SAE J1772 plug. L2 chargers should be located at sites where longer dwell times are possible, such as at destinations or near shops and restaurants.

Routes of significance (RoS)
As part of Pennsylvania's Regional Operations Plan (ROP) development process, each region in PA has developed "Corridors and Areas of Transportation Significance," referred to in this memo as "Routes of Significance." All routes on the PA 511 core network[1] are included as RoS. Additional routes are included at the discretion of the ROP development group. PennDOT states that RoS are defined as those that are important for the transportation of goods and services, and that significantly contribute to the economic sustainability and growth throughout the region.

[1] PA 511 core network routes are a network of routes included in PA's 511 system. The PA 511 system provides reliable traffic, weather, and transit information to travelers on these routes. The routes were selected as part of the design process of the 511 system.

Executive Summary

2,000 New EV Charging Ports at 800 Sites in 5 Years

Pennsylvania is actively supporting the adoption of EVs across the Commonwealth. The Federal Highway Administration (FHWA) is aggressively supporting EVs and has expanded and created several programs as part of the Bipartisan Infrastructure Law (BIL)[2].

Pennsylvania's Department of Environmental Protection (DEP) developed an EV roadmap for Pennsylvania in 2019 and updated the plan in 2021. In line with this effort, Pennsylvania Department of Transportation (PennDOT) is establishing an EV Mobility Plan. The EV Mobility Plan identifies specific actions PennDOT can take to facilitate the transition to electrified mobility across Pennsylvania. This plan lays the groundwork for the next step, which is the development of a full NEVI (National Electric Vehicle Infrastructure) plan to meet FHWA's objectives.

This plan recommends PennDOT support the installation of least 2,000 new EV charging ports at 800 sites by 2028. This will be accomplished by leveraging various funding mechanisms across the state, as well as funding from the IIJA/BIL. $170 Million is earmarked for Pennsylvania for this period through the NEVI formula program. 2,000 charging ports will cost anywhere from $250 Million (50/50 mix of L2/DCFC) to $500,000 Million (all DCFC)[3], depending on the mix of charger types. PennDOT can leverage a percentage of the NEVI formula funding, the NEVI discretionary grant program, the NEVI corridor and community grant programs, and budgeting mechanisms to meet this goal. As part of updating this plan in the next few years, this goal may be increased.

Figure 1 provides a high-level view of the recommended PennDOT EV Mobility 5-Year Plan. Upgrading all Interstates to alternative fuel corridors (AFCs) under the new FHWA guidance is the main priority, with many additional areas of focus to be addressed over the next five years. Specific numbers of chargers recommended in this plan are meant as a guideline, not as a rule. As this is an evolving space, PennDOT should update these numbers annually during the five-year period.

Goals

To concentrate effort for PennDOT's planning for EV mobility, three primary and three secondary goals were developed around travel needs of Pennsylvanians. These six high-level goals are further split into 13 focus areas. These are summarized in Figure 2 below and explored in detail in Chapter 2. The next step to be completed following this plan is to re-examine goals as part of the NEVI Plan.

Primary Goals

1. Interstate / long-distance travel – alternative fuel corridors, gaps, and Interstate look-alikes
2. Regional RoS – three levels based on traffic volumes
3. Destination travel – year-round and seasonal destinations

Secondary Goals

4. Emergency travel – mobile solutions and emergency routes
5. Commuter travel – mobility hubs / multimodal travel
6. Medium- and heavy-duty travel – Long-distance travel, rural deliveries, and emergencies

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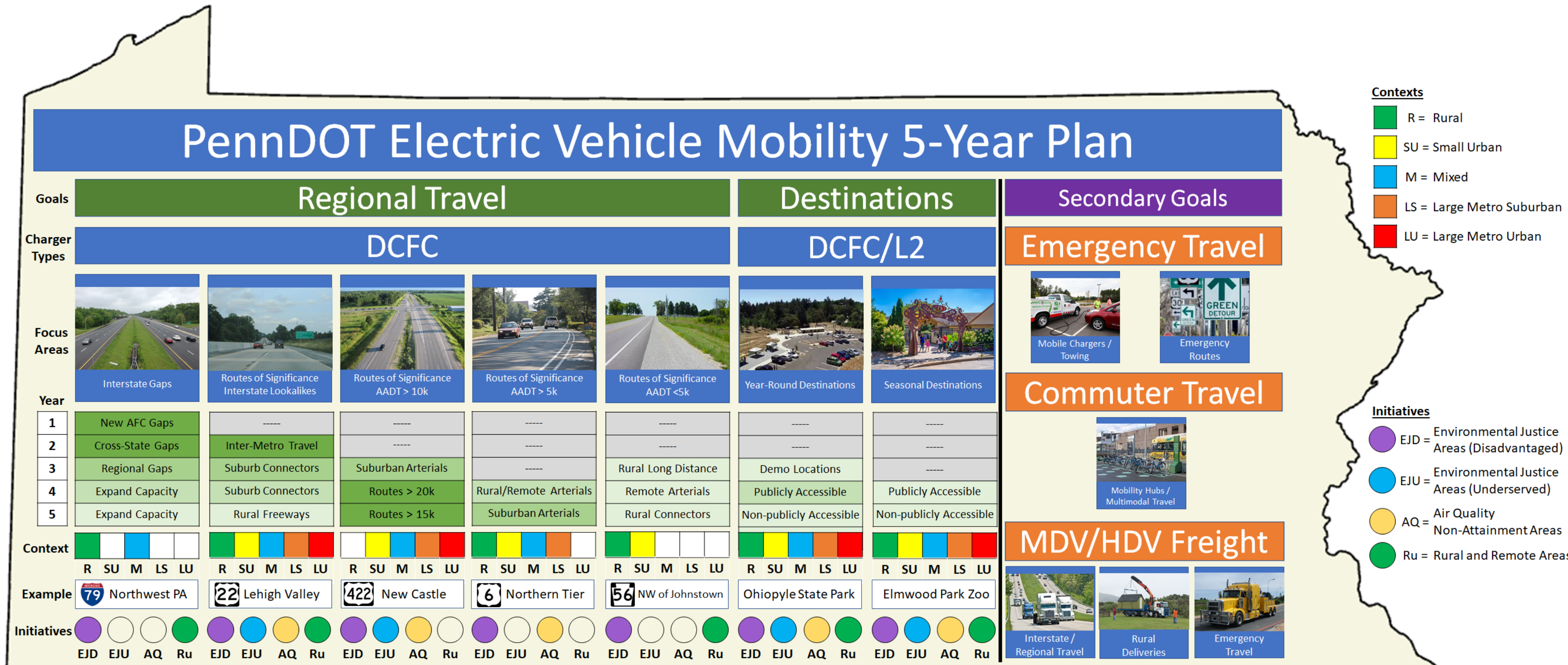
[2] Also referred to as the Infrastructure Investment and Jobs Act (IIJA)

[3] DCFC installations range from $20k-$150k, depending on power requirements, existing power grid and networks, construction costs, and support equipment. L2 installations cost from $2,500 to $5,000 per charger. Factors such as NEVI funding's "Buy America" requirement, inflation, and supply chain shortages may cause these rates to increase. Thus, conservative values of $250k per DCFC and $10k per L2 installation are used.



Objectives

Economic	Grow the EV market in Pennsylvania by making smart EVSE infrastructure decisions
Safety	Provide safe charging locations and support motorist emergencies
Mobility	Increase range confidence by making every square mile of PA reachable by EV
Environment	Reduce levels of greenhouse gas emissions and quantity of air pollutants
Equity	Provide EVSE in underserved areas, disadvantaged communities, and rural PA

Five-Year Metrics

EV Chargers	2,000 new EV charging ports
EVSE Locations	800 new EV charging sites
Interstate Coverage	All interstates and look-alikes in PA have EVSE every 20 miles or less
Air Quality	Reduce annual CO_2 emissions by 4 Million Metric tons
Environmental Justice	320 charging sites in environmental justice areas

Figure 1. PennDOT EV Mobility 5-Year Plan

	Goals	Focus Areas
Primary	Interstate / Long-Distance Travel	• Interstate Gaps • Interstate Look-alikes
	Regional Routes of Significance (RoS)	• High to Very High Traffic Volume • 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

Figure 2. Outline of PennDOT EV Charging Goals

The Need for Public Charging

The International Council on Clean Transportation (ICCT) predicts there will be 26 million EVs on the road in the United States by 2030, with 15 million of these on the road by 2028[4] including 360,000 in Pennsylvania. This is in line with the low estimate presented in Pennsylvania's EV Roadmap[5]. High estimates in the EV Roadmap predict nearly 1 million EVs in Pennsylvania by 2028.

To meet the ICCT estimate of EV demand, Pennsylvania will need around 50,000 non-home chargers by 2028. This EVSE will be a mix of public and private installations. To support this level of charging access, it is recommended that PennDOT support the installation of 2,000 charging ports at 800 sites by 2028. It should be noted that 2,000 currently considered the low bar, and more aggressive installation strategies are also explored in this report.

Table 14 in Section 3.2.4 summarizes these EV and charging estimations. This table also splits out types of non-home chargers needed further into three groups: workplace, public Level 2 (L2) chargers, and public direct current fast chargers (DCFCs). Detail on the data behind this table are presented in Section 3.2.4.

[4] Interpolated based on https://theicct.org/wp-content/uploads/2021/12/charging-up-america-jul2021.pdf, International Council on Clean Transportation (theicct.org)
[5] https://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAEVRoadmap.pdf

Objectives

Beyond the economic demand for charging, there are additional objectives that should be adhered to as growth in EVs is supported in Pennsylvania. Each of the five objectives – economic, safety, mobility, environment, and equity – are summarized in Table 1.

Table 1. Primary Objectives of the EV Mobility Plan

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 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 the goals of the Justice40 initiative[6], each goal should be fulfilled in an equitable way so all groups, including disadvantaged and underserved communities, can benefit from the positive outcomes.

Equity Initiatives

To ensure equitable access to EVs in Pennsylvania, four initiatives have been identified to guide EVSE location decisions and fill critical market gaps.

- Environmental Justice (EJ) Areas
  - High-minority EJ populations
  - Low-income EJ populations
- Rural and Remote Areas
- Air Quality Non-Attainment Areas

Proposed Charging Locations

This plan provides guidance on general locations where EVSE should be installed, guided by the outlined goals, focus areas, objectives, and equity initiatives. At many of these locations, more than one charger/port is recommended, and many of the locations should plan for future expansion by providing more space and electrical capacity.

Figure 3 shows 461 charging locations recommended from the high-level analysis to be considered for EVSE installation during the five-year plan. Chapter 3 breaks these locations down in detail and provides a rationale for the selections. Additional and alternative locations should be selected and added as the 5-year plan progresses and as needs grow and adapt.

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[6] https://www.transportation.gov/equity-Justice40

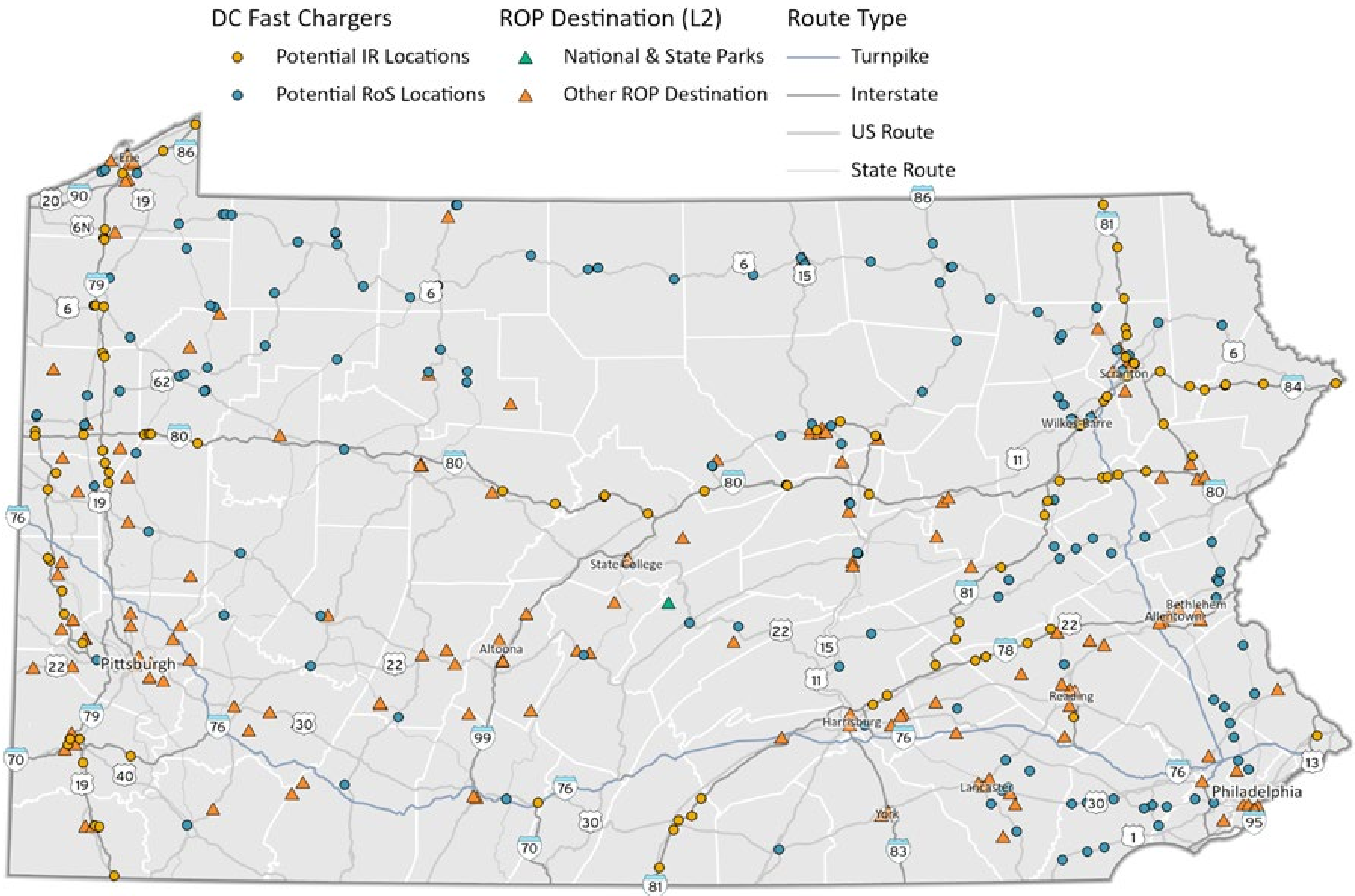

Figure 3. 461 Recommended Locations for EVSE Installation Consideration

Five-Year Metrics

Table 2 lists the metrics will be used to measure the success of the EV Mobility Plan and corresponding initiatives.

Table 2. 5-Year EV Mobility Plan Metrics

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

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

Next Steps

The EV Mobility Plan lays out the existing EV mobility infrastructure in PA and makes recommendations on moving forward with a 5-year plan. To support the plan, more work will need to be done in various areas. The first phase of this development will be the NEVI Plan, which will be developed in mid-2022. The NEVI Plan will focus on specific strategies to implement portions of this plan as specified under the BIL legislation.

- Planning
  - Finalize phases of EVSE deployment
  - Develop standard procurement plan
  - Plan for upgrading corridors to the new AFC EV Ready for AFC Round 6
  - Identify new alternative fuel corridors
- Coordination and outreach
  - Metropolitan Planning Organizations (MPOs) and Rural Planning Organizations (RPOs)
  - Public-private partnership (P3) partner identification and development
  - Clean Cities' partners
  - Utilities
  - Other third parties (e.g., site hosts)
  - Public education
- Site selection and design
  - Scoring criteria for site selection (e.g., jobs, population, traffic, equity)
  - Determine the quantity of chargers at each location
  - Develop standards for EV sites

EV Mobility Plan Outline

This EV Mobility Plan is broken down into the following chapters and appendices:

1. Background
Background on EVs in Pennsylvania and discussion of EV technology, best practices, climate and air quality, and equity considerations

2. Goals and Objectives
Detail on the goals and objectives of EVSE deployment which directs the EV Mobility Plan recommendations

3. Existing Conditions and Recommendations
Scan of the existing EV charging network in Pennsylvania to inform detailed recommendations, including analysis and methodology

4. Recommendations for 5-Year Mobility Plan
Detailed recommendation for 13 focus areas of EVSE installations in PA as part of the 5-Year Mobility Plan

5. Next Steps
Outline of the next steps needed to implement the EV Mobility Plan including recommendations for the NEVI Plan

Appendix A. Technology Scan
A summary of the current and future alternative fuel technologies and support systems

Appendix B. Best Practices
Discussion of EV Mobility Plan best practices including examples from other entities and barriers to EV adoption

Appendix C. Impact on Climate and Air Quality
Examination of the potential of the EV Mobility Plan to reduce greenhouse emissions and pollution

Appendix D. Equity Considerations
Discussion of the equity challenges of EVSE deployment and methods of addressing these challenges

Appendix E. Additional Maps and GIS Files
Additional maps were prepared to assist with EV planning efforts including digital project data

Appendix F. PennDOT's EV Equity Guiding Principles
In February 2022, PennDOT released their 18-point equity guiding principles document including many points addressed in this report

1 Background

Pennsylvania has been taking several steps forward to actively pursue electrification efforts and planning on multiple fronts to help advance EV adoption over the next five years. With the advent of the NEVI Plan as part of the IIJA/BIL, there will be significant funding over this period.

1.1 Pennsylvania's EV Roadmap

Pennsylvania's DEP developed an EV Roadmap for Pennsylvania in February 2019[7] and updated the roadmap in January 2021[8]. The purpose of this roadmap was to review the state of the EV market in Pennsylvania, define a set of proposed strategies to support the expansion of the EV market, and provide estimates of the potential benefits and impacts to the state from an increased EV market. The EV roadmap was used as a baseline for many of the recommendations in this EV Mobility Plan. A summary of recommended strategies from the 2019 EV plan are shown in Table 3.

Table 3. Timeline of Recommended Strategies to Support EV Adoption in Pennsylvania[9]

Strategy	Near-term actions (0-2 years)	Mid-term actions (2-5 years)	Long-term actions (5+ years)
Establish utility transportation electrification directive			
Establish statewide EV sales goals			
Expand and improve AFIG rebate program			
Strengthen statewide EVSE network planning, investment, and communications			
Establish fleet education, cooperative purchase, and technical assistance program			
Create EV marketing and education campaign targeted at consumers			
Establish dealer outreach and support program			
Encourage residential and commercial EV rate designs			
Advance public and residential EVSE investment			
Develop municipal support, technical assistance, and grant program			
Establish workplace and multifamily EVSE education and outreach programs			
Adopt EV-ready building code amendments			
Explore development of financing for EVs/EVSE			

[7] https://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAEVRoadmap.pdf

[8] https://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAElectricVehRoadmapBookletDEP5334.pdf

[9] Reproduced from the Pennsylvania EV Roadmap, https://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAEVRoadmap.pdf

Several of the near-term recommendations were acted upon over the past three years. The items below were addressed in the 2021 EV roadmap update.

- ***Expand and improve Alternative Fuels Incentive Grant (AFIG) rebate program:*** In 2019 the DEP Alternative Fuel Vehicles Rebate Program[10] provided Pennsylvanians with over 2,400 rebates, totaling more than $3.6 million, for the purchase of a new or used battery electric or plug-in hybrid vehicle for personal use. Low-income households are eligible for higher rebate amounts.
- ***Establish statewide EV sales goal:*** Other states have set sales mandates or financial incentives to increase EV model availability. A bill was considered in the Pennsylvania 2019-20 legislative session that would have required electric utilities to invest in charging infrastructure and establish an EV sales goal of at least 50 percent above market forecasts. A similar bill is expected to be considered in the 2021-22 session (Senate Bill 435)[11].
- ***Advance public and residential EVSE investment:*** The DEP Driving PA Forward program[12] launched rebates to incentivize new L2 charging infrastructure and competitive grants to support new public DC fast charging stations. Any organization, business, or government can apply for these rebates and grants. DC fast charging station projects located in EJ areas receive higher consideration.

1.2 Status of EVs in Pennsylvania and Goals Overview

Currently, municipalities and regions across the state have deployed varying levels of charging infrastructure, with about 1,469 public Level 2 or DC Fast Chargers available throughout the state as of 2020[13]. Although the statewide network is growing, significant gaps exist in the electric EVSE network when considering regional and destination travel across Pennsylvania.

To meet the needs of current EV owners and grow the system to accommodate and incentivize future EV owners, an aggressive strategy is recommended to install 2,000 EV charging ports at 800 sites by the beginning of 2028. Specific recommendations for a phased approach to meet the six high-level goals and 13 focus areas are discussed in this plan (see Table 8 for complete list).

The primary focus for this effort is to improve the EVSE network, or charging stations, for the passenger vehicle segment. Light-duty vehicles (LDVs) are the primary focus of Pennsylvania's EV Roadmap. LDVs make up 89% of vehicle miles traveled in Pennsylvania[14] and as such have the widest-spread need for reliable EVSE across the state.

Specific goals and objectives are addressed in detail in Chapter 2. Recommendations are discussed in Chapter 4.

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[10] dep.pa.gov/Citizens/GrantsLoansRebates/Alternative-Fuels-Incentive-Grant/Pages/Alternative-Fuel-Vehicles.aspx
[11] https://www.legis.state.pa.us/cfdocs/billinfo/billinfo.cfm?syear=2021&sind=0&body=S&type=B&bn=435
[12] http://www.depgis.state.pa.us/drivingpaforward/
[13] PA EV Roadmap, 2021 Update: https://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAElectricVehRoadmapBookletDEP5334.pdf
[14] PennDOT Highway Statistics 2016

1.3 EV Technologies

A multitude of technologies currently exist in the market or anticipated to exist in the near future as it relates to EVs and alternative energy sources to power EVs. EVs have two common drivetrain types, plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). BEVs primarily benefit from charging infrastructure, as PHEVs primarily rely on the gasoline while enroute. Hybrid electric vehicles (HEVs) charge through internal mechanisms and do not plug in, thus are not included in this report.

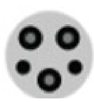
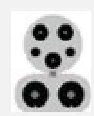
There are three primary types of EV charging for light duty BEVs (Table 4). The charge times vary depending on the type of charger, on-board vehicle charging equipment, the vehicle's battery capacity and type of battery, and the battery's depletion level. The two primary methods discussed in this plan are DCFC, recommended for Interstates and RoS, and L2 charging, recommended for destination charging where dwell times are long enough to top off battery charge.

The mix of chargers will include L2s and DCFCs. Only BEVs can use the DCFCs, whereas L2 chargers can be used to charge PHEVs as well as BEVs. Early / legacy EVs could only charge to 50kW. In an emergency, a L2 charger could provide 50 miles of range to get the vehicle to the next DCFC location.

The plan should maintain budgetary flexibility to take advantage of new EV and EVSE technologies that can be expected in the coming 5-year period. For example, chargers can move toward wireless connections (as well as in-ground transmitters). The EVSE could derive power from solar arrays or wind generators with battery back-up. Heavy-duty trucks may be powered by hydrogen-fueled fuel cells. This will allow for PennDOT to take best advantage of evolving technologies as the plan progresses.

Other charging options and technologies are discussed in the full technology scan, included as Appendix A.

Table 4. EV Charging Types for Light-Duty Vehicles

Level 1 (AC) Charging (Home use)	Level 2 (AC) Charging (Home and public charging)	DC Fast Charging (Public Charging)
• Lower Power AC • 120-volt (V) AC circuit or 20 amperes (A) • 4-6 miles of range per hour of charge • Charger unit cost (single port) range: $300-$1,500 • Installation cost: $0-$3,000 • Most often used in homes, sometimes used at workplaces	• Mid to High Power AC • 208/240-volt (V) AC circuit or 20-100 amperes (A) • 10-20 miles of range per hour of charge • Charger unit cost range: $400-$6,500 • Installation cost: $600-$12,700 (~$3,000 average) • Used in homes, workplaces, and for public charging	• DC Power • 208/480-volt (V) AC 3-phase or 20-400 amperes (A) • Charger unit cost range: $10,000-$40,000 • Installation cost: $4,000-$150,000 • Higher maintenance costs. Higher power requires water-cooled cables. • Most often used for public charging, along heavy traffic corridors. Higher power EVSEs suitable for buses and mid- to heavy trucks (higher power DC fast chargers in development).
SAE J1772: Any vehicle with this plug receptacle can  use any Level 1 or Level 2 charger. All major vehicle (except Tesla) and charging system manufacturers support this standard.		**CHAdeMO:** This fast-charging connector  type is now considered to be a legacy standard, with Nissan now discontinuing the CHAdeMO connector type on new vehicles[15]. **J1772 Combo (CCS):** This is the most  common DC fast charger plug. Uses the same SAE J1772 charge port when charging with Level 1 or 2. The CCS plug includes 2 additional DC pins below the standard J1772 plug. All new EVs that can accept a DC Fast charge now come with the CCS connector type or an adaptor. **Tesla combo:** This is a unique charge port  for Tesla vehicles capable of Level 1 to supercharging levels.

[15] https://insideevs.com/news/433929/nissan-switches-to-ccs-in-us-europe/

1.4 Nationwide Best Practices

To ensure the best practices are implemented with regards to the EV Mobility Plan, the project team met with five transportation entities from other state DOTs and agencies who have advanced EV mobility. The discussion focused on the efforts or initiatives already taken to foster EV adoption, advance favorable policies, plan for EV charger infrastructure, conduct utility coordination, address equity, and measure environmental benefits. Table 5 summarizes the key takeaways from the benchmarking calls.

The full best practices overview, complete with state-by-state specific information, is included as Appendix B.

Table 5. Summary of Benchmarking Best Practices

Topic	Advice and Key Observations
General	Collaboration is key. Coordinate with utilities, MPOs and RPOs, Clean Cities organizations, county and local municipalities, businesses, developers, and vendors throughout the process.
	Automated vehicle companies aren't deploying in rural or low-income areas due to a lack of EV charging.
	Highly visible charging every 50 miles along major corridors will provide potential buyers the confidence to convert to an EV.
	The State can play a role in filling the EV charging coverage gaps that the private sector won't fill because there is not yet a business case to do so.
Fleet and Employee Charging	Consider replacing state fleet vehicles with EVs to lead by example.
	Plan to get more EVs on the Commonwealth term contract.
	Survey employees to identify which facility locations to prioritize.
EV Adoption	Consumer EV rebate programs and EV charger rebate programs have proven to be a beneficial piece to spur EV adoption.
	Education programs help consumers understand the benefits of electrification.
Funding	States should consider other road use fees to offset gas tax revenue lost because of more widespread EV adoption.
	Consider outreach, support programs, and financial incentives for auto dealers to increase the number of EV options available in the state.
Site Planning	While EV signage at exits and along corridors may not be needed by EV drivers themselves, as most rely on smartphone apps or in-car navigation systems to get to chargers, it serves a public relations purpose. It helps demonstrate to potential EV buyers that charging is widely available.
	Follow ADA guidelines for all charging equipment and ensure at least one accessible space per installation.
	Where space allows, orient chargers so that vehicles pulling trailers can access them.
	Consider sites that offer redundant power or are candidates for backup power generation (including natural gas) for chargers.
	The power level of Direct Current Fast Charging should be at least 150kW to serve Interstate travel and help future proof sites for new EV models coming to the market.
Policy	Include requirement for site hosts to share charger usage data in RFP and agreements.
	Review zoning requirements and modify, if necessary, to encourage – not perpetuate barriers – for businesses to install EV charging.
	Require EV-ready infrastructure be installed for new construction or major building improvements. This includes the installation of wire and conduit, and that sufficient electrical capacity is available for future charger installation. In the future, charger installation could be required as well.

1.5 Impact on Climate and Air Quality

Climate change and health impacts from poor air quality are already making significant impacts across Pennsylvania and disproportionately impacting systemically disadvantaged and underserved communities. One of the primary motivations in transitioning the vehicle fleet to electric is to reduce and ultimately eliminate tailpipe emissions.

According to the US Energy Information Administration (EIA), CO_2 emissions related to the transportation sector accounted for 37.6% of the nation's total[16] in 2019 (the most recent data available). Pennsylvania's transportation sector accounts for about 28.2% of the state's emissions. Reducing emissions will both lessen the impacts of climate change and reduce the effects of air pollution in Pennsylvania.

The PA EV Roadmap outlined four possible scenarios for EV deployment based on high and low levels of technology support and policy support to estimate items such as energy use, greenhouse gas (GHG) emissions, criteria pollutant emissions, social impacts, and cost-benefit results.

In an effort to simplify and update the process used in the PA EV Roadmap, two scenarios were modeled as part of this plan, using Pennsylvania vehicle registration data as a basis. Descriptions of the two scenarios are shown below:

- Scenario 1: The first scenario is based off the projected EV adoption trendline using actual registration data from 2013-2020. A best fit polynomial trendline was developed for future years to project a more status quo rate of EV adoption.
- Scenario 2: The second scenario projects a more aggressive adoption rate trajectory assuming that PA adopts more EV-supportive policies such as California's zero-emission vehicle (ZEV) standard[17]. By signing the ZEV memorandum of understanding (MOU)[18], PA will commit to fleet EV adoption goals that they will try to achieve in future milestone years. Using goals that similar ZEV states have set, it was assumed that PA would reach 5% total passenger vehicle EV registrations by 2025, 8.9% by 2030, 14.7% by 2040, and 20.6% by 2050[19]. Using these milestone targets by year, a trendline was projected from the baseline year of 2020.

Argonne National Laboratory's Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) tool was then used to calculate the EV Mobility Plan specific impacts to climate and air quality.

Table 6 shows the estimated baseline year of 2020 at 34.7 million metric tons of GHGs for both scenarios. Table 7 estimates the criteria pollutants by scenario and year using data from AFLEET.

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[16] https://www.eia.gov/environment/emissions/state/

[17] https://ww2.arb.ca.gov/sites/default/files/2022-03/%C2%A7177%20States%20%283-17-2022%29%20%28NADA%20sales%29.pdf

[18] Pennsylvania has already adopted California's low emission vehicle (LEV) program that sets limits for tailpipe pollution for auto manufacturers, meaning it requires manufacturers to deliver new light- and medium-duty vehicles to the Pennsylvania market that produce lower emissions of greenhouse gas and other air pollutants.

[19] https://mjbradley.com/sites/default/files/NE_PEV_CB_Analysis_Methodology.pdf

Table 6. Projected Light Duty Passenger Vehicle GHG Emissions by Scenario and Year

Greenhouse Gas Emissions, million metric tons		
Year	Scenario 1	Scenario 2
2020	34.7	34.7
2023	-0.17%	-1.84%
2028	-0.80%	-4.35%
2033	-2.01%	-6.36%

Table 7. Projected Light Duty Passenger Vehicle Criteria Pollutants by Scenario and Year

Criteria Pollutant, millions of lbs.		2020	2023	2028	2033
Carbon Monoxide (CO)	Scenario 1	289.9	-0.3%	-1.3%	-3.4%
	Scenario 2	289.9	-3.1%	-7.3%	-10.6%
Nitrogen oxides (NOx)	Scenario 1	3.9	-0.3%	-1.3%	-3.4%
	Scenario 2	3.9	-3.1%	-7.3%	-10.6%
Large particulate matter (PM10)	Scenario 1	7.3	0.0%	-0.1%	-0.2%
	Scenario 2	7.3	-0.2%	-0.4%	-0.6%
Fine particulate matter (PM2.5)	Scenario 1	1.3	-0.1%	-0.4%	-1.1%
	Scenario 2	1.3	-1.0%	-2.4%	-3.5%
Volatile organic compounds (VOC)	Scenario 1	37.2	-0.3%	-1.3%	-3.4%
	Scenario 2	37.2	-3.1%	-7.3%	-10.6%
Sulfur oxides (SOx)	Scenario 1	0.4	-0.3%	-1.3%	-3.4%
	Scenario 2	0.4	-3.1%	-7.3%	-10.6%

In 2018, the transportation sector in Pennsylvania was responsible for 61.2 million metric tons of CO_2 emissions[20] of which 34.7 million metric tons are attributed to LDVs. This plan specifically recommends that a target be set to reduce annual GHG emissions by 1.5 million metric tons by 2028, which aligns with the Scenario 2 estimate of a 4.35% reduction.

The full climate and air quality overview is included as Appendix C.

[20] https://www.eia.gov/environment/emissions/state/excel/table4.xlsx

1.6 Equity Considerations

Economic incentives often do not align with equitable technological proliferation. In the interest of providing EV access to diverse population within Pennsylvania and aligning with the 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.

At the center of the equity discussion surrounding EVs is EJ. The term itself dates to the 1980s, but the idea is based upon justice for racist policies and decisions, particularly in the early- to mid-20th century, that led to disproportionate environmental quality in communities of color across the United States. Over the years, the term has expanded to include unequal environmental outcomes across many groups including disadvantaged groups. Low socio-economic status (SES) communities generally experience lower air quality because of higher exposure to traffic and air pollution. Supporting the replacement of vehicles that burn fossil fuels with ZEVs, including EVs, will support positive public health impacts in low SES neighborhoods.

PennDOT recently developed 18 EV equity guiding principles in five general areas[21]:

A. Make EVs more affordable
B. Make EV charging more accessible
C. Invest in fleet electrification
D. Invest in Traditionally Underserved, Low-income, Persons of Color, and Otherwise Vulnerable Population Areas
E. Increase EV Awareness, Education, and Technical Capacity

These areas are addressed throughout this plan as relevant. This plan specifically addresses the needs of low-income communities and high minority communities. Additional consideration is given to supporting people with disabilities. Figure 4 (statewide) and Figure 5 (metropolitan insets) identify EJ communities by race, defined as census tracts where more than 30% of the population identifies as a non-white minority. Figure 6 (statewide) and Figure 7 (metropolitan insets) highlight EJ communities by income level, identified as a census tract where 20% or more of people live at or below the federal poverty level.

This plan sets a goal of establishing EV charging sites in 320 EJ areas by the end of the five-year period. This follows the Justice40 initiative in designating 40% of EV resources towards EJ areas. Using these maps as a basis, recommendations for selecting EVSE locations based on EJ areas are made in Chapter 3. Care should be taken to work with community leaders to locate specific sites in the most appropriate locations.

At each charging location, not just EJ locations, at least one charger should be located at an accessible parking space and all chargers must meet Americans with Disabilities Act (ADA) requirements. This includes, but is not limited to, charging equipment and kiosk information at the proper height, appropriate parking space size, and accessible route and cross slope. ADA requirements have been established for workplace charging, and these should be used as guidance[22].

Additional equity background and considerations are included as Appendix D. PennDOT's EV equity guiding principles are included in Appendix F.

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[21] https://www.penndot.pa.gov/ProjectAndPrograms/Planning/Documents/EV%20Equity%20Principles_02072022.pdf
[22] https://afdc.energy.gov/files/u/publication/WPCC_complyingwithADArequirements_1114.pdf

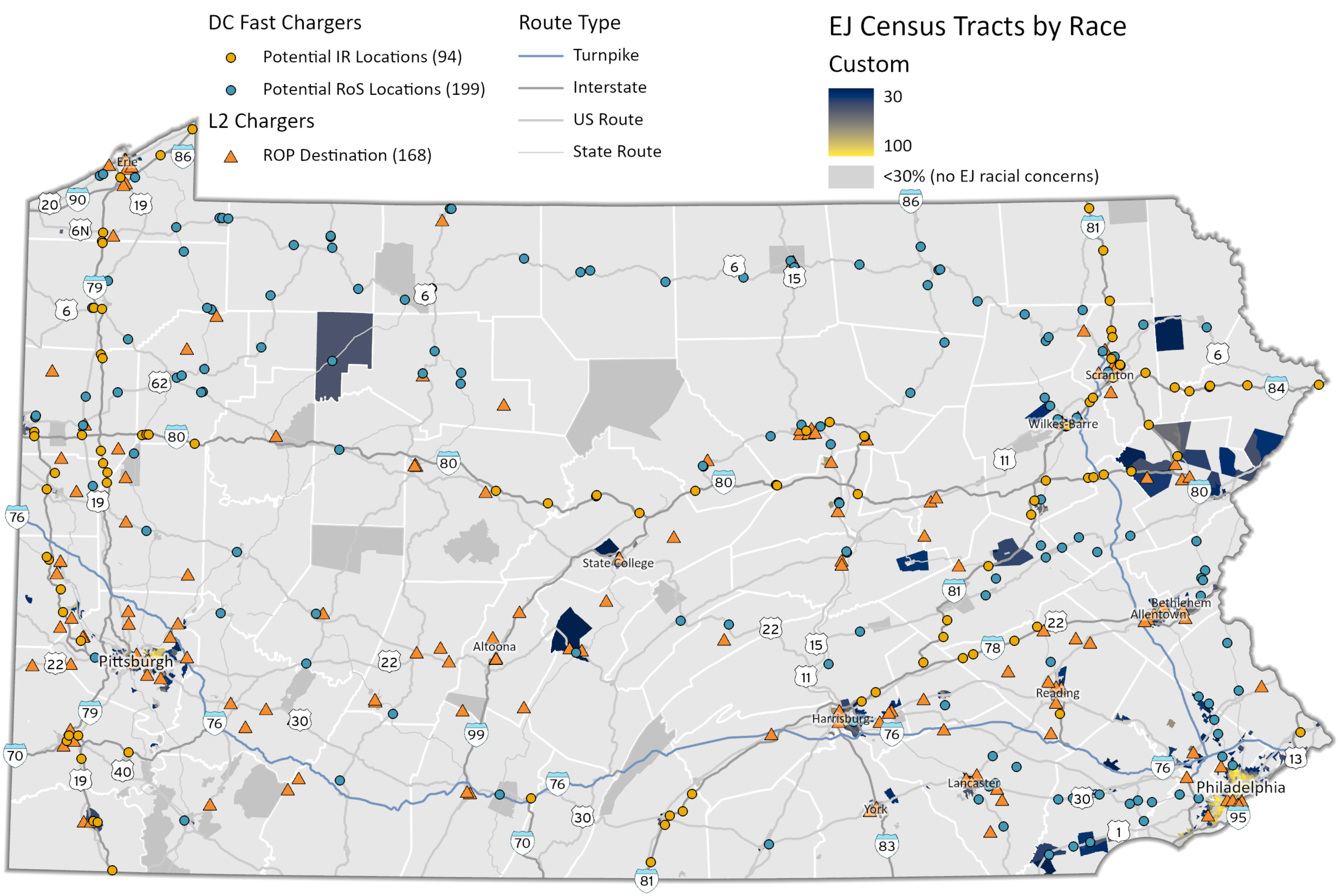

Figure 4. EJ Communities by Race

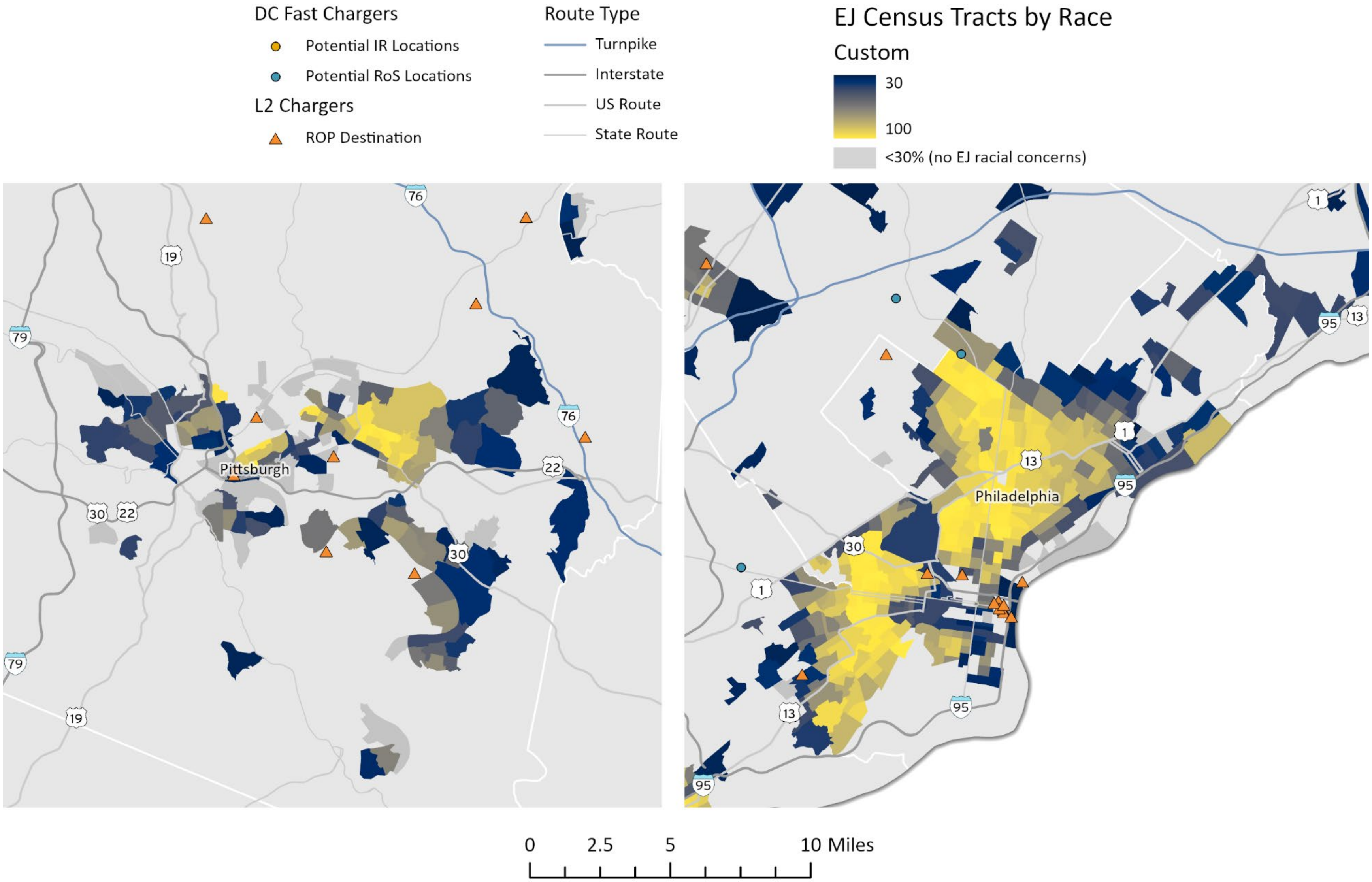

Figure 5. EJ Communities by Race (Pittsburgh and Philadelphia Inset Maps)

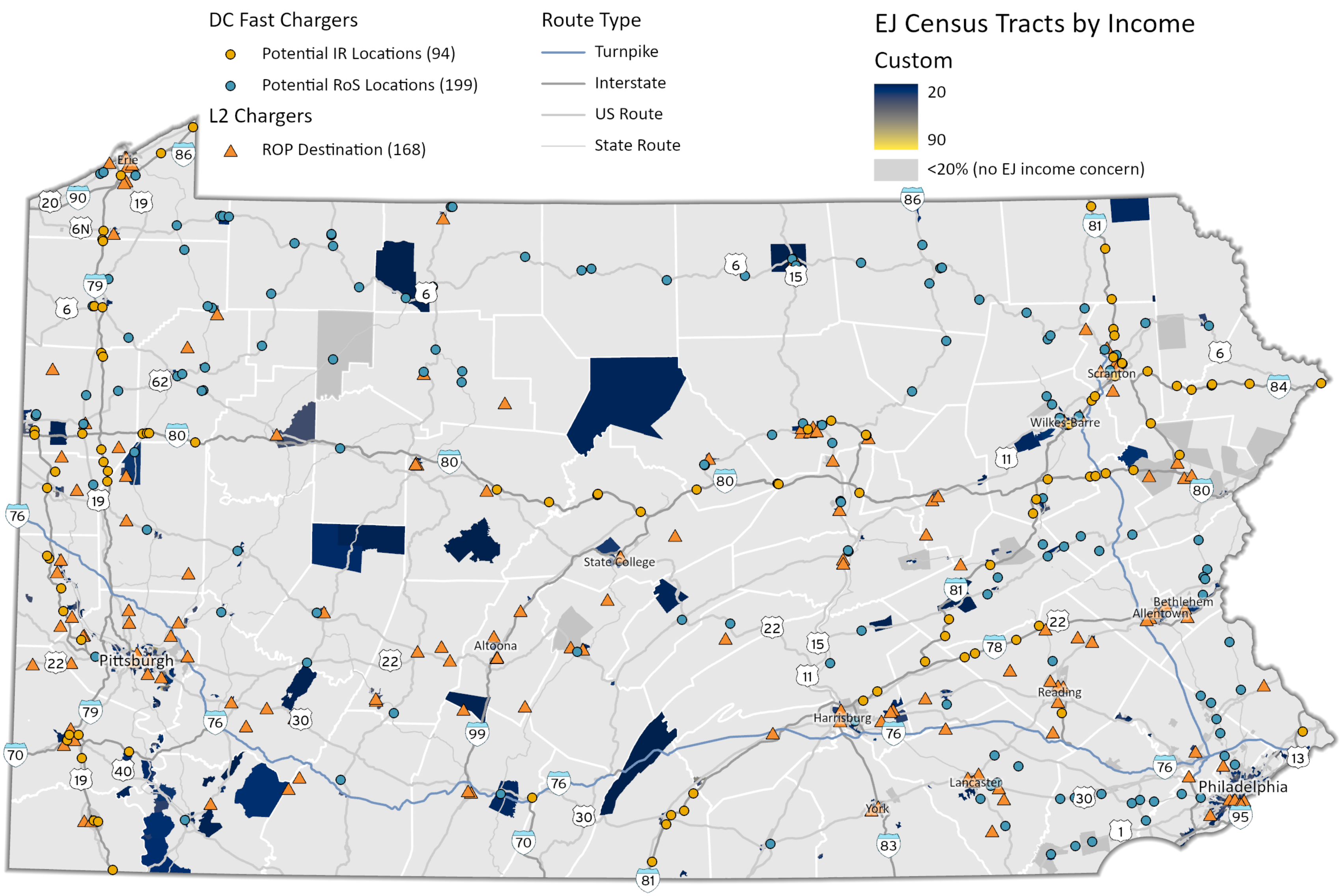

Figure 6. EJ Communities by Income

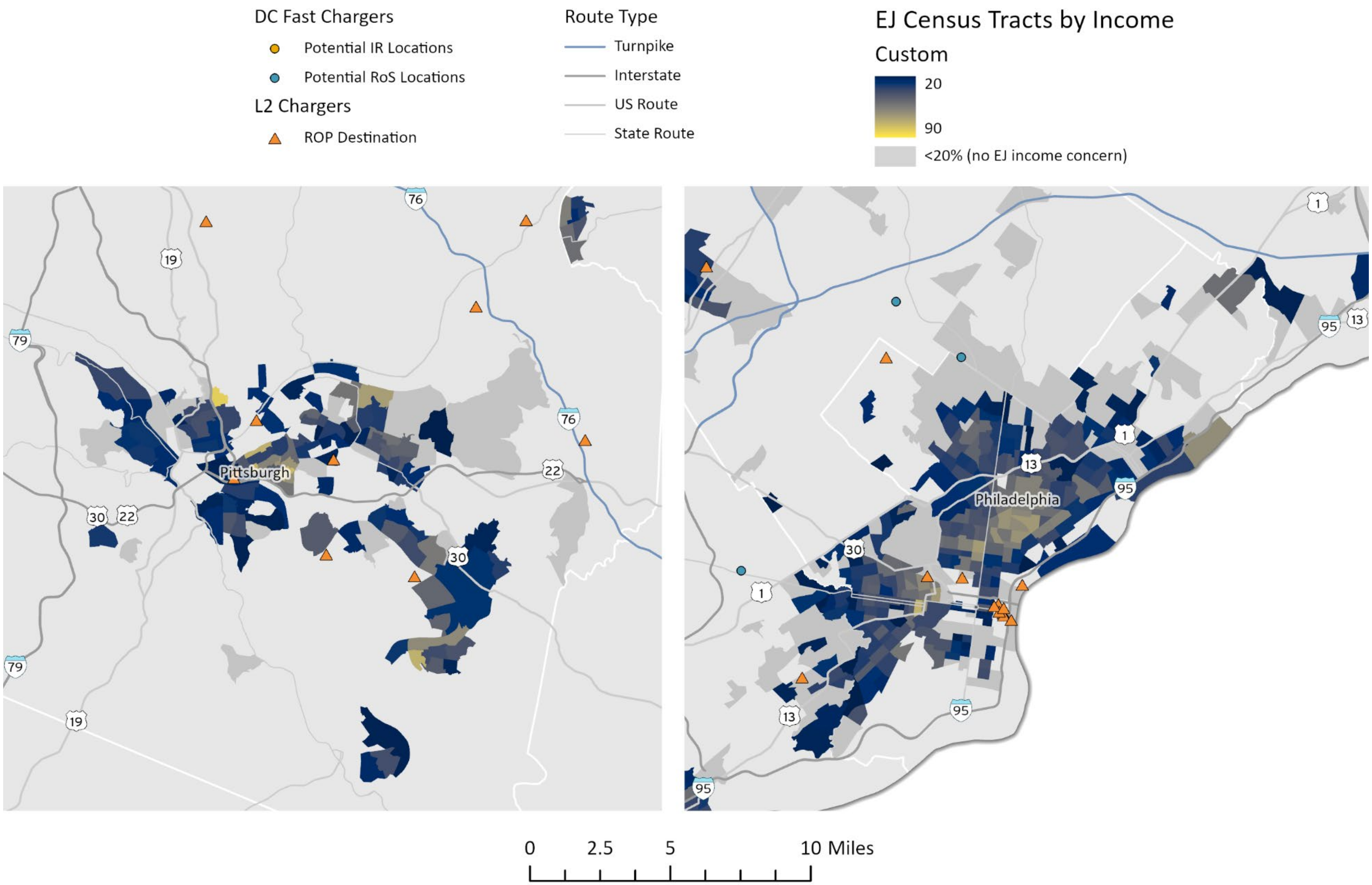

Figure 7. EJ Communities by Income (Pittsburgh and Philadelphia Inset Maps)

2 Goals and Objectives

This EV Mobility Plan identifies specific actions to facilitate the transition to electrified mobility across Pennsylvania. The first step in this process was to frame the plan into several goals and objectives. The primary focus of this plan is EV charging for the passenger vehicle segment, both on major routes and to support major destinations. Secondary goals are also defined for both passenger vehicles and medium- and heavy-duty freight. These goals and focus areas are summarized in Table 8.

In addition, there are five overarching objectives that should be intertwined into achieving each goal. The objective areas are economic, safety, mobility, environment, and equity.

The following sections describe in more detail each of the six goals, including 13 focus areas, and the five objectives. Specific recommendations based on these focus areas are given in Chapter 4.

Table 8. Goals and Focus Areas of PennDOT EV Charging

	Goals	Focus Areas
Primary	Interstate / Long-Distance Travel	• Interstate Gaps • Interstate Look-alikes
	Regional RoS	• High to Very High Traffic Volume • Moderately High Traffic Volume • Moderate Traffic Volume
	Destination Travel	• Year-Round Destinations • Seasonal 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

2.1 Primary Goals

One of the most significant barriers to wide-spread EV adoption is lack of range confidence. It is paramount that all drivers that wish to cross Pennsylvania or make long intrastate trips feel there is adequate infrastructure to do so. New guidance from FHWA for alternative fuel corridors recommends that DCFC locations be located at least every 50 miles along the corridor and be located within 1-mile of the corridor. Another area where range confidence is a low is when people travel to destinations. Pennsylvania has many destinations in rural areas or not on major highways, and these routes should have access to charging.

2.1.1 Interstate and Long-Distance Travel

Interstate (including Turnpike) travel regionally and for long-distances accounts for the majority of vehicle miles traveled on Pennsylvania's road network. This plan recommends that Interstates and interstate look-alikes have charging locations every 20 miles along the corridor and that EVSE be located less than one mile of the Interstate.

2.1.1.1 Interstate Gaps

The Interstate highway system carries the majority of vehicular traffic across Pennsylvania and is the backbone of the highway network. Currently, through FHWA's alternative fuel corridor program, there are several Interstate highway sections that were designated as "EV Corridor Ready." Several others are "EV Corridor Pending" or have yet to become "EV Corridor Ready," including many rural Interstate segments, as well as segments through many of Pennsylvania's largest metro areas outside of Philadelphia and Pittsburgh. Based on the new AFC guidance[23], prior "EV Corridor Ready" sections of Interstate will not lose their designation, but will not be considered "fully built out" until new AFC guidance is met. All AFCs must be fully built out before NEVI funding can be used on other routes.

2.1.1.2 Interstate Look-alikes

Pennsylvania has several RoS that are freeways which function like Interstate highways and see similar traffic volumes. Some of these routes are AFCs, while others are not. These routes, similar to Interstates, should be upgraded to "EV Corridor Ready" or to AFC standards, respectively, in the next five years.

2.1.2 Regional RoS

Each of Pennsylvania's four transportation systems management and operation (TSMO) Pennsylvania regions has developed Regional Operations Plan (ROP) to identify a regional approach to traffic operations. Each ROP is developed with extensive input from stakeholders, including MPOs/RPOs, counties, and many other agencies.

As part of this development process, each region in PA has developed "Corridors and Areas of Transportation Significance," referred to in this memo as RoS. All routes on the PA 511 core network are included as RoS, and regions are free to include additional routes, though there is no quantitative definition of an RoS. Development of RoS throughout the ROP process ensures that regionally the RoS are a robust network with extensive stakeholder support.

RoS are recommended as the next in line after Interstate routes to strengthen the state network for EV charging. There are 107 identified RoS across Pennsylvania's four transportation systems management and operation (TSMO) regions, shown in Table 9.

Segments of these routes are classified based on nine TSMO tiers as defined by PennDOT. These tiers are based on functional classification, national highway system (NHS) classification, and average annual daily traffic (AADT). Recommendations are made in the final EV Mobility Plan based on TSMO tiering of the segments. Tiers are listed in Table 10 and linked to the three different RoS traffic volume groups as utilized in this plan. These traffic volume groups are described in the following subsections.

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23 https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/nominations/90d_nevi_formula_program_guidance.pdf

Table 9. Complete List of PennDOT Regional RoS

Route Type	RoS Routes
Primary Interstate Highways	I-70, I-76, I-78, I-79, I-80, I-81, I-83, I-84, I-90, I-95, I-99
Auxiliary Interstate Highways	I-176, I-180, I-276, I-279, I-283, I-376, I-380, I-476, I-579, I-676
Mainline US Highways	US-1, US-6, US-11, US-13, US-15, US-19, US-20, US-22, US-30, US-40, US-62
Spur US Highways	US-119, US-202, US-209, US-219, US-220, US-222, US-322, US-422
Business US Highways	US-322 Business (State College)
One- and Two-Digit State Routes	PA-3, PA-8, PA-10, PA-23, PA-26, PA-28, PA-29, PA-32, PA-33, PA-41, PA-43, PA-51, PA-52, PA-56, PA-60, PA-61, PA-63, PA-65, PA-66, PA-73, PA-82
Three-Digit State Routes	PA-100, PA-113, PA-132, PA-147, PA-152, PA-162, PA-179, PA-212, PA-213, PA-228, PA-232, PA-252, PA-255, PA-263, PA-272, PA-282, PA-283, PA-291, PA-309, PA-313, PA-320, PA-332, PA-340, PA-345, PA-352, PA-363, PA-372, PA-412, PA-413, PA-420, PA-452, PA-463, PA-472, PA-491, PA-513, PA-532, PA-563, PA-611, PA-663, PA-724, PA-796, PA-841, PA-842, PA-896, PA-926

Table 10. PennDOT TSMO Roadway Tiering System

Highway Type	Tier	Criteria	EV Plan RoS Traffic Volume Group
Limited Access (NHS)	1A	AADT > 75,000	Interstates or Interstate Look-alikes
	1B	50,000 ≤ AADT ≤ 75,000	
	1C	AADT < 50,000	
Non-Limited Access (NHS)	2A	AADT > 25,000	Very High
	2B	10,000 ≤ AADT ≤ 25,000	High
	2C	AADT < 10,000	Moderately High or Moderate
Non-NHS	3A	AADT > 10,000	High or Very High
	3B	2,000 ≤ AADT ≤ 10,000	Moderately High or Moderate
	3C	AADT < 2,000	Moderate

2.1.2.1 High to Very High Traffic Volume

For the purposes of this plan, high to very high traffic volume on arterials is considered to be an AADT of greater than 10,000 vehicles per day, with very high traffic volume being in excess of 25,000 vehicles per day. These routes are very important regional routes where the majority of traffic is seen other than on Interstates and look-alikes. This category is further segmented in Chapter 4.

2.1.2.2 Moderately High Traffic Volume

For the purposes of this plan, moderately high traffic volume on arterials is considered to be and AADT of greater than 5,000 vehicles per day, but less than 10,000 vehicles per day. These routes represent some of the major rural arterials that are used for regional travel as well as important urban and suburban routes. This category is further segmented in Chapter 4.

2.1.2.3 Moderate Traffic Volume

For the purposes of this plan, moderate traffic volume on arterials is considered to be any AADT between 1,000 and 5,000 vehicles per day on an RoS route. Some rural routes that have regional significance to some of the smaller metropolitan and micropolitan areas in Pennsylvania are included in this category. This category is further segmented in Chapter 4.

2.1.3 Destination Travel

In order to promote equity and additional charging opportunities in communities not along highway systems, additional locations were analyzed for their potential to support charging. 326 destinations were identified from the ROPs, which took into account the importance of destinations to the region and the public. Focus should be placed on arterials near attractions and supporting on-site charging. Additional consideration should be given to seasonal versus year-round destinations. As destinations generally involve more vehicle dwell time, L2 charging is recommended when for on-site charging. DCFC should be used for near-arterial charging.

Public parks and related destinations, including libraries, community centers, and recreation sites, are areas where Pennsylvania has an interest in providing services to the public. Additionally, many of Pennsylvania's most visited sites are privately owned or managed by non-profits. Both public and private sites may be publicly accessible or not, and have 24/7 access or time-restricted access. PennDOT should focus on publicly accessible sites first, where no fees are required for entry and where access can be provided 24/7 or for as much time as possible.

2.1.3.1 Year-Round Destinations

Year-round destinations will see more stable visitation numbers and year-round demand for EV charging. PennDOT can best support destination travel by strategically locating charging stations on arterials near both urban and rural destinations across Pennsylvania. Several sites, such as state parks, have begun placing charging stations directly in the parking lots at their attractions. PennDOT can support expansion of this network by working with site owners directly to implement destination charging.

2.1.3.2 Seasonal Destinations

PennDOT can use their established knowledge working with year-round destinations to support these destinations as well. Focus should be placed on near-arterial charging so that chargers will have a use throughout the year to residents and travelers beyond just the destination travelers. Additionally, some seasonal destinations may hold events one to three times a year. In these type of locations, mobile charging may be sufficient.

2.2 Secondary Goals

Beyond travel along highly trafficked routes and to major destinations, there are many other important areas that should be supported for current and future EV charging needs. This section outlines needs related to emergency travel, commuter travel, and freight-specific needs. Recommendations are made for secondary goals in Section 4.2.

2.2.1 Emergency Travel

Dealing with emergencies is another area where there is low confidence among vehicle owners around switching to EVs. This plan outlines two different emergency scenarios for light-duty vehicles: mobile charging and towing for disabled vehicles and charging support along emergency routes.

2.2.1.1 Mobile Charging / Towing

There are many situations where charging demand will fluctuate, and charging may be needed in additional locations. Major events such as large athletic events, festivals (e.g., Groundhog's Day, fairs), and other special events occur infrequently throughout the year in locations that otherwise may not need charging. Additionally, motorists may run out of charge while driving on the highway.

To support these situations, it is recommended that mobile charging units can be quickly deployed regionally as needed for events and emergencies. For special events, these can generally be treated similar to destination travel and L2-type charging should be sufficient. For stranded drivers, the best option is to have a mobile charging unit come to their location and provide enough charge to get to an EVSE station. Many of the current solutions involve the use of a fossil fuel generator, which still supports the incentive to purchase an EV, but may offer poor optics for those looking to criticize EVs.

An additional advantage of mobile chargers is that these units may also be used to provide building power during an outage. It would increase the cost of the mobile unit but would be seen as another advantage of EVs.

For stranded vehicles, a more viable short-term alternative may be to have a tow truck tow the vehicle to the nearest EVSE station. In the future, as demand for EVs grows and charging capability improves, this equation will begin to shift in favor of mobile charging.

Starting in 2011, AAA introduced a pilot program in select metro areas deploying mobile charging trucks to get stranded EVs charged up enough to get moving. The program was suspended in 2019 after "fairly low" demand, even in the EV-dense California markets, and was not seen as a viable business option to continue. However, AAA is exploring ways to make charge-on-the-spot services viable[24].

It is recommended that PennDOT pilot a mobile charging program in strategic areas across the state as part of efforts to improve charging availability.

2.2.1.2 Emergency Routes

Emergency travel demand can create an increased need for charging in areas that typically do not see that level of need. It is important to address mobility both into and within Pennsylvania during emergencies, in particular winter weather events, storm evacuation, and emergency closures.

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[24] https://www.colorado.aaa.com/automotive/electric-vehicle-charging

There are three methods PennDOT can use to support charging for emergency routes. The first is to integrate emergency route criteria with the RoS site selection process so that these both needs are accomplished in tandem. The second is to specifically target these routes for additional EVSE where additional needs can also be met. The third is to address these needs with mobile charging infrastructure as mentioned in the previous subsection.

2.2.2 Commuter Travel

Commuter travel is an area where current EVs have sufficient energy capacity to serve most commuters needs. In general, commuters charge up at home, and then have enough charge for the day. Many workplaces, building managers, and parking lot operators have set up charging infrastructure in their parking lots to support EV owners and incentivize EV ownership.

Although this area is largely covered by homeowners and workplaces, there are a variety of scenarios that can be supported by public entities to improve commuter charging opportunities. Specifically, it is recommended that PennDOT begin with commuter travel support by focusing on mobility hubs and multimodal travel. Taxis and transportation network companies (TNCs) should be engaged to determine locations where their drivers will see the highest demand for charging, such as staging areas or strategic locations near the airport. Other areas should be explored over the next five years for future implementation.

2.2.2.1 Mobility Hubs / Multimodal Travel

Mobility hubs encourage a reduction in single-occupant vehicle travel. Even with EVs eventually taking over from internal combustion engine (ICE) vehicles, congestion and its ill effects will still need to be addressed. PennDOT can support passenger vehicle commuter travel through providing charging at PennDOT-maintained park and ride facilities and providing resources for MPOs and municipalities to fund EVSE installation at mobility hubs to encourage multi-modal travel.

2.2.3 Medium-Duty / Heavy-Duty Freight

Although electrification of medium-duty vehicles (MDVs) and heavy-duty vehicles (HDVs) is currently in pilot phases, there is no doubt that these types of vehicles will become more common over the next several decades. The EPA recently released its proposal for stronger clean air standards for heavy-duty vehicles, supporting a transition to a zero-emissions future.[25] In 2020, Pennsylvania signed onto the Multi-State Medium- and Heavy-Duty Zero Emission Vehicle memorandum of understanding.[26]

For this reason, it is recommended that PennDOT begin to explore charging options for these larger vehicles, as they will require more power. Megawatt charging systems (MCSs) are currently being tested up to 3.75 MW[27], which is much higher than the standard for light-duty DCFC of 150 kW. These systems will have many limitations on placement and could easily put a strain on the power generation and distribution system. Additionally, many MDV/HDV fleets may prefer to rely on their own private chargers at depots. As smaller fleets explore EVs for their operations, they will more likely be interested in shared charging locations. Three areas for charging for MDVs/HDVs are recommended for exploration: Interstate and regional travel, rural deliveries, and emergency travel.

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[25] https://www.epa.gov/newsreleases/epa-proposes-stronger-standards-heavy-duty-vehicles-promote-clean-air-protect

[26] https://www.nescaum.org/documents/mhdv-zev-mou-20220329.pdf

[27] https://www.nrel.gov/news/program/2021/industry-experts-researchers-put-charging-systems-for-electric-trucks-to-test.html

2.2.3.1 Interstate / Regional Travel

Similar to LDVs, the largest need for HDV charging will be along Interstate highways and Interstate look-alikes.

Long-haul truckers drive an average of 600 miles per day, which currently matches the typical 120-gallon fuel tanks estimated milage. Therefore, a good initial target area is for overnight charging, which can be done at a slower rate and with less power consumption than a mid-drive charge. This should include provisions for charging at rest stops and truck stops along Interstates and Interstate look-alikes.

2.2.3.2 Rural Deliveries

In today's economy, there is an ever-increasing demand for online shopping and immediate, cheap delivery. This has put stress on delivery companies to meet this massive demand. Rural deliveries are particularly expensive and time consuming, as packages need to make it to destinations anywhere in the highway network, including to the most remote parts of the state.

In order to incentive delivery services to change their MDVs to electric, strategies must be pursued to increase confidence when driving in rural areas. Although many strategies exist, a good start is to support MDV charging along rural RoS, where an MDV may not seek a full charge, but enough charge to get back to a depot.

2.2.3.3 Emergency Travel

Similar to electric LDVs, medium- and heavy-duty vehicles will need support if they run out of charge. It is recommended that this area be studied in more detail to determine if large wreckers could include a high enough power charger to support a quick electric boost to stranded vehicles in order to get them to the nearest charging station. Currently, there are higher power EV chargers that rely on diesel generators[28]. If these are considered, care must be given to public outreach as this might seem contradictory to EV objectives. Towing should also be considered through coordinating with towing companies.

Additionally, MDVs/HDVs are used for emergency response such as incident response, disaster response, and weather response. These vehicles would also benefit from mobile charging availability.

2.3 Objectives

The five objectives for this plan are overarching areas of concern that should inform decision-making for the strategies to achieve the program goals. The focus of these objectives is on sustainability; ensuring that the Pennsylvania of 2050 is as or more livable than today.

2.3.1 Economic

One of the main reasons gasoline vehicles are purchased at a higher rate than EVs is the ubiquity of the fueling network. EVs need to make economic sense to consumers for them to decide to make the switch, and in turn vehicle manufacturers need to see increased public demand to decide to produce more EVs across all passenger vehicle classes. PennDOT can help improve incentives by providing for EV charging in strategic locations, including by using economic indicators to select locations, ensuring that locations have ample amenities for travelers to use while charging, and supporting charging in travel to destinations.

[28] https://www.chargedfleet.com/10139149/larson-electronics-portable-ev-charging-station

An additional economic focus should be on supporting small businesses across Pennsylvania. Site locations should be chosen to support small businesses and minority-owned businesses. Charging business models can be developed to support these businesses and the local economy.

2.3.2 Safety

Occupant safety drives many of PennDOT's decisions from geometric design to driver education. When enhancing the EV network, particular emphasis should be placed on driver and traveler safety. This includes safety while charging, such as encouraging development of charging locations that are well-lit with security cameras and have appropriate and well-functioning infrastructure and amenities.

Supporting safety also includes an understanding of how to best assist motorists during emergencies.

2.3.3 Mobility

People want to get from any point A to any point B using their vehicles, with limited dwell time for fueling/charging. Planning for EV charging with mobility in mind means ensuring motorists can drive EVs across the state with confidence that high-speed charging will be available when necessary. This is why there must be a wide-ranging, robust network that focuses on a variety of travel needs.

2.3.4 Environment

Greenhouse gas emissions are contributing to climate change, which contributes to the dynamics in a range of environmental challenges such as hurricanes, winter storms, and drought. Replacement of fossil fuel vehicles with EVs is one way to generate fewer greenhouse gas emissions and slow climate change, lower its costs, and reduce its impacts.

Fossil fuel vehicle emissions also contribute to the more immediate effect of decreasing air quality in metro areas as well as rural valleys. EVs can improve air quality by eliminating line sources of pollution.

2.3.5 Equity

If left to private incentives, charging infrastructure could very easily overlook or end up inadequate for many Pennsylvania citizens. In the interest of providing access to diverse populations within Pennsylvania, the state should consider how each goal can be fulfilled in an equitable way so all groups can benefit from the positive outcomes. Additionally, a wide range of payment options must be considered. To locate sites based on equity considerations, PennDOT should work with community leaders to locate sites in the most appropriate locations.

3 Existing Conditions

This chapter assesses existing conditions of EVSE in Pennsylvania. Existing coverage was analyzed using 2021 data and before the NEVI guidance was completed. Additional analysis should be completed as part of NEVI Plan development and when updating this plan in the future.

3.1 Existing EV Charging Coverage in Pennsylvania

The first step in making decisions on the future EVSE focus for PennDOT is to understand Pennsylvania's current standing with EV charging equipment. A variety of data collection methods were used to put together datasets and maps of existing conditions. After data were collected, an analysis of existing conditions along Interstates and other RoS was completed, followed by an analysis of destinations to support destination charging.

3.1.1 Data Collection Methods

Several data sets were collected to better understand and analyze the existing conditions of DCFC infrastructure in the Commonwealth of Pennsylvania and determine the most suitable locations to deploy DC fast chargers to support Pennsylvania's goals of equitable and comprehensive EVSE deployment.

- **Road Network:** The Pennsylvania inventory for Interstates, US Highways, and major State Routes were mapped. Other RoS, from PennDOT's ROPs, were also mapped.
- **Traffic Measures:** Traffic volume information, such as AADT, were integrated to identify the most traveled routes.
- **EV Charging Infrastructure:** Data from the US Department of Energy's Alternative Fuel Data Center (AFDC), a database of existing EV charging stations, was mapped and supplemented with crowdsourced EV charging infrastructure data from apps like PlugShare.
- **Regional Operations Plan:** RoS and significant destinations from the ROPs were analyzed.
- **Fueling Stations/Grocery Stores:** This data set was used primarily to identify large enough truck stops, gas stations, and grocery/convenience stores to support the deployment of DCFC.
- **PennDOT Facilities:** PennDOT rest areas, district facilities, and outpost garages were mapped.
- **State Parks:** Park offices and geographies were identified and studied for consideration as possible siting locations. PA Department of Conservation and Natural Resources (DCNR), which manages the parks, seems to be ahead of the curve on installing chargers.
- **Transportation Hubs:** Airports, ferry terminals, ports, park and rides and public transportation facilities were collected.
- **Attractions:** Common attractions such as amusement parks, sports venues, zoos, major shopping centers, museums, golf courses and state parks were mapped for possible locations.
- **Utility Coverage Areas:** Coverage areas for Pennsylvania's investor-owned utilities, Municipal Power Companies, and Co-ops around the State were collected.
- **Other:** Data sets with information on colleges and universities, fairgrounds, major hospitals, population, and urban areas were utilized.

3.1.2 Charging along RoS

This section describes the approach that was used, leveraging GIS, to identify gaps in corridor charging for RoS in Pennsylvania.

FHWA recently updated requirements for routes to be designated alternative fuel corridors. To be considered a "fully built out" and signage ready alternative fuel corridor by the FHWA, Interstates, US Highways, and State Routes must meet the following requirements:

- Corridors must have EV charging infrastructure at least every 50 miles along the highway within 1 mile of the nearest interchange
- Each station must include at least four 150kW DCFCs with CCS ports capable of simultaneously charging four EVs
- Each station must include a total of 600kW for the total station power capability, with at least 150 kW available to each port simultaneously

To meet the first requirement, Interstates, US Highways, and State Routes were evaluated to determine where there were gaps in DCFC infrastructure of more than 50 miles. Interstate corridor gaps were evaluated first, followed by gaps along Interstate look-alikes and other RoS corridors.

Corridor charging, by definition, necessitates DCFC infrastructure to allow for typically a half hour (or less) to achieve most charging needs. Table 11 shows **e**xisting chargers within 0.5, 1.0, and 1.5 miles of the Interstate/US/SR system by port type. As of July 2021, there are 44 DCFC stations within 0.5 miles of Pennsylvania's Interstate/US/SR system and 70 DCFC stations within 1.5 miles of the Interstate/US/SR system. A 1-mile threshold was ultimately used as it is the new FHWA guidance, and the distance represents a reasonable amount of travel off the Interstate/US/SR system for charging while still being generally within the network and existing signage areas.

Being this study was completed with 2021 data, bullet's two and three in the previous list were not checked, so the information presented in this chapter includes many stations that may have fewer than four ports, and do not meet charging requirements. Although these stations will still allow corridors originally considered "EV Corridor Ready" to keep their designations, they will not be considered "fully built out" until these stations are updated or replaced. The new requirements will be integrated when creating the NEVI plan and updating this plan in the future.

Table 11. Public Direct Current Fast Charging Stations in Pennsylvania

		Charging Stations within X miles of Interstate or RoS*		
Connector Types	**Total Stations (Ports)**	**Within 0.5 miles**	**Within 1.0 mile**	**Within 1.5 miles**
CHAdeMO Only	20 (30)	7 (12)	11 (17)	12 (18)
CCS Only	15 (18)	6 (6)	7 (7)	7 (7)
CHAdeMO & CCS	39 (114)	11 (40)	20 (67)	26 (85)
Tesla	41 (330)	20 (164)	25 (208)	25 (208)
Total	**115 (492)**	**44 (222)**	**63 (299)**	**70 (318)**

*In this instance, 'stations' represent the number of locations with charging, while 'ports' represent the number of vehicles that can charge at one time at the given location. This project excludes Tesla Chargers and private businesses/limited-hour chargers. Accessed July 2021.

Figure 8 indicates publicly accessible, non-Tesla DCFCs within 1 mile of Interstate exit ramps. The coverage area highlighted is based on a buffer radius of 20 miles (rather than 25 miles) to account for extra travel distance required to negotiate interchanges and navigate to the charger.

The infrastructure shown only includes 24/7 publicly available facilities, to ensure access to charging at any time of day. This study does not include Tesla Superchargers since non-Tesla vehicles cannot use these chargers, and they are not considered by FHWA for Alternative Fuel Corridor Funding. Additionally, sites shown do not necessarily meet all of the new AFC criteria, and further analysis should be considered to determine which stations meet the second and third criteria as defined above.

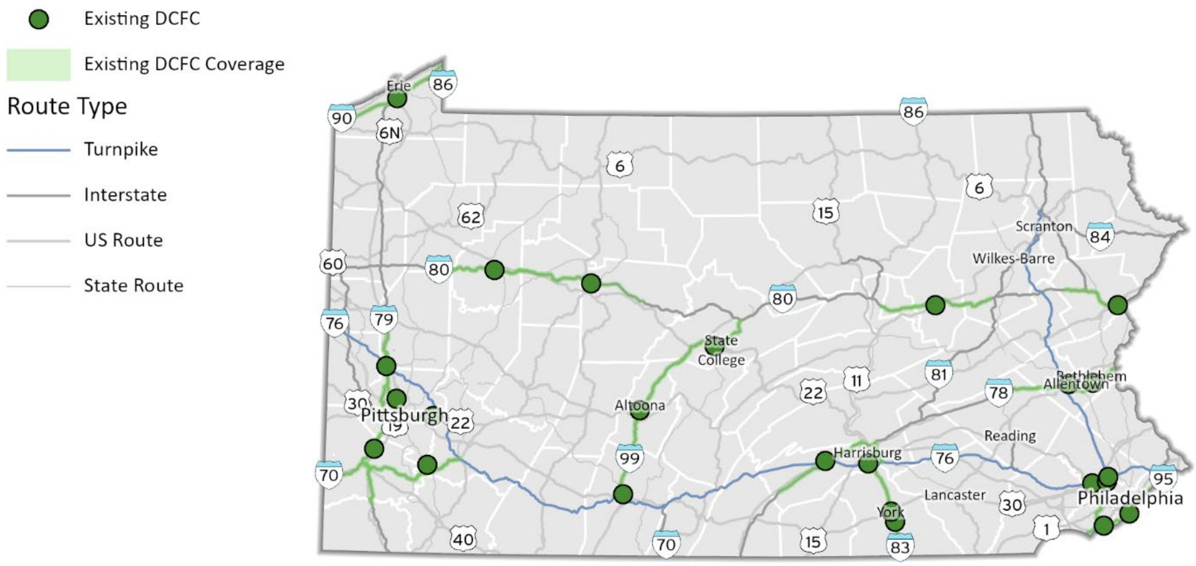

Figure 8. Existing DCFC Infrastructure and Coverage (20-Mile Buffer) along Interstates

3.1.3 Charging to Support Destinations

326 destinations were identified from the ROPs, which took into account importance of destinations to the region and the public.

A straight-line approach was used first to identify specific charging equipment currently installed near support destinations. Then, actual drive distances were used for a more realistic analysis. Drive time was not used because vehicle range depends primarily on distance, not speed, and most EVs display a "distance remaining" measure instead of a "time remaining", much like an ICE vehicle's fuel gauge. Although the ROPs already defined sites based on economic viability measures, additional analysis could be done to consider traffic volumes, populations, or other demographic information near destinations to further prioritize the destinations.

While the previous analyses have focused on DCFC to support long trips along a corridor with minimal stops, destination charging is almost always L2. Certain urban locations with high turnover may support DCFC, and DCFC may be desirable from an equity perspective. This destination charging analysis was primarily conducted with two principles in mind. First, that a DCFC should be available on the way to the destination in case a user needs to recharge quickly on their way. Second, the destinations were evaluated for their ability to support L2 charging, so that customers could top off while they were visiting.

3.1.3.1 Straight-Line Distance to DCFC

To support state tourism and equitable deployment of EVSE, a list of popular destinations from the ROPs was analyzed. Of the 326 sites, L2 charging was deemed potentially viable at 224 of them, not viable at 47, and 55 were either outside of Pennsylvania's jurisdiction (like national parks) or appeared to have their own EVSE planning process in place (PA State Parks). Viability was determined by reviewing each site in Google Maps satellite view to check for the presence of improved buildings, parking lots, and streetlights, to determine if the site could support charging infrastructure or not.

The distribution of distances between each site and the closest DCFC and L2 charger was graphed in Figure 9. Each bar in the figure shows the percentage of chargers that are within the given mileage range to destinations, as shown on the x-axis.

Of the 17 sites that do not have a DCFC within the 95^{th} percentile distance (30.49 miles), 10 are state parks, four are potentially viable for charging, and 3 are not. Of the 28 sites that do not have an L2 charger within the 95^{th} percentile distance (24.13 miles), nine are State Parks, 14 are potentially viable for charging, and five are not. In addition, 55 of the sites already have some sort of charging within ¼ mile of the destination – either an L2 or 24/7 DCFC. This distance indicates that charging is present at the destination.

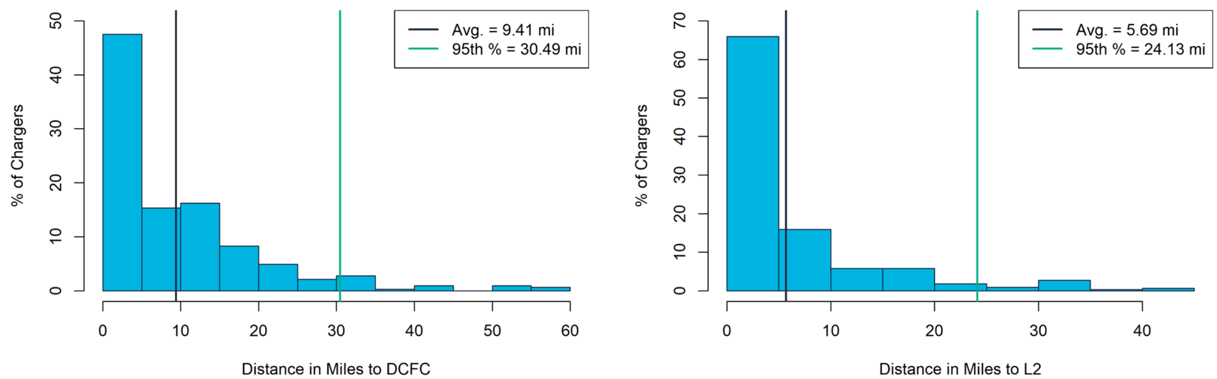

Figure 9. Straight-Line Distance to Nearest DCFC and L2

3.1.3.2 Driving Distance Zones to DCFC

To provide additional detail, polygons describing the driving distance to each of the 326 destinations were computed at 5, 25, and 50 miles, and the number of DC fast chargers within each polygon was computed. This analysis attempts to approximate if a traveler is likely to find a charger on their way to a destination.

Without knowing travelers' origins, it is difficult to say with certainty that a high number of chargers within these zones means that travelers can charge on the way, although a low number of chargers indicates that they will likely have trouble finding a charger. Further analysis should be completed to determine primary traffic flows to and from destinations in order to better locate EVSE. For example, if a site is four miles west of an Interstate which is its primary access point, preference should be given for EVSE placement nearer to the Interstate or along the connecting arterial versus in a small town to the west of the site.

Charging thresholds were chosen for the following reasons:

- 5 miles: This is likely as far as someone would go out of their way, one-way, to find a charger near a destination. It also corresponds with the former FHWA guidelines for designating an Alternative Fuel Corridor requiring an EVSE to be within 5 miles of a highway.
- 25 miles: The radius of the 50-mile spacing requirement for EV Alternative Fuel Corridor designation along a highway.
- 50 miles: The maximum distance from an existing DCFC before another one is required to maintain Alternative Fuel Corridor status. Driving this distance off a highway without other chargers would probably require destination charging for the EV driver to feel comfortable making the trip.

Figure 10 shows one of these drive-distance polygons for the Pittsburgh Zoo and PPG Aquarium as an example. One of these sets of polygons was generated for each destination to conduct the analysis.

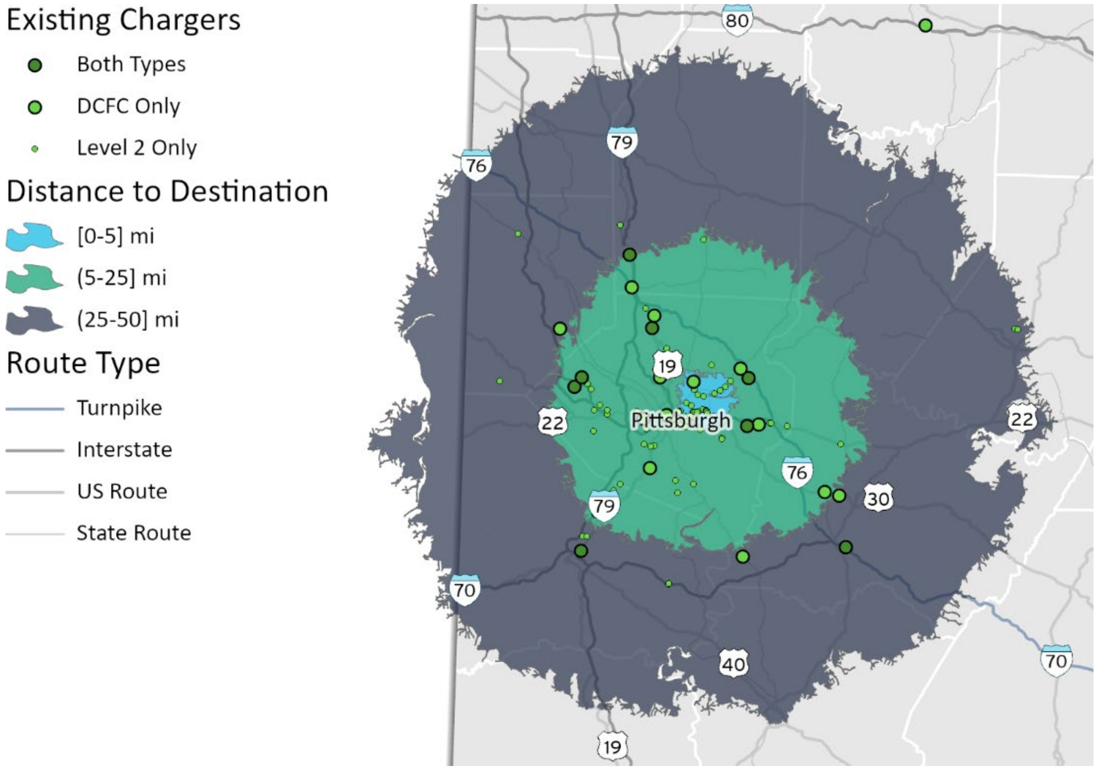

Figure 10. Drive Distance Buffer for Pittsburgh Zoo

Of the 326 destination locations identified in the ROPs, 79 (24%) have at least one DCFC within 5 miles driving distance, 216 locations (66%) have at least one DCFC within 25 miles driving distance, and 310 locations (95%) have at least one DCFC within 50 miles driving distance. Of the 16 locations without a DCFC in 50 miles, 9 are state parks, four are colleges or universities, and the other three are other tourist sites. The full list of these sites is shown in Table 12. As in the previous analyses, only publicly accessible 24/7, non-Tesla chargers were used for this analysis.

Table 12. ROP Locations more than 50 Miles from a DCFC

State Parks	Cherry Springs State Park, Hyner Run State Park, Kettle Creek State Park, Kinzua Dam Kinzua State Park and Skywalk, Lackawanna State Park Trails, Little Pine State Park, Lyman Run State Park, Ole Bull State Park, Sinnemahoning State Park
Colleges and Universities	Back Campus Trails at Keystone College, Keystone College, Mansfield University, Theil College
Other Tourism Sites	Austin Dam, Coudersport Ice Mine, Zippo/Case Museum

3.2 Analysis and Methodology

This section describes the process involved to analyze current conditions and the methodology developed and used to decide on charging locations and priorities. The analysis was performed to help Pennsylvania plan for increasing EV adoption by deploying EVSE at strategic locations within the state.

Note that all existing EVSE locations used in this report are valid as of June 16, 2021. The landscape of EV charging is changing rapidly, so it was necessary to take a snapshot in time to do the analysis. This analysis should be updated as part of the NEVI Plan, and again as necessary over the next five years of implementation.

3.2.1 Interstates

Figure 11 shows all Interstate highways in Pennsylvania, highlighting which corridors are "EV Corridor Ready," "EV Corridor Pending," or neither. These are AFC Round 1-5 designations and do not necessarily meet the new Round 6 AFC guidelines.

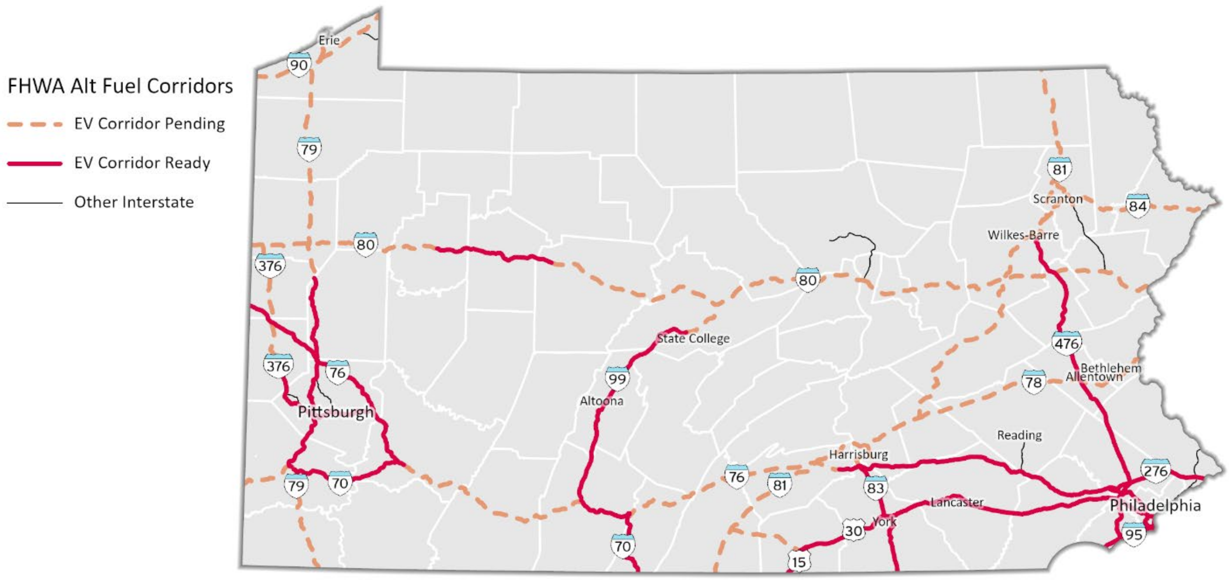

Figure 11. Alternative Fuel Corridors within Pennsylvania

After importing the data sets mentioned in 3.1.1, the following approach was used to determine the best locations for DCFCs on the Interstates:

1. Identify existing public DCFCs within one mile of Interstate interchanges.
2. Create a 20-mile radius buffer around the current DCFC identified in Step 1 and trim to be within a mile of the Interstate to identify gaps of more than 50 miles between DCFC along the Interstates. See Figure 12 for a map of these gaps.
   Note: Gaps along the Pennsylvania Turnpike were not included in the analysis.
3. Identify possible DCFC locations to fill the gaps, starting with previously "EV Corridor Ready" corridors no longer meeting AFC requirements, then "EV Corridor Pending" corridors, followed by non-EV corridors. Preferred locations are sites with high enough current economic activity to support charging and:
   a. Have ample parking.
   b. Are within 1 mile of an exit ramp.
   c. Are adjacent to restaurants or other amenities for drivers to visit while the vehicle charges.
   d. Appear to have enough power to support DC Fast Charging.
4. Add interchanges that have viable charging locations to the map using the 20-mile buffer. Verify that gap is filled by each recommended DCFC. If not, adjust or repeat until coverage is at desired level. See Figure 13 for a map of this coverage.

This process has created a list of candidate sites for the given coverage areas. These sites should be pursued during the first phase of the Interstate charging plan. Using this list of candidate sites, the following process should be used to determine if there is sufficient power capacity to support DC Fast Charging at each site:

1. Identify the serving utility providers
2. Contact utility providers for each site to obtain power distribution maps
3. Use GIS to determine power available at charger site
4. Determine cost for power upgrade, if applicable

After power availability is determined, sites should be ranked based on several factors, including site host interest, available amenities, and other features.

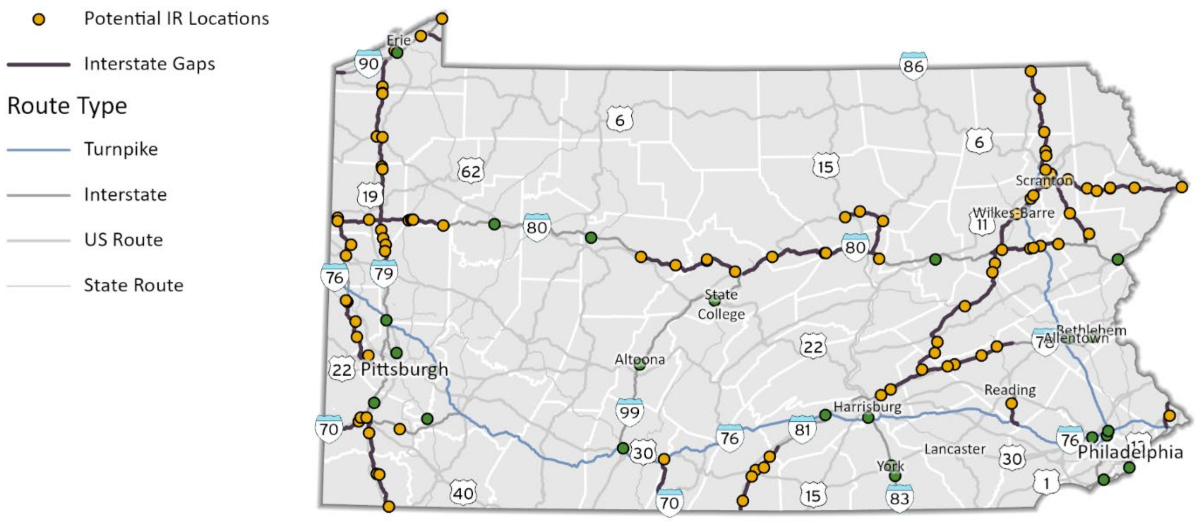

Figure 12. Interstate DCFC Gaps with Possible Charging Locations

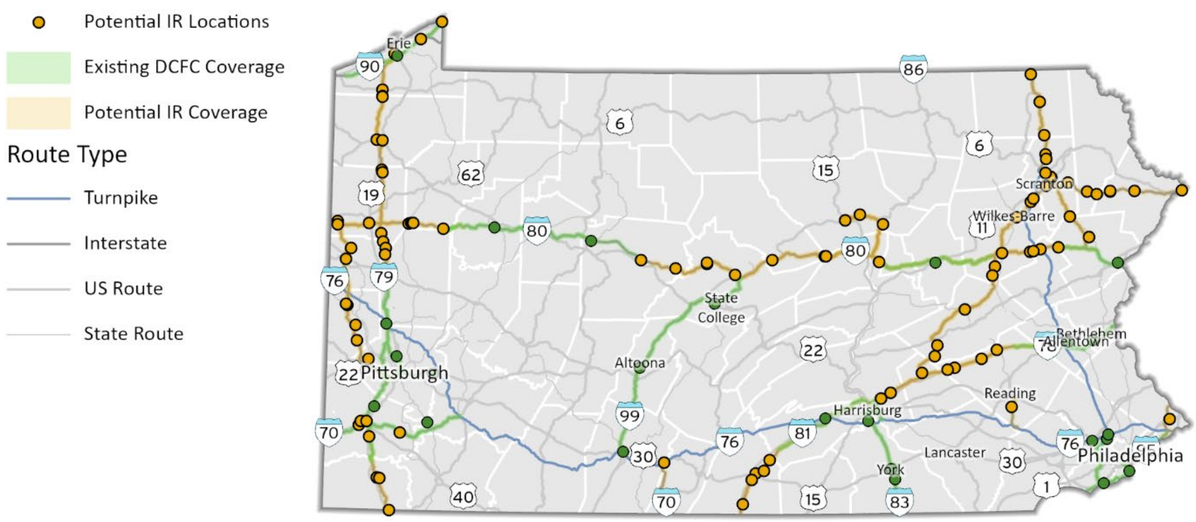

Figure 13. DCFC Interstate Coverage with Possible Charging Locations

3.2.2 RoS

There are 107 identified RoS across Pennsylvania. Figure 14 shows all RoS in Pennsylvania by functional class. The following approach was used to determine the best locations for additional DCFCs along the RoS as deemed by PennDOT in each region's ROP:

1. Identify the RoS as described by the ROPs.
2. Map existing public DCFCs within one mile of the RoS, including portions of the route that are not identified in the ROPs.
3. Create a 20-mile radius buffer (trimmed to the RoS as described in Section 3.2.1) around the existing infrastructure found in step 2 to ensure chargers are no greater than 50 miles apart. Note any proposed chargers from the previous analysis that will also fill RoS gaps.
4. Identify the current gaps in the network segments identified in step 1. Route segments may be grouped into one "gap" at an intersection to simplify analysis. See Figure 15 for a map of these gaps.
5. Identify possible DCFC locations to fill the gaps. Preferred locations are sites with high enough current economic activity to support charging and:
    a. Have ample parking.
    b. Are within 1 mile of an exit ramp or the corridor, depending on functional class. If no sites are available within 1 mile, sites at a slightly further distance can be considered.
    c. Are adjacent to restaurants or other amenities for drivers to visit while the vehicle charges. Locations with ample lighting and security measures are preferred.
    d. Appear to have enough power to support DC Fast Charging.

Sites should be prioritized based on power availability, traffic counts, desire to expand EV AFCs, whether or not the RoS is an Interstate look-alike, and EJ considerations.

Figure 14. RoS by Functional Class

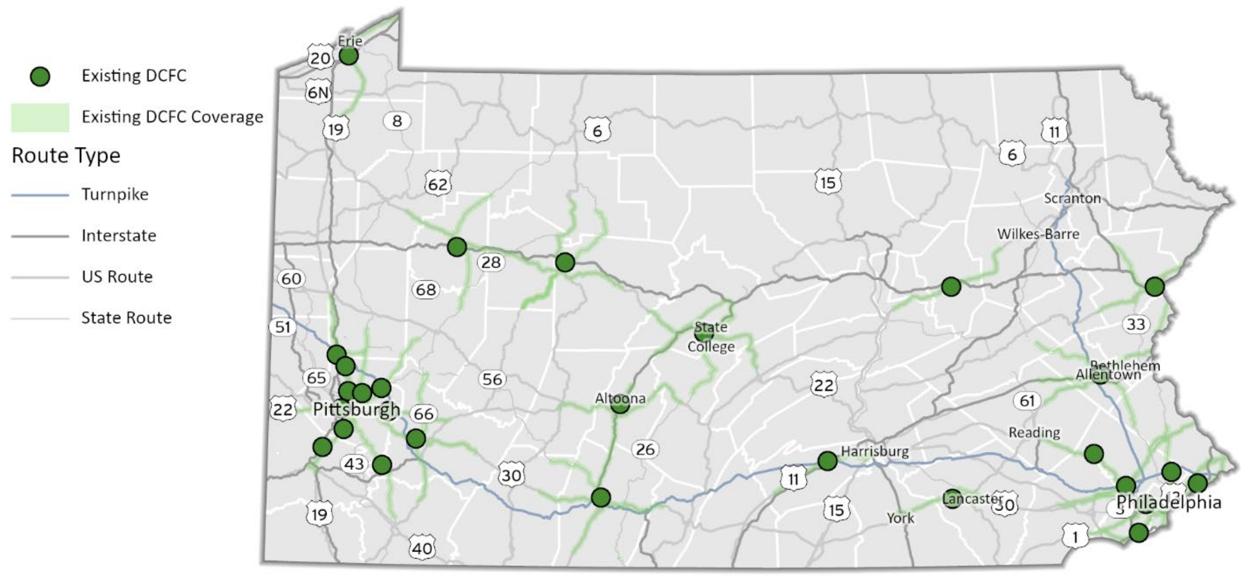

Figure 15. Existing DCFC Infrastructure and Coverage along RoS

The gap located along US 219 from Northern Cambria to US 322 and identified with a ❶ in Figure 16, did not have any suitable potential locations along the route or within 5 miles. This location is extremely rural and does not see a lot of traffic. A charger could potentially be located in Burnside or Grampian to fill the gap, but it is not clear that there will be sufficient power or demand to justify this.

The gap located along US 30 from the Ohio border to US 22 and identified with a ❷ in Figure 17, did not have any suitable locations within 1 mile but did have a shopping plaza that was suitable within 5 miles of the southern end, along State Route 60.

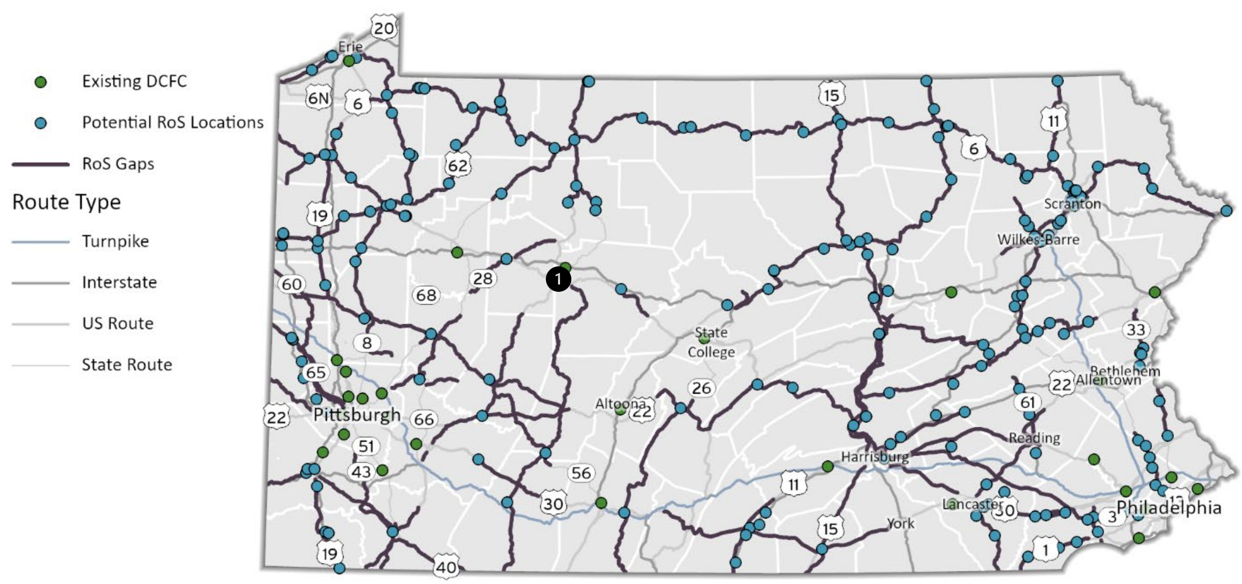

Figure 16. RoS DCFC Gaps with Possible Charging Locations

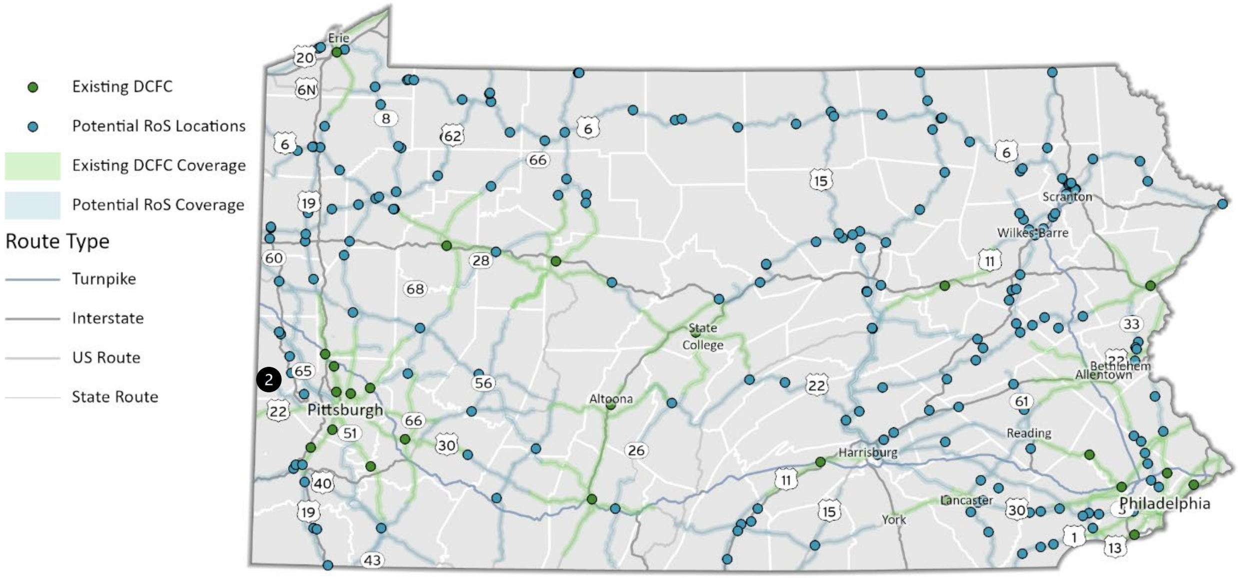

Figure 17. DCFC RoS Coverage with Possible Charging Locations

3.2.3 Charging to Support Destinations

Knowing the distribution of existing chargers and important destinations from the ROPs, the following priority for EV funding for support destinations is recommended:

1. Work with PA DCNR to complete their charging goals and fill gaps (probably L2)
2. Other public destinations that may need destination charging (L2)
    a. Rural areas (see Figure 18)
    b. High minority and low-income EJ areas (see Figure 4 and Figure 6)
    c. CMAQ nonattainment areas (see Figure 19)
3. Assist willing non-profit and private entities to install chargers, possibly on a sliding scale (mix)
    a. Rural areas (see Figure 18)
    b. High minority and low-income EJ areas (see Figure 4 and Figure 6)
    c. CMAQ nonattainment areas (see Figure 19)
4. Identify further destinations beyond those identified in this plan and work with these entities on installing chargers

Table 13 shows a breakdown of the 169 identified destinations that currently do not have charging capabilities and where charging is viable. These sites are broken down to show how many are in each of the four equity initiative areas.

Table 13. Equity Considerations for Destinations

Equity area of emphasis	Number of destinations without charging where L2 charging is viable
In high minority EJ areas	25 / 169 destinations (15%)
In low-income EJ areas	48 / 169 destinations (28%)
In rural/remote areas	24 / 169 destinations (14%)
In CMAQ nonattainment areas	133 / 169 destinations (79%)

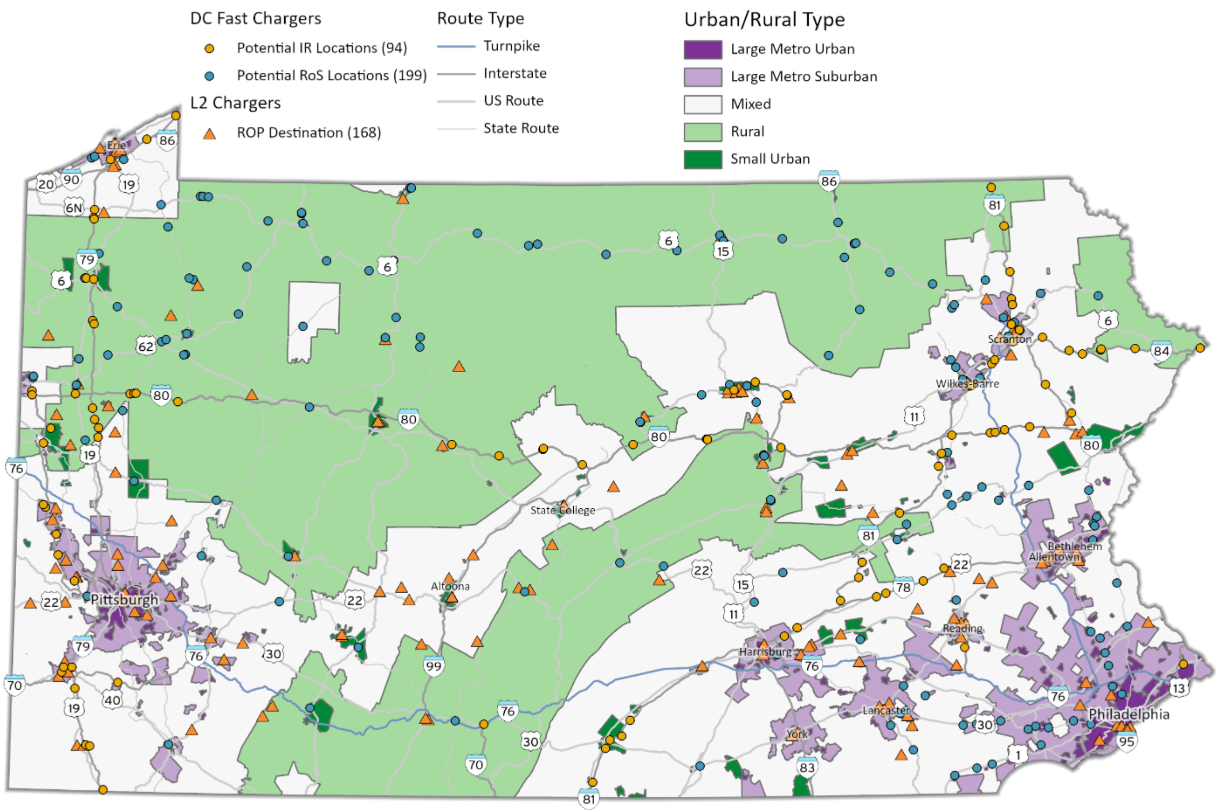

Figure 18. Urban and Rural Zones in PA

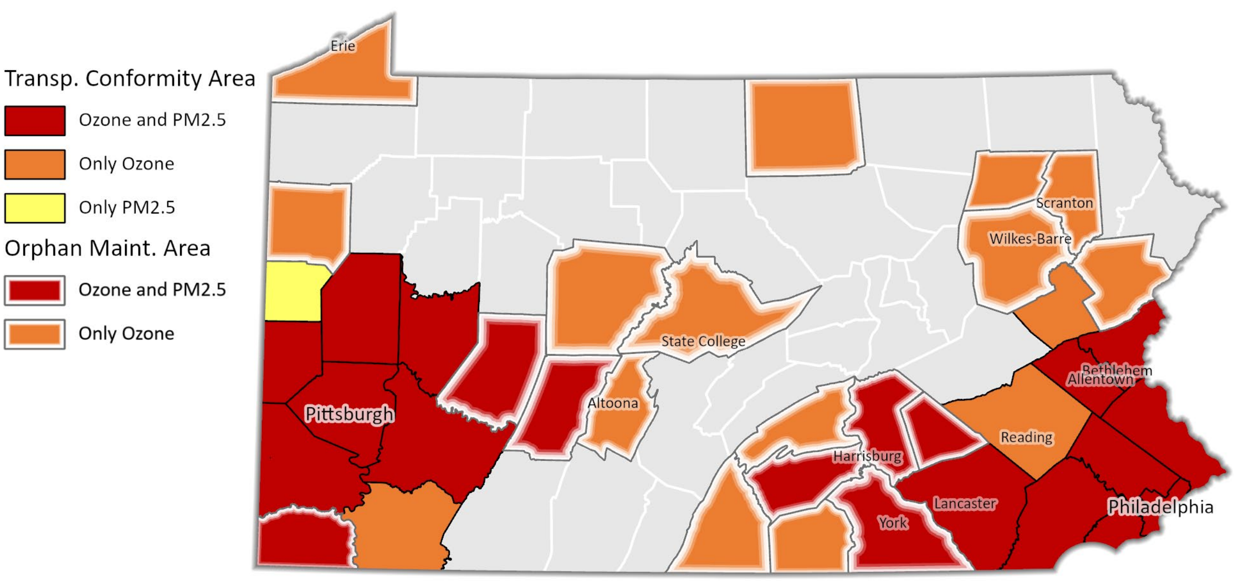

Figure 19. Transportation Conformity Areas

3.2.4 Number of Chargers and Charging Stations

This plan recommends PennDOT support the installation of 2,000 EV charging ports at 800 sites over a five-year period. The rationale for these numbers is explained in this section.

The ICCT predicts there will be 26 million EVs on the road in the United States by 2030, with 15 million of these on the road by 2028[29]. They also predict that Pennsylvania will have 363,000 registered EVs by 2028, which is in line with the low estimate presented in Pennsylvania's EV Roadmap[30]. High estimates in the EV Roadmap predict nearly 1 million EVs in PA by 2028.

Table 14 summarizes these EV and charger estimations. This table also splits out types of non-home chargers needed further into three groups: workplace, public L2 chargers, and public DCFCs.

Table 14. EV and Charging Estimations Based on the PA EV Roadmap and the ICCT

Year	Scenario	EVs Registered	Chargers Needed	Workplace	Public L2	Public DCFC
2020	--	29,000	2,700*	1,500	1,000	200
2023	EVRM 1	98,000	9,000	4,900	3,400	700
	ICCT	86,000	15,000	8,200	5,700	1,100
	EVRM 4	181,000	17,000	9,100	6,300	1,300
2028	EVRM 1	358,000	33,000	18,000	12,500	2,500
	ICCT	363,000	49,000	26,800	18,500	3,700
	EVRM 4	966,000	88,000	48,100	33,300	6,600
2033	EVRM 1	636,000	58,000	31,700	21,900	4,400
	ICCT	1,535,000	103,000	56,300	38,900	7,800
	EVRM 4	2,887,000	264,000	144,200	99,800	20,000

*a total of 1,469 public L2 or DCFC chargers are installed in PA as of 2020[31]

Scenarios listed in Table 2 are from the EV Roadmap and ICCT report and include:

- EVRM 1: EV Roadmap low policy, low technology scenario
- ICCT: International Council on Clean Transportation scenario, interpolated per year based on 2025 and 2030 estimates
- EVRM 4: EV Roadmap high policy, high technology scenario

Various recommendations have been made on the number of chargers needed per EV. In the EV Roadmap report, a benchmark used for density of chargers was set at 275 plugs per million residents. The target density will rise as percentage of EVs increases as part of the light-duty vehicle mix. The ICCT report recommends 10.9 EVs per public charger by 2030.
Specifically, the ICCT recommends the following:

> "To support an EV stock of 26 million in the United States in 2030, public and workplace charging will need to grow from approximately 216,000 chargers in 2020 to 2.4 million by 2030, including 1.3 million workplace, 900,000 public Level 2, and 180,000 direct current fast chargers."

[29] https://theicct.org/wp-content/uploads/2021/12/charging-up-america-jul2021.pdf, International Council on Clean Transportation (theicct.org)
[30] https://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAEVRoadmap.pdf
[31] https://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAElectricVehRoadmapBookletDEP5334.pdf

ICCT recommends that the ratio of chargers per EV will initially be high to support EV access in enough locations. As more EVs are registered, the number of chargers per EV will decline. For this reason, the ICCT estimate for 2023 is much larger per registered EV than the EVRM estimations.

The number of EVs registered in the table are projections made from the EV Roadmap and ICCT report. Chargers needed is then calculated by multiplying EVs registered by the recommended number of chargers per EV per category based on 10.9 EVs per public charger (EVRM models) and the dynamic model for ICCT. This was broken down into workplace, public L2, and DCFC based on the percentages of chargers needed in the previous statement.

To meet the ICCT estimate of EV demand, Pennsylvania will need around 50,000 non-home chargers by 2028. This will be a mix of public and private installations. To support this level of charging access, it is recommended that PennDOT provides 4% of the needed number of ports, or 2,000 EV charging ports, by 2028. It should be noted that 2,000 is the low bar, and more aggressive installation strategies should also be considered when pursuing this five-year strategy and the NEVI Plan.

In general, new DCFC locations should support four chargers, each with the ability to supply 150kW simultaneously. Several L2 installations at destination sites are also recommended, and in general, these can have fewer charge ports. Overall, 800 specific EVSE locations are recommended with an average of 2.5 ports per location. These sites include new sites as shown on Figure 3, redundant sites, upgrades to existing sites, and newly determined sites as planning is updated.

These targets are broken down by focus are included in Section 4.1.

PennDOT should re-evaluate the total number as the five-year period progresses and demand estimated are updated.

4 Recommendations for 5-Year Mobility Plan

This chapter proposes detailed EV charging recommendations for PennDOT to pursue in the next five years, split into primary and secondary goals.

4.1 Phased Recommendations for Primary Goals for the 5-Year Plan

This section presents the specific recommendations and strategies for a phased approach to installing EVSE over the next five-year period. A multi-pronged approach is recommended, starting with previously designated AFCs and other Interstates and Interstate look-alikes, then moving to other RoS, and finally examining locations near significant destinations identified in PennDOT's Regional Operations Plans (ROPs). This process is outlined in Figure 20 and detailed in this section.

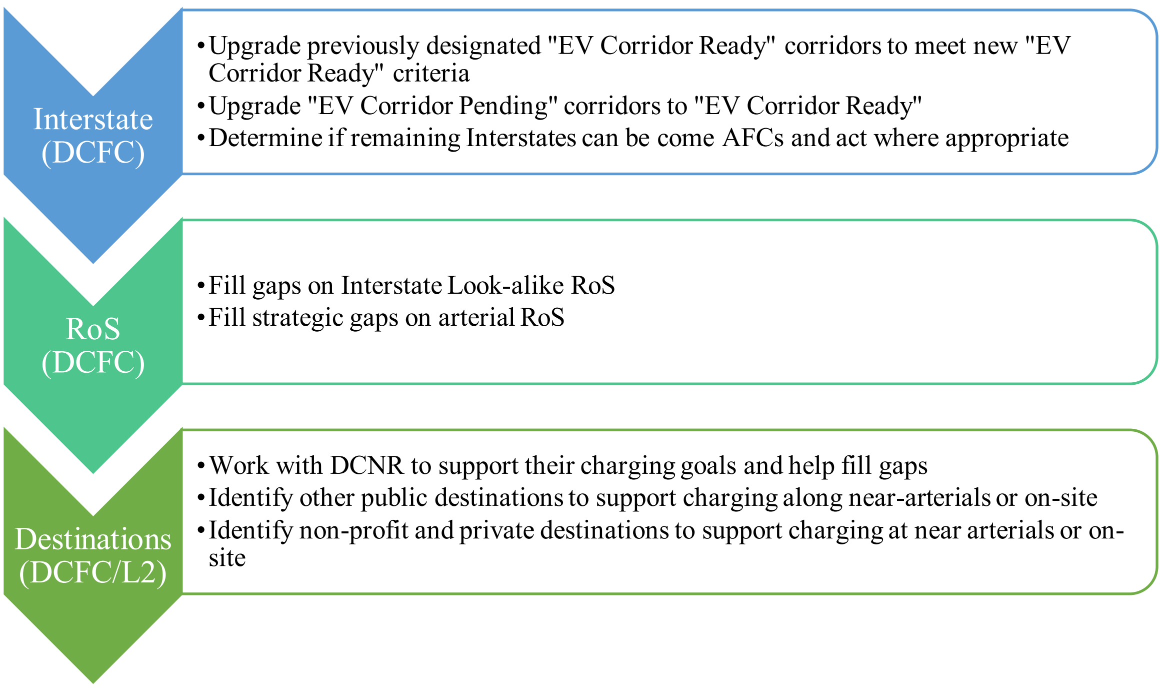

Figure 20. Process for Evaluating Sites for Charging

Each section contains a rationale for the focus area, the context classes where EVSE will typically be installed, and a description of the equity initiatives that should be pursued as part of the focus area. There is also a table in each section that shows the phased approach by year and the specific targets, chargers per stations, and detailed information about the phase. Instead of showing the number of recommended charging stations per year, a color scale is used to show coverage intensity for the year. The color intensity scale signifies the focus on the category from high (50 or more sites - dark green) to low (5 or more sites - light green). Grey years include no emphasis, although some sites may still be selected during these years for various reasons.

It should be noted that when specific target examples are given, effort should be made to encourage and incentivize applications for EVSE funding from sites in or near these specific areas. These phases are listed as guides – there will most certainly be overlap between the phases and an imperfect match to this plan. The phases are meant as a guide to focus efforts versus a prescriptive mechanism. It is recommended that more exacting methods and ranking criteria be established as part of the upcoming NEVI Plan.

4.1.1 Focus Area 1: Interstate Gaps

Rationale:
Filling Interstate gaps are the top priority in providing adequate charging infrastructure for cross-state and regional travel. Gaps should be filled beyond the FHWA AFC requirements to provide a robust network that will support rapid EV adoption over the next decade. Specific guidance for this focus area is described in Table 15.

Contexts:
In general, most of these stations will be in rural or mixed urban contexts, however some stations may be in urban and suburban areas.

Equity Initiatives:
Focus for stations should include low-income EJ areas, particularly rural and remote areas where infrastructure is sparse.

Table 15. Phased Plan for Focus Area 1: Interstate Gaps

Year / Phase	Specific Target	Ports per Site	Detailed Information	Example
1	New AFC Gaps	4	Update all prior "EV Corridor Ready" corridors to meet new AFC criteria	I-78, Allentown
2	Cross-State Gaps	4	Upgrade all "EV Corridor Pending" corridors to "EV Corridor Ready"	I-80, Centre County
3	Regional Gaps	4	Focus on filling gaps that support regional travel, ensuring all AFCs are "fully built out"	I-81, Scranton / W-B
4	Expand Capacity	4-8	Expand capacity to meet 20-mile criterion and expand capacity at existing stations	I-79, Meadville
5	Expand Capacity	4-8	Expand capacity to meet 20-mile criterion and expand capacity at existing stations	I-95, Philadelphia

4.1.2 Focus Area 2: Interstate Look-alikes

Rationale:
Pennsylvania has many freeways that are designated as US or State highways which look and operate like Interstate highways. These routes have high volumes and serve long-distance travel. As such, these are the next most important focus area to support with charging infrastructure. Specific guidance for this focus area is described in Table 16.

Contexts:
Interstate look-alikes exist in all context classes from rural to large urban metros. The phased approach in Table 16 targets one or two context classes per year.

Equity Initiatives:
Interstate look-alikes serve a variety of underserved and disadvantaged communities in both rural and urban areas. Each year, several stations should be designated specifically to accommodate these EJ areas. Additionally, air quality non-attainment areas should be a priority for station locations.

Table 16. Phased Plan for Focus Area 2: Interstate Look-alikes

Year / Phase	Specific Target	Ports per Site	Detailed Information	Example
1	---	---	---	---
2	Inter-Metro Travel	4	Key sites should be identified, including at least two in each initiative area	US-22, Allentown
3	Suburb Connectors	4	Focus on major routes connecting suburbs to major metros	US-30, Downingtown
4	Suburb Connectors	4	Continue to focus on major routes connecting suburbs to major metros	US-15, Dillsburg
5	Rural Freeways	4	Provide all rural freeways with EVSE access at strategic points	PA-43, Uniontown

4.1.3 Focus Area 3: RoS – High to Very High Traffic Volume

Rationale:
Principal arterials form the backbone of travel in many communities across Pennsylvania, or else serve as prime alternates to Interstate travel. High to very high traffic volume arterials, with AADTs greater than 10,000 vehicles per day, are very important routes that carry the largest amount of non-freeway traffic in the state. Phased targets are classified by amount of traffic above 10,000 vehicles per day. Specific guidance for this focus area is described in Table 17.

Contexts:
Arterials with high to very high AADTs are typically located near major metropolitan areas but are also seen in Interstate connectors to mixed and small urban areas.

Equity Initiatives:
High to very high traffic volume RoS typically serve more urban populations, many of which are located in disadvantaged and/or underserved EJ areas. Each year, several stations should be designated specifically to accommodate these EJ areas. Additionally, air quality non-attainment areas should be a priority for station locations.

Table 17. Phased Plan for Focus Area 3: RoS – High to Very High Traffic Volume

Year / Phase	Specific Target	Ports per Site	Detailed Information	Example
1	---	---	---	---
2	---	---	---	---
2	Suburban Arterials	4	Suburban arterials with the largest traffic volumes, > 25k	PA-3, Newtown Square
3	Routes > 20k	4	Arterials with the highest traffic volumes, regardless of context	PA-61, Pottsville
4	Routes > 15k	4	Arterials with the next highest traffic volumes	PA-8, Butler

4.1.4 Focus Area 4: RoS – Moderately High Traffic Volume

Rationale:
Pennsylvania has many medium-sized cities distributed across most of the state. Many of these locations have moderately high traffic volumes on two-lane arterials that connect communities to each other and to the Interstate system. Phased targets are classified by location contexts, with particular emphasis on remote and rural travel. Specific guidance for this focus area is described in Table 18.

Contexts:
Moderately high volume, between 5,000 and 10,000 vehicles per day, principal arterials primarily serve smaller metro areas, small urban, and rural areas. Initial focus should be on remote routes which have not yet been served by the preceding focus areas.

Equity Initiatives:
RoS with moderately high traffic volumes serve many low-income communities, so focus should be placed on low-income EJ areas, including air quality non-attainment areas.

Table 18. Phased Plan for Focus Area 4: RoS – Moderately High Traffic Volume

Year / Phase	Specific Target	Ports per Site	Detailed Information	Example
1	---	---	---	---
2	---	---	---	---
3	---	---	---	---
4	Remote/ Rural Arterials	4	Remote, small urban, and rural areas, particularly in low-income communities	US-119, Marion Center
5	Suburban Arterials	4	Suburban arterials with lower volumes than Focus Area 3	PA-23, King of Prussia

4.1.5 Focus Area 5: RoS – Moderate Traffic Volume

Rationale:
All RoS were chosen for a reason. Many regionally important arterials serve only moderate traffic volumes, less than 5,000 vehicles per day down to 1,000 vehicles per day. These routes need adequate charging facilities to allow for more complete statewide coverage. Phased targets are classified primarily by typical length of travel, with particular emphasis on remote and rural travel. Specific guidance for this focus area is described in Table 19.

Contexts:
Most RoS with moderate traffic volumes are in rural or small urban areas. These routes can service as cross-state routes in remote areas, connectors between small urban areas, and arterial connections to higher use facilities.

Equity Initiatives:
Most of these routes serve lower population areas in rural and remote areas, many of which are well below the median income in the state. Particular emphasis should be placed on low-income EJ areas or ones that are not officially EJ areas but are still of lower income than average.

Table 19. Phased Plan for Focus Area 5: RoS – Moderate Traffic Volume

Year / Phase	Specific Target	Ports per Site	Detailed Information	Example
1	---	---	---	---
2	---	---	---	---
3	Rural Cross-State	2	Longer rural routes that are used for longer distance travel	US-6, Smethport
4	Remote Arterials	2	Arterials in remote areas that do not have any EV charging service within 50 miles	US-219, Johnsonburg
5	Rural Connectors	2	Arterials that connect rural and small urban areas	PA-56, NW of Johnstown

4.1.6 Focus Area 6: Year-Round Destinations

Rationale:
Year-round destinations can be major draws for residents from across the state as well as visitors from bordering states. Year-round destinations have a constant demand for EV charging, though these demands may still fluctuate throughout the year. These include both public and private destinations. Public destinations include public parks, including federal, state, county, and municipal units along with related public-owned destinations, such as colleges, fairs, and public sporting venues. Private destinations include amusement parks, zoos, museums, racetracks, villages, expo centers, private sporting venues, and private colleges.

These areas can be 20 or more miles from a population center or route of significance. Focus should be placed on two main locations, DCFC at support locations along arterials leading to the destinations, and L2 charging at the destinations themselves. Specific guidance for this focus area is described in Table 20.

Contexts:
Destinations exist across the state, from the most remote regions to the most densely populated urban cores. Thus, charging needs will vary significantly and are context specific. A ranking using many factors such as number of visitors, EJ status, etc. should be used to rank order the list of destinations.

Equity Initiatives:
Underserved EJ areas have many destinations where charging would be otherwise overlooked if not specifically accounted for as part of this plan. Emphasis should also be placed on locating EVSE in EJ areas, air quality non-attainment areas, and rural areas.

Table 20. Phased Plan for Focus Area 6: Year-Round Destinations

Year / Phase	Specific Target	Ports per Site	Detailed Information	Example
1	---	---	---	---
2	---	---	---	---
3	Demo Locations	4	Demonstration locations to model how this type of station can be funded and located	Ohiopyle State Park
4	Publicly Accessible Locations	2-4	Top destinations that are publicly accessible 24/7	Harrisburg Area CC
5	Non-Publicly Accessible Locations	2-4	Top destinations that are not publicly accessible and require fee for parking / entry	Zippo/Case Museum

4.1.7 Focus Area 7: Seasonal destinations

Rationale:
Seasonal destinations such as ski resorts, racetracks, and fairgrounds may have high demand only at certain times throughout the year. To maximize the value of charging at these locations, charging should be primarily considered through DCFC or L2 charging at support locations along arterials leading to the destinations, which will allow for more steady usage throughout the year. Some seasonal destinations may have a low number of events (three or less), and these destinations should be considered for mobile charging as opposed to static sites. Specific guidance for this focus area is described in Table 21.

Contexts:
Destinations exist across the state, from the most remote regions to the most densely populated urban cores. Thus, charging needs will vary significantly and are context specific. A ranking using many factors such as number of visitors, EJ status, etc. should be used to rank order the list of destinations.

Equity Initiatives:
Many seasonal destinations are in rural areas and are the primary economic drivers in their community. These can be largely lower-income areas and/or underserved areas. Emphasis in selecting locations should be placed on EJ areas, air quality non-attainment areas, and rural areas.

Table 21. Phased Plan for Focus Area 7: Seasonal Destinations

Year / Phase	Specific Target	Ports per Site	Detailed Information	Example
1	---	---	---	---
2	---	---	---	---
3	---	---	---	---
4	Publicly Accessible Locations	2-4	Top destinations that are publicly accessible 24/7	Knoebles Amusement Park
5	Non-Publicly Accessible Locations	2-4	Top destinations that are not publicly accessible and require fee for parking / entry	Philadelphia Sports Complex

4.2 Recommendations for Secondary Goals for the 5-Year Plan

This section presents general recommendations and strategies for approaching planning for and installing EVSE to meet secondary goals over the next five-year period. Although each of these focus areas will not be fully supported like the primary goal areas, a variety of charging recommendations are recommended including pilot programs and demonstration sites.

Each section contains a rationale for the focus area, the context classes where EVSE will typically be installed, and a description of the equity initiatives that should be pursued as part of the focus area. Additionally, recommendations are made for charging and planning over the next five-years.

It is recommended that these focus areas be further developed as part of the upcoming NEVI Plan.

4.2.1 Focus Area 8: Mobile Chargers / Towing

Rationale:
Special events will need charging opportunities and these areas with demand fluctuation will be best served by quickly deployable mobile chargers. Additionally, there is a significant disadvantage to running out of charge versus running out of gasoline. At least with current battery technology, you cannot walk to a station and pick up a replacement battery or other form of temporary charge relief like you can a can of fuel. Thus, this need must be met if EVs are going to be competitive.

Contexts:
Special events happen across the state, in both urban areas where more charging near the event locations may be available and in rural areas that may otherwise have lower demand for charging. Additionally, vehicles can run out of charge anywhere in the state. In particular, rural areas with low densities of available charging are most vulnerable. Large metro areas will likely have a greater number of these stranded vehicles due to high number of travelers.

Equity Initiatives:
Special events in rural areas are most likely to need dynamic charging infrastructure through mobile charging. People in underserved and disadvantaged EJ areas are more likely to travel in older vehicles, and these vehicles are more likely to have unstable batteries and run out of charge while enroute. Due to lack of affordable housing near jobs and schools, trip lengths are increased meaning these residents are more likely to need to drive longer distances as well. In rural areas, the cost of running out of charge is higher and there are few if any services available within walking distance. Thus, emphasis should be placed on serving EJ areas and rural areas.

5-Year Recommendation:
Mobile trailers, 1-4 chargers each – Provide each district in PA with at least one demonstration vehicle that has a mobile charger for supporting special events, emergency use, and stranded vehicles. Some of the demonstration units should include a bank of chargers for a focus on special event and/or emergency use. Additional chargers can be made available through a grant program for counties and municipalities.

Furthermore, educational programs, support, and coordination efforts should be provided for towing companies to help encourage them to support EV towing and charging for stranded vehicles. Flatbed towing is recommended as rope- or lift-style towing can damage EVs.

4.2.2 Focus Area 9: Emergency Routes

Rationale:
Emergencies place a large demand on roadway networks that otherwise may not see as much traffic. Pennsylvania has an extensive network of detour routes that are used for a variety of planned and emergency situations. Municipalities have a variety of snow and emergency routes that are critical network links. Additional EV infrastructure should support these routes to improve safety during emergencies. Mobile chargers can also be deployed to support these emergencies.

Contexts:
Emergency routes can become most congested in larger metro areas and along freeways in suburban and rural areas.

Equity Initiatives:
Severe weather will have a larger impact on EJ areas as the infrastructure in these areas is less climate resilient. Thus, these should be a primary focus in emergency route charging.

5-Year Recommendation:
Demonstration stations, 1-2 chargers each – Demonstration chargers prescribed along state detour routes, and additional chargers made available to counties and municipalities to support charging along snow emergency routes and evacuation routes. Additional emphasis should be placed on planning for RoS EVSE to support installation on or near these routes. Furthermore, mobile charging units (as procured for mobile charging) should be considered for deployment to these routes and additional units should be considered if necessary.

4.2.3 Focus Area 10: Mobility Hubs / Multimodal Travel

Rationale:
Supporting multimodal travel can reduce demand on the highway network and enable more possibilities for citizens of Pennsylvania to reach more destinations. Mobility hubs should be the first area of focus for commuter travel, as these hubs generally support transit users who either park a private vehicle for an extended period or are dropped off by a taxi or TNC vehicle. Charging for these vehicles can be provided at L2 either for multi-hour charging or DCFC for a small charge while waiting for a new passenger.

Contexts:
Mobility hubs are typically in suburban and urban areas, as well as key locations along freeways and arterials in rural areas outside the urban fringes. All of these areas could see a benefit from providing additional charging services.

Equity Initiatives:
Reducing the number of single-occupancy, fossil-fuel burning vehicles on the road can directly impact air quality from emissions. Providing charging at mobility hub gives more incentives to change driving behavior and rely more on multi-occupant vehicles.

5-Year Recommendation:
Demonstration stations, 4 chargers each – Provide chargers at demonstration mobility hub sites dispersed across Pennsylvania's metro areas. Plan for additional commuting support methods. Work with TNCs to identify locations that would be ideal to site these chargers.

4.2.4 Focus Area 11: Interstate / Regional Travel (MDV/HDV)

Rationale:
HDVs primarily utilize the Interstate network when making long-haul deliveries to and through Pennsylvania. Though HDV charging is in its infancy, PennDOT can support growth in this area by developing a few key demonstration sites.

Contexts:
Though HDVs travel all over the state through urban and rural areas, rural areas (where there is adequate power supply) should be the first focus this effort to demonstrate charging for long-haul trucking.

Equity Initiatives:
Idling diesel trucks reduce air quality by emitting pollutants. Providing access for EV HDVs will eventually help reduce emissions at truck stops, warehouses or distribution centers, ports, and on roads at intersections or in congestion.

5-Year Recommendation:
Demonstration stations, 4 chargers each – Set up demonstration sites at private truck stops and Pennsylvania Turnpike service plazas to demonstrate charging capabilities for HDVs. If laws are modified, rest areas should be considered as well.

4.2.5 Focus Area 12: Rural Deliveries (MDV/HDV)

Rationale:
Many MDVs make rural deliveries more frequently now than ever before. To incentivize delivery companies to buy EVs instead of gasoline or diesel vehicles, charging opportunities must be available for vehicles to get a small charging boost, requiring high-power charging, to allow them to reach rural and remote destinations.

Contexts:
The primary context of consideration for this focus area is rural areas.

Equity Initiatives:
The initial delivery focus is on low-income rural and remote areas, where it may be difficult for delivery vehicles to get to and from their depot without the need to recharge while enroute. At least initially, it is assumed that urban delivery vehicles will have the option to recharge at their depot.

5-Year Recommendation:
Demonstration stations, 1 charger each – Work with private shipping companies and the US Postal Service to identify pilot locations where charging would support remote deliveries.

4.2.6 Focus Area 13: Emergency Travel (MDV/HDV)

Rationale:
When trucks are stranded on the side of the road, deliveries cannot be made on time. To support MDVs and HDVs that run out of charge on the highway, this area be studied in more detail to determine if large wreckers could include a high enough power charger to support a quick electric boost to stranded vehicles.

Additionally, MDVs/HDVs are used for emergency response such as incident response, disaster response, and weather response. These vehicles would also benefit from mobile charging availability.

Contexts:
Trucks are most likely to have problems running out of charge in rural areas and in large metro areas. Additionally, emergency response will be most difficult in these areas. Thus, these areas should be the primary focus.

Equity Initiatives:
In the case of power outages, backup power sources should planned to be equitably distributed, with particular emphasis on EJ areas.

5-Year Recommendation:
Mobile stations, 1 charger each – Provide each PennDOT TSMO region and the PA Turnpike with an experimental wrecker charger as they become available. In the interim, planning work should be done to determine charging requirements, best locations for deployment, and a cost-benefit versus towing as an option.

5 Next Steps

The EV Mobility Plan lays out the existing EV mobility infrastructure in PA and makes recommendations on moving forward with a 5-year plan. To support the plan, more work will need to be done in various areas including planning, coordination and outreach, site selection and design, and operations and maintenance. Some of this work will be done as part of the NEVI Plan, however it is expected that this EV Mobility Plan will also be updated periodically, as the suite of PennDOT's EV charging support will extend beyond the AFC goals in the NEVI Plan.

5.1 Planning

This plan outlines recommendations for PennDOT to deploy EVSE across Pennsylvania and support the growth of EV charging options. The following steps should be taking to codify the recommendations and begin installations. Much of this work is recommended for integration into the upcoming NEVI Plan.

5.1.1 Finalize Phases of EVSE Deployment

Using the recommendations in this plan, outline a final investment strategy, timeline, and rough number of stations per category to support the installation of all EVSE sites over the five-year period. AFC build-out and initial RoS buildout should be the focus of the NEVI Plan, with further planning and funding for additional site types and supplemental sites.

5.1.2 Develop Standard Procurement Plan

In order to select sites to establish EV charging, a standard procurement plan needs to be put in place to streamline the process from applications to installations. This plan should be developed as part of the NEVI process and modified for additional sites.

5.1.3 Plan for Upgrading Corridors to the "Fully Built Out" for AFC Round 6

The new AFC criteria for "EV Corridor Ready" means that existing "EV Corridor Ready" corridors need to be verified and updated to the new "fully built-out" standards. Additionally, "EV Corridor Pending" corridors should be made into "EV Corridor Ready" corridors following "fully built out" guidelines. This should be the primary focus of the first stages of implementation of this plan.

5.1.4 Identify New AFCs

The next priority after converting all "EV Corridor Pending" corridors is to decide which corridors to focus on next for AFC upgrades. This will likely include Interstate look-alikes and very high volume RoS.

5.1.5 Origin-Destination Analysis

National parks and other destinations may see more unique travel patterns that require further analysis to understand. For example, many travelers may opt to take scenic routes instead of the fastest route. In these cases, there may be arterials in need of charging capabilities that are otherwise not included. An in-depth origin-destination analysis can pinpoint these types of routes and determine further charging needs in Pennsylvania.

5.2 Coordination and Outreach

An outreach plan should be developed to include a variety of stakeholders across Pennsylvania. This should include all public entities responsible for serving vehicle traffic, EV groups that operate in the state, utility providers, and site hosts and other third parties. Materials should also be developed for public education so the public understands and can provide input on the program.

5.2.1 MPOs and RPOs

MPOs and RPOs have access to a wide range of regional resources including networks of businesses and professionals in the EV space, regional datasets, and funding mechanisms. It is important to engage these groups in order to develop regional plans and select specific sites for EV charging infrastructure.

5.2.2 P3 Partner Identification and Development

P3s have been very effective over the past 20 years in efficiently creating and maintaining transportation resources across the United States. The BIL places a large emphasis on P3s as a mechanism to support grant programs. One downside to P3s is that they can take a long time, at least 18 months, to be established, and there is a risk of them falling through in this time. Thus, AFC build-out will likely not use P3s. Instead, P3s and other cost sharing methods should be explored to support the build-out of EV charging infrastructure in more difficult to site areas or Pennsylvania and more as a support mechanism to PennDOT's main funding distribution efforts.

5.2.3 Clean Cities' Partners

Clean city groups across Pennsylvania are advocating for a number of initiatives that align with vehicle fleet electrification. These groups include the Eastern Pennsylvania Alliance for Clean Transportation and the Pittsburgh Region Clean Cities, which are both part of the Department of Energy's Clean Cities Coalition Network.

5.2.4 Utilities

Utility providers will ultimately be the energy providers on most EV installations and as such need to be engaged throughout the process of site selection. Understanding utilities abilities and constraints is critical for successful deployment of EV infrastructure.

5.2.5 Other Third Parties (e.g., Site Hosts)

Site hosts and other third parties will be involved in the ownership, management, and/or maintenance of EV infrastructure. Many others will be stakeholders with an interest in the success or failure of the EV chargers. These groups need to be engaged throughout the process of site selection.

5.2.6 Public Education

It is critical that the public understand the PennDOT EV mobility goals and objectives and that these are aligned with public needs. Specific programs should be developed to explain to the public the importance of the program, allow for public involvement in site selection, and understand the publics interests in EV charging.

5.3 Site Selection and Design

Site selection and design are not developed in this plan beyond recommending site locations and types of chargers. This section outlines the next steps to select and design charging sites.

5.3.1 Develop Standard Site Scoring Mechanism

This plan recommends a variety of methods, initiatives, and metrics that could be used to select sites. These include job locations, population, traffic volumes, equity considerations, available amenities near site, etc. The next step is to develop these recommendations into a standard scoring template. This template can have some flexibility as different focus areas may require slightly different scoring techniques.

5.3.2 Determine the Quantity of Chargers at Each Location

AFC sites are recommended to include four chargers that are capable of charging four vehicles at 150 kW simultaneously, providing 600 kW total. All other sites in this plan do not include specific power recommendations. This plan lays out some initial values to be used for quantity of chargers, but it is recommended that the next steps look specifically at modifying these numbers based on current and future charging demand, power availability, and other factors.

5.3.3 Develop Standards for EV Sites

Although this plan recommends specific location options, there are few recommendations on site design. Standard designs should be developed that include charging hardware size and locations, parking stall marking and signage, and ADA accessibility, among other items.

5.4 Operations and Maintenance

In some instances, site owners have decided to remove equipment. Although this may be beneficial to the site host in the short term to meet their own economic interests, public EV charging needs will suffer if stations are removed. PennDOT has an interest to make sure any new infrastructure can survive until EV adoption becomes large enough where demand is met in these locations.

Because PennDOT does not want their investments to go under in a few years, additional funding should be planned for operating assistance at select locations, especially EJ and rural areas.

Appendix A Technology Scan Memorandum

PennDOT is developing the EV Mobility Plan to unlock the potential benefits of EVs in Pennsylvania. The EV Mobility Plan will identify specific actions to facilitate the transition to electrified mobility across Pennsylvania.

The purpose of this memorandum is to summarize the various technologies that currently exists in the market or anticipated to exist in the future as it relates to EVs and alternative energy sources to power EVs.

A.1 Vehicles

EVs are powered by electricity, an alternative fuel. Electricity is a scalable, domestic source of energy that is low and stable in price and produced from both non-renewable (e.g., coal, natural gas) and renewable sources (e.g., solar, wind).

EVs use electricity as their primary fuel or to improve the efficiency of conventional vehicle designs by using a battery pack charged by an electric power source to then power an electric motor – all while producing less/no direct tailpipe emissions.

Overall, EVs can help increase energy security, improve fuel economy, lower fuel costs, and reduce emissions.

A.1.1 Drivetrain Types

There are two types of vehicles that use electricity either as their primary fuel or to improve the efficiency of conventional vehicle designs, both types are known as plug-in electric vehicles (PEV):

A.1.1.1 Plug-In Hybrid Electric Vehicles

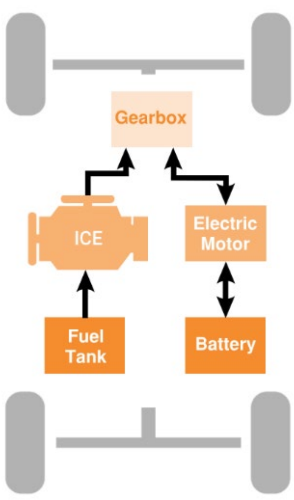

Figure 21. Plug-in Hybrid Electric Vehicle Diagram

These vehicles have both an internal combustion engine and an electric motor that uses energy stored in a battery (Figure 21). They can run on either gasoline or electric power. The electric power to charge the battery can either be supplied externally by plugging into a charger or internally through regenerative braking. HEVs are a separate class of vehicles from PHEVs and are not plugged in to charge the battery, rather the battery is charged internally through regenerative braking. Range extending electric vehicles (REEVs), such as the Chevrolet Volt or BMW i3, use an internal combustion engine to power a generator to charge the battery. HEVs and REEVs are not part of this report. The vast majority of PHEVs cannot use DC fast chargers. Argonne National Laboratory reported that in August of 2021, a total of 43,721 plug-in vehicles were sold, with 15,261 being a PHEV[32] and 28,460 were purely battery electric.

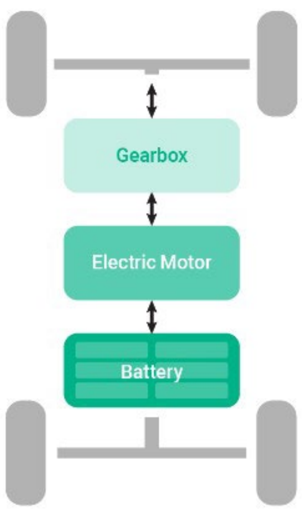

Figure 22. Battery Electric Vehicle Diagram

[32] https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates

A.1.1.2 Battery-Electric Vehicles

Also known as all-electric vehicles, BEVs run on electricity alone. They use a battery to store the electric energy that powers one or more electric motors (Figure 22). EV batteries are charged by plugging the vehicle in to an electric power source and through regenerative braking. These are categorized as zero-emission vehicles because they produce no direct exhaust or emissions.

A.1.2 Battery Technology

Battery technology is one of the key drivers of transportation electrification adoption. Barriers to widespread EV adoption have included the charge time, cost, size, and weight of the battery required to power electric traction motors. However, each of these barriers has been declining rapidly over the past decade, while energy density (amount of energy stored in proportion to its weight) has increased (Figure 23).

Battery costs have been driven down by advances in battery cell chemistry and by increased production volumes.

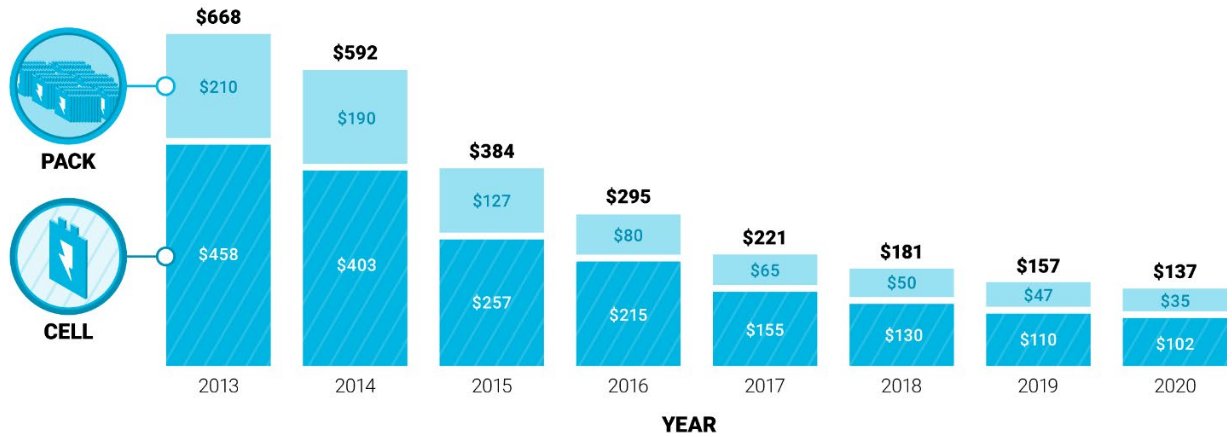

Figure 23. Volume-Weighted Average Pack and Cell Price Split[33]

A.1.2.1 Battery swapping

It is possible to replace a depleted battery in an EV with a fully charged one. A few automakers, such as the Chinese company Nio[34], have embraced battery swapping in passenger vehicles. However, the passenger vehicle industry has largely trended away from this technique and rapidly charging energy-dense batteries seems to be the way forward. Companies such as Ample[35] envision modular battery swapping stations that remove depleted battery modules from cars with fully charged modules waiting at the station.

This technology is said to take less than 10 minutes to swap out a battery, but many barriers still exist such as OEM battery module standardization. Even so, battery replacement may be an appealing option when these constraints can be overcome for niche applications for fleet vehicles where manufacturers and/or larger fleet operators could build out battery swapping networks that addressed specific needs.

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[33] https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/

[34] https://www.nio.com/news/nio-announces-nio-power-2025-battery-swap-station-deployment-plan

[35] https://ample.com/2021/03/03/introducing-ample/

A.1.2.2 Second life battery

EVs have batteries that may have useful life after they are no longer suitable for transportation. They can be repurposed as stationary battery storage for a micro-grid system to increase resiliency, add value, and flatten demand from the grid. During off-peak times, the battery can be charged, “filling in” excess generation capacity, while the battery can be used to meet demand during peak times, “flattening” the demand curve. While grid-scale energy storage is growing rapidly, this manner of utilizing the batteries after their vehicle life is still in the early stages of development.

A.1.2.3 Battery Recycling

Vehicle manufactures such as Ford[36] and GM[37] are partnering with battery recycling companies to ensure that battery materials can be recycled and reused. The goal is to create more of a closed-loop system that reduces the number of materials such as lithium, nickel, cobalt, and copper being imported and mined. Companies such as Redwood Materials[38] and Veolia & Solvay[39] are working to enable the circular economy of EV battery metals through closed-loop recycling.

Note that the rare earth metals in second life EV batteries can be recycled just as well as a single use battery. as they do not erode or break down with usage. With new innovations in battery technology without the use of rare earth metals (e.g., sodium-ion batteries), the importance of battery recycling may be greatly reduced.

A.1.3 Other Alternative Fuels

The number of fuel alternatives that exist for passenger vehicles is relatively small.

A.1.3.1 Ethanol Blend

Almost all gasoline currently consumed in the US is blended with 10% ethanol, referred to as E10, and can be used in any modern gasoline engine[40]. Higher blends of ethanol blended fuel exist such as E15 with a 15% blend and E85 which contains 51% to 83% ethanol by volume, the latter of which can only be used in flex fuel designated engines. These ethanol blended fuels can help to reduce GHG emissions when considering life cycle emissions, but still generate tailpipe emissions.

A.1.3.2 Compressed Natural Gas (CNG)

CNG offers life cycle GHG benefits when compared to conventional fuels but is not widely offered in passenger vehicles and fueling stations are limited.

A.1.3.3 Biodiesel

Biodiesel is a fuel derived from vegetable oils and/or animal fats generated as waste products at restaurants. Although burning it releases less carbon dioxide, it is more expensive and much less commonly available than standard diesel. Biodiesel meets ASTM D6751 and is approved for blending with petroleum diesel.

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[36] https://media.ford.com/content/fordmedia/fna/us/en/news/2021/09/22/ford-redwood-materials-battery-recycling.html

[37] https://plants.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2021/may/0511-ultium.html

[38] https://www.redwoodmaterials.com/

[39] https://www.solvay.com/en/press-release/solvay-and-its-partner-veolia-set-demo-plant-recycling-battery-metals

[40] https://www.eia.gov/todayinenergy/detail.php?id=26092#:~:text=Blends%20of%20petroleum%2Dbased%20gasoline,motor%20vehicles%20with%20gasoline%20engines.

A.1.3.4 Fuel Cell Electric Vehicles (FCEV)

The only fuel type other than electricity that offers zero tailpipe emissions is hydrogen in FCEVs. A FCEV uses a propulsion system similar to a BEV, except that the energy is stored in the form of hydrogen and converted to electricity by the fuel cell (Figure 24). The fuel cell can be considered as a replacement of the ICE in a PHEV. The hydrogen fueling process is similar to gasoline, but infrastructure is very limited and, like electricity, is not necessarily produced from a carbon-free source. Beyond the pathway to zero emission vehicles, the interest in hydrogen as a transportation fuel stems from its promise for domestic production, high energy density, extended vehicle range potential, fast filling times, and FCEVs' high efficiency when compared with internal combustion engines[41]. For these reasons, FCEVs are largely seen more as future options for medium and heavy-duty freight vehicles that need to haul cargo at longer range, than for widespread use in passenger vehicles.

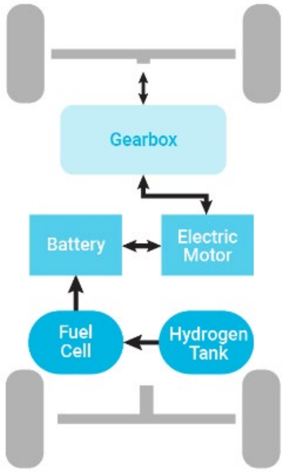

Figure 24. Fuel Cell Electric Vehicle Diagram

A.1.4 Autonomous Vehicles = Electric Vehicles

A trillion-dollar market[42] is being developed around driverless technology and numerous autonomous features are already part of existing models. For example, features such as automatic braking, lane keeping assist, and adaptive cruise control are autonomous technologies that are currently available and will continue to be developed to make vehicles safer.

Major automakers[43] see EVs as the best platform for AVs because of the simplicity of the drivetrain and the rapid response of electric motors to control commands. EVs contribute strongly to the development of AVs since autonomous technology integrates easier with the advanced computers, sensors, and electric motors in EVs and early AV adopters will likely want the most innovative vehicles available.

To support the development and testing of AVs, a robust EV charging network will be needed. California recently announced a requirement that all light-duty AVs must be zero emission starting in 2030[44,45]. This requirement serves to ensure that the upcoming era of AVs will not bring with it more pollution.

A.2 EV Chargers

EVSE consist of the equipment used to deliver electrical energy from an electricity source to an EV battery. This is done by securely connecting the charger plug to the EV to supply a flow of electricity.

A.2.1 Charging Levels and Uses

There are three primary types of EV charging (Table 4). The charge times vary depending on the type of charger, on-board vehicle charging equipment, the vehicle's battery capacity and type of battery, and the battery's depletion level.

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[41] https://afdc.energy.gov/fuels/hydrogen_basics.html
[42] https://www.cnbc.com/2020/02/05/gms-cruise-values-autonomous-vehicle-industry-at-8-trillion.html
[43] https://www.gm.com/masthead-story/electric-vehicles-AV-EV.html
[44] https://www.theverge.com/2021/9/24/22691410/california-autonomous-vehicles-zero-emission-2030-newsom
[45] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB500

A.2.2 Ultra-Fast Charging, MW+, MDV/HDV Vehicle Charging

Ultra-fast charging typically refers to charging levels well above 50 kW that allows some EVs to charge in as little as 10-15 min, provided that the vehicle can accept the high-power level. For example, a Nissan Leaf can only accept about 50 kW while a Porsche Taycan can accept up to 270 kW.

As vehicle and battery technology advances, more EVs will be able to charge at higher power levels, reducing the time needed to stop and charge. Tesla is reportedly developing a charger to power its Semi at rates of up to 1.6MW. Megawatt Charging Systems (MCS) that are currently under development for medium and heavy-duty vehicle applications will charge at rates up to 4.5 MW.

A.2.3 Inductive Charging

For inductive charging by sending current from the power supply through a coil, a spinning magnetic field is created that acts on a second coil within the vehicle where it is converted back into an electrical current. A simplified version of the principle is illustrated in Figure 25.

The overall system efficiency is sensitive to the size of the air gap between the charger coil and the onboard coil, as well as the location of the two coils relative to each other. This is an obstacle for public induction chargers since vehicle ground clearance can vary considerably, and the location of the charger coil can vary among EVs.

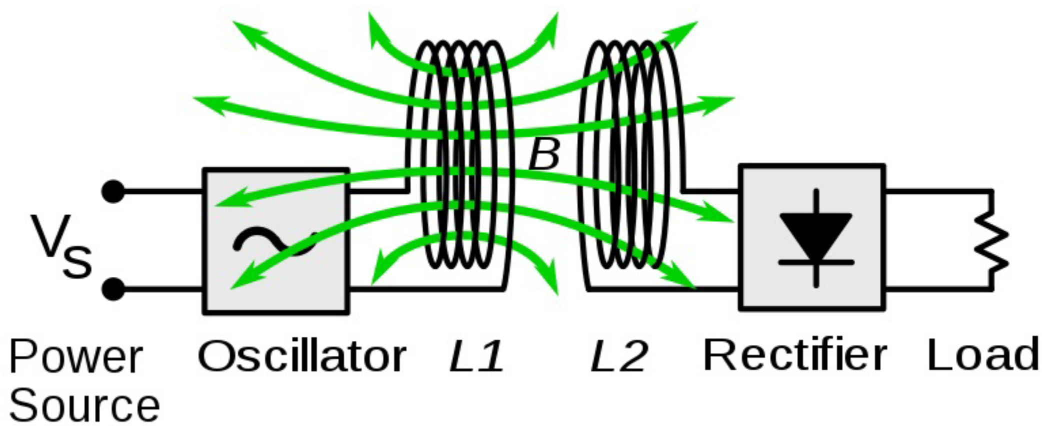

Figure 25. A Simplified Illustration of Inductive Charging (Source: FleetCarma)

Barriers to commercialization of induction charging in passenger vehicles include cost and added vehicle weight, which is already a struggle with EVs when compared to conventional vehicles. The cost of installation of the wireless chargers can be comparative to typical level 2 chargers if the transmission coil is in a pad that can lie on the ground. However, for public charging, the charging pad would likely have to be buried, which would increase the costs.

For on-route charging of transit buses where the transit system has standardized bus height, the transmitter coil can be in a tower above the bus with the receiving coil in the bus roof. The bus roof must be designed to prevent leakage of the magnetic field into the passenger compartment of the bus. Alternatively, charging can be restricted to buses at the terminal. For use in the terminal, the reception coil can be in the bottom structure of the bus and the transmitter can be in a pad on the terminal floor.

A.2.3.1 In-Road Charging

Dynamic or in-road chargers can be laid in the road to charge vehicles in motion. In-roadway induction charging for EVs is being tested in various small-scale deployments. The vehicle to be charged needs to maintain the same position in a lane for the time period of the charge. This requires either the development of more accurate lane-keeping than is now available, or the use of onboard sensors that identify coils buried beneath the surface of the roadway. Business models that recover the cost of embedding the charger coil in a roadway, maintaining the coils, and electricity costs have not been developed and implemented. A business model could include a dedicated high-capacity charging lane with access requiring a toll payment.

Research pilots are underway in France, Sweden and Israel for transit buses and heavy-duty trucks. The state of Michigan announced an initiative to be the first state in the US to construct a segment of road that will charge EVs while in motion[46]. But with falling battery prices and the availability of other charging methods, at $1m-$4m per mile for the infrastructure in addition to the costs associated with modifying or reconstructing the road, dynamic charging is currently not economically feasible for most applications.

A.2.4 Load Management

When many chargers are deployed at a single site, load management, also known as adaptive charging technology, offers a way to meet EV charger demand while still staying within a power limit threshold, which is particularly important for large charger deployments at one facility. Lack of load management results in significantly higher power requirements and could result in prohibitive demand charges for site owners and/or require utilities to build additional infrastructure. The impact of load management on power requirements is significant and can be seen in Figure 26.

The load management system collects information from the operating chargers and information on the completion time required and the starting state of charge. It then controls charging power and maximum output to avoid or minimize demand charges. Notice how in the bottom portion of the figure the same number of vehicles are charged in the same amount of time using less power capacity. Careful urban and regional planning in coordination with utilities is especially important when charging sites are clustered near one another.

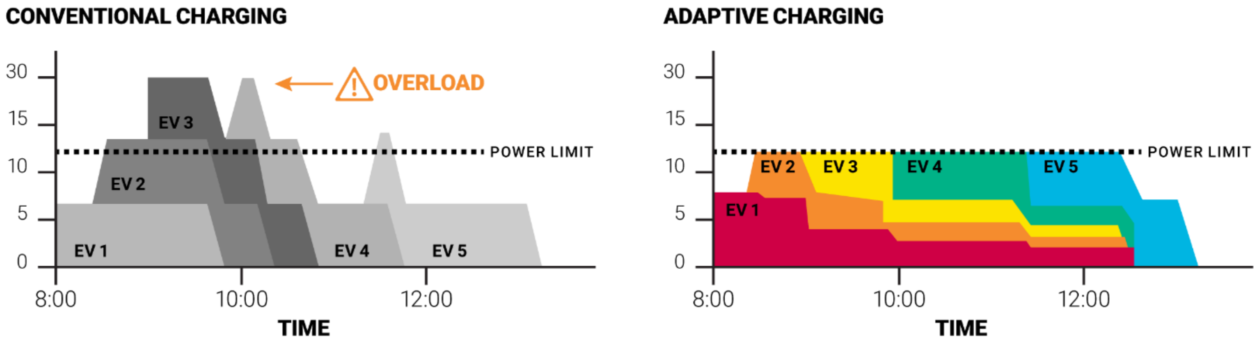

Figure 26. Adaptive Charging Benefits

46 https://www.michigan.gov/whitmer/0,9309,7-387-90487-568674--,00.html

A.2.5 On-Site Generation

On-site electricity generation can help offset electricity costs during peak demand times. Solar energy is one of the most promising sources of local, renewable generation for local generation due to its relatively low cost, zero emissions, and the fact that much of their energy production coincides with daytime peak demand, making it a good candidate for peak leveling to reduce demand charges and improve grid stability. Panel prices have come down significantly in the last 10 years while efficiency has gone up, making them more attractive for large-scale use.

Coupling solar panels with battery energy storage provides a significant level of control to the charging system. Other types of distributed generation such as wind energy can also serve to provide power during peak periods or when the larger grid is not available. Note that on-site electricity generation for EVSE would largely by used as a supplementary power source to offset grid demand and would not currently be reasonable as a primary source of power, especially for sites with a DC fast charging.

A.2.6 On-Site Backup Power

As the cost of batteries decreases, on-site battery storage is an increasingly affordable option for reducing the costs of electricity. On-site storage allows a property to draw electricity from the grid during off-peak times or from an alternative power source (e.g., solar) and store it on-site for later use, often with the goal of avoiding demand charges. It's also a potential second use for older vehicle batteries that no longer maintain enough of a charge to use in operation but are valuable for other purposes.

The use of on-site diesel or natural gas generators could also provide resiliency benefits to power EV chargers in the event of a power outage. However, these backup power options would likely only be used in emergency situations and would not be a viable solution for frequent use due to the cost of fuel and maintenance. These generators also would not have the same environmental benefits of battery storage.

A.2.7 V2G/Bidirectional Charging

Vehicle to grid (V2G), is a type of bi-directional charging that allows energy stored in an EV battery to be fed back into the energy grid. In this scenario, an EV can accept power from a charger via energy from the grid, but during times of peak demand, the flow of energy can change direction and be put back into the grid. With this type of arrangement, the utility operator may be willing to purchase energy from individual EV owners, fleet operators, or vehicle manufacturers.

As EV adoption increases and millions of these batteries on wheels sit plugged in in consumer's garages, utility companies may become more and more interested in this type of 'crowdsourced' energy to support local energy distribution and mitigate intermittency issues relating to renewable energy. Various manufacturers and research institutions are testing V2G technologies, but no commercially available solution currently exists and, presently, use of V2G invalidates many EV warranties.

V2G requires a 2-way circuit and an inverter that converts DC to AC power when needed. It also requires an agreement with the vehicle owner. The easiest approach is to use a vehicle fleet with common vehicles and a single owner. Electric school bus fleets are ideal since they are parked in a common area through most of the day. Similar setups such as vehicle to home (V2H), vehicle to building (V2B), or more broadly, vehicle to everything (V2X), may be available sooner and could be used to supplement energy during peak demand for on-site applications. These applications should be considered as part of PennDOT's future planning for EV charging.

A.2.8 Microgrids

Microgrids are typically designed to reduce the critical load, but also offer resiliency in the event of a power outage by the ability to break off from the grid and operate on their own. They typically integrate renewable solar or wind generation, batteries, distributed generators, and can power building operation and charging infrastructure. See Figure 27 for a simple example of a microgrid.

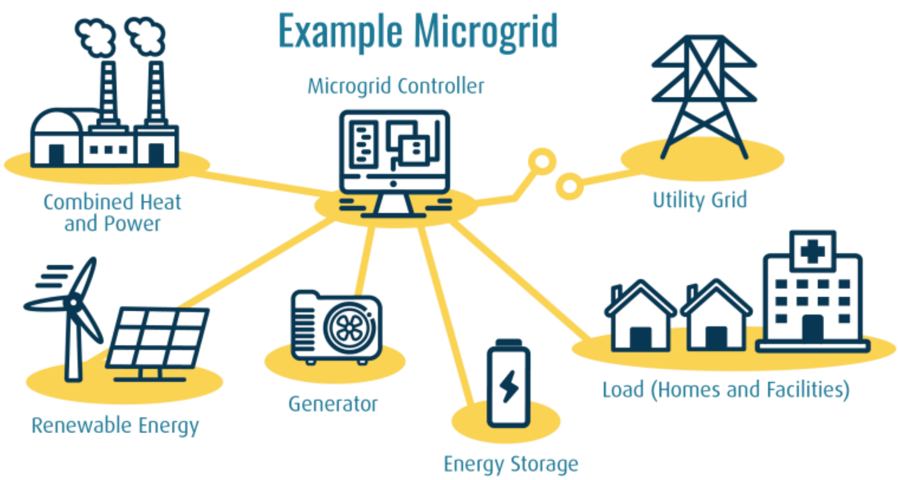

Figure 27. Example Microgrid[47]

A.2.9 Mobile Charging

In addition to the second life battery uses discussed in **Section A.1.2.2**, companies such as FreeWire[48] have developed a portable charging station powered by second life EV batteries to charge other EVs. The mobile charger is made from repurposed EV batteries and allows EV charging without installation and permitting costs. Other companies such as SparkCharge[49] offer mobile EV charging as a service where the user can have the charge come to them.

The FreeWire charger, an L2 charger, can also be in a fixed location and use either grid power or solar energy to recharge the battery storage between charging events; thus avoiding the high cost of installing expensive electrical infrastructure to mimic fast charging.
Tesla has demonstrated the use of a mobile Supercharger called Megapack[50] which combines 3 MWh of battery storage and Tesla's Superchargers on a mobile trailer to be used during surges in demand (such as a holiday weekend) or when a station is temporarily down.

Larson Electronics introduced a portable DC fast EV charging station that can be deployed in remote areas without connection to the grid[51]. These can be used in emergency situations or for seasonal events that do not typically see the demand need for the installation of a fixed charger. The charging station relies on a 120 kW diesel generator to supply 62.5 kW output. The unit is available on a heavy-duty skid platform or can be mounted on a trailer. If connection to the grid is available, other options such as ABB's skid-mounted compact secondary substation with integrated DCFCs[52] could be deployed quickly without a lot of site work.

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47 https://www.naseo.org/issues/electricity/microgrids
48 https://freewiretech.com/
49 https://www.sparkcharge.io/about
50 https://electrek.co/2019/11/29/tesla-mobile-supercharger-megapack/
51 https://www.government-fleet.com/10139149/larson-electronics-portable-ev-charging-station
52 https://library.e.abb.com/public/772b779c4ab8468492c6fa7231a8c7be/E-mobility_Electrical_Terra54_Solution_Sheet.pdf

A.2.10 Payment Models

Public charging stations require easy to operate payment methods. Some charging companies use a membership model. However, public charging stations are more accessible if they accept credit cards and other card-based payment methods such as pre-paid cards and debit cards.

Payment can be made at each charger or at a kiosk serving multiple chargers. In either case, the card information must be securely communicated to a central server that provides validation, data storage, and timely response to the customer—in this case that includes turning on the charger and turning it off at the proper time while conveying correct billing information to the customer.

A.2.11 EVSE Communications

Each system of chargers must communicate with a common protocol. The protocol defines the language that each element of the system (charger, card reader, encryption device, transmitter, receiver, decryption device, data storage and analysis, and retransmission) uses to communicate.

Open-source protocols are recommended as they allow for greater compatibility and wide-spread use. There are numerous protocols that are available that serve both hardwire and wireless communications. Each of the protocols below is used to communicate between the charging station and another element of the system:

A.2.11.1 Open Charge Point Protocol (OCPP)

The global open communication protocol between charging stations and back-end systems of charging station operators. This protocol handles the exchange of charging data and can trade information between EVs and the electricity grid. OCPP is maintained by the Open Charge Alliance (OCA), a worldwide consortium of EV infrastructure pioneers that foster open standards in EV charging infrastructure.

A.2.11.2 Open Smart Charging Protocol (OSCP)

The open communication protocol between a charge point management system and an energy management system. OSCP is maintained by the OCA.

A.2.11.3 Open Charge Point Interface (OCPI)

An open protocol used to connect charging station operators with service providers by facilitating automated roaming for EV drivers across different EV charging networks. The protocol, an EVRoaming initiative, provides charging station data including location, accessibility, and pricing, and considers real-time billing and mobile access to charge stations.

A.2.11.4 ISO 15118

An international standard that defines a communication protocol between EVs and charging stations. The protocol enables plug & charge capability, where authorization to start charging is triggered by connecting a vehicle to the charger, greatly simplifying the EV driver's charging experience. ISO 15118 also enables bi-directional EV charging, known as vehicle-to-grid (V2G).

A.2.11.5 OpenADR

An open, secure, and two-way information exchange model facilitating automated demand response (DR) actions that help balance grid supply and demand or mitigate high electricity costs. This protocol ensures that dynamic price and reliability signals are uniformly exchanged between utility companies, system operators, and energy management and control systems during DR events.

Appendix B Best Practices Memorandum

To ensure the best practices are implemented with regards to the EV Mobility Plan, the project team met with five transportation entities from other state DOTs and agencies who have advanced EV mobility.

B.1 Summary of Best Practices

The agency discussions focused on the efforts or initiatives already taken to foster EV adoption, advance favorable policies, plan for EV charger infrastructure, conduct utility coordination, address equity, and measure environmental benefits. Table 5 summarizes the key takeaways from the benchmarking calls which supported in finalizing the goals, objectives and use cases for the deployment of the EV Mobility Plan.

B.2 Additional Information from Virginia Department of Transportation

- Released an EV Readiness study in March 2021 to further prepare Virginia for the various deployment scenarios and position the Commonwealth to continue to be a leader in EV infrastructure. Recommendations for Interstate charging followed the FHWA criteria for alternative fuels corridors for EVs: DC Fast Charging stations no more than 50 miles apart and less than 5 miles from the roadway.
- Virginia's General Assembly approved an EV rebate program (slated to begin Jan. 1, 2022) which would offer buyers a $2,500 rebate for the purchase of a new or used EV. An "enhanced rebate" of $2,000 would also be available to buyers whose household income is less than 300 percent of current poverty guidelines.
- Virginia instated an annual mileage-based user fee for vehicles that have an efficiency higher than 25 MPG. EVs are required to pay a fixed highway use fee, which is currently $109.00.

B.3 Additional Information from Maryland Department of Transportation

- Currently existing charging stations – 1,031 Stations, 2,708 Outlets
  - 121 DC Fast
  - 58 DC Fast/Level 2
  - 849 Level 2
  - 3 Level 1
- Public service commission pilot program - 5-year EVSE program. Plan to install over 900 utility owned and operated public charging stations at government owned sites over the next 5 years. The goal of the project is to collect data about demand, operating costs, and energy consumption of the chargers.
- Focus on state coverage more so than Interstate coverage (except I-95).
- Involve counties and towns for their inputs and collaborate with neighboring states (PA or OH).
- Tracking EV registrations and charging station locations is recommended monthly to help guide EV planning.
- Hydrogen is currently being preferred over BEV for heavy duty vehicles.
- Maryland has studied truck parking locations to see if plausible for EV charging.

B.4 Additional Information from National Renewable Energy Lab (NREL)

- Working with the University of South Florida on an EV resilience project studying natural gas generators to power EV chargers in the event of a power outage during an emergency evacuation.
- Florida is purchasing DCFCs on skids to deploy them rapidly in the event of an emergency.
- Suggested DC Fast Charging stations should be 150-350kW, even though many vehicles cannot accept these power levels yet.

B.5 Additional Information from US Department of Energy

- EV infrastructure cannot just focus on urban areas but should also include rural areas.
- There may be opportunities for solar to supplement power requirements for EV chargers, which also serves as a benefit for resilience.
- EV chargers every 50 miles on the Interstate may be conservative, but the visibility provides EV drivers and future EV drivers with more confidence.

B.6 Additional Information from Colorado Energy Office

- The Colorado Energy Office (CEO) identified key barriers to widespread EV adoption: a lack in EV charging infrastructure, a lack of EV awareness, the cost of EVs, and a lack of benefits.
- To address these barriers, CEO helped develop charging infrastructure grants, execute a contract with a public relations company for an "EV Education and Awareness Campaign", and push for some of the most generous state EV incentives in the country.
- Immediate ROI has been a challenge for DCFC site hosts. Some utilities in CO have offered EV only rates which make it possible for site hosts to recover costs for DCFCs that have low utilization. Some rates also remove demand charges or reduce the demand charges with a Time of Use (TOU) rate, which is more favorable for DCFC installations. Some utilities even own and operate DCFCs in parts of the state.
- Rivian reached out to CEO about a campaign to install EV chargers at all state parks in Colorado. Colorado Parks and Wildlife is working with Rivian on a tiered approach to locate chargers at state parks based on site viability since some of the parks are extremely rural with limited access to power.
- CEO is working on a study (to be released in October 2021) that will analyze locations across the state that could benefit from battery storage to offset demand charges and provide a rate-based business case for grid edge charger applications.
- CEO is also working on a separate EV equity study that will address how grant funds for charging are awarded. Colorado CarShare is working to transition its vehicle fleet to all electric and is partnering with Multi-Unit Dwelling (MUD) developers to install shared use EV chargers for public and car share use.
- Xcel Energy already has a large focus on equity with 15% of their budget allocated based on income qualified applications. A senate bill is being proposed to look at how utilities can increase their focus on equity.

Appendix C Impact on Climate and Air Quality Memorandum

C.1 Introduction

Climate change and health impacts from poor air quality are already making significant impacts across Pennsylvania and disproportionately impacting systemically disadvantaged and underserved communities. These communities are often located in urban areas close to roadways with high volumes of emissions-producing traffic or in rural areas highly dependent on natural resources that will likely be more vulnerable to the effects of climate change.

One of the primary motivations in transitioning the vehicle fleet to electric is to reduce and ultimately eliminate tailpipe emissions. According to the US Energy Information Administration (EIA), CO_2 emissions related to the transportation sector accounted for 37.6% of the nation's total[53] in 2019 (the most recent data available), as shown in Figure 28. Pennsylvania's transportation sector accounts for about 28.2% of the state's emissions. Reducing emissions will both lessen the impacts of climate change and reduce the effects of air pollution in Pennsylvania.

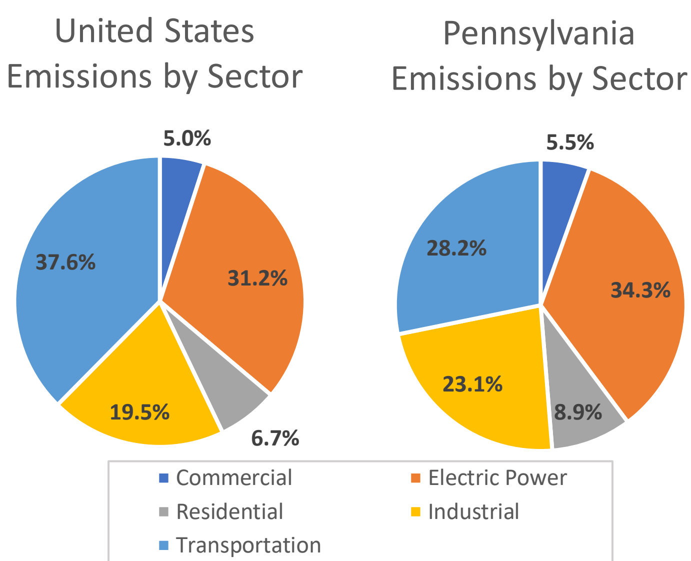

Figure 28. Emissions by Sector[54]

C.2 Methodology

C.2.1 Current EV Adoption Trends, 2013-2020

The PA Bureau of Motor Vehicles publishes an annual report of registrations for vehicles with active registrations as of the end of each respective calendar year[55]. Vehicle registrations by fuel type were compiled for each county for years 2013-2020[56]. Passenger vehicles were the focus of this study, and it was assumed that all EVs registered were also passenger vehicles. By compiling the

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[53] https://www.eia.gov/environment/emissions/state/

[54] Source: US EIA, 2019 data

[55] https://www.dmv.pa.gov/VEHICLE-SERVICES/Title-Registration/Pages/Annual-Report-of-Registrations-.aspx

[56] Vehicle registrations by fuel type first appeared in the annual registration reports in 2013. At the time of writing, 2020 data is the most recent available.

number of passenger vehicles and number of EVs by county, EV adoption percentages could be calculated for each year by dividing the number of EVs by the number of passenger vehicles. Results for the EV adoption rate in Pennsylvania is shown in Figure 29.

As shown in the figure, the rate of EV adoption has been accelerating with rates more than doubling between 2018 and 2020. It should be noted that the accuracy of the vehicle registration data is currently dependent on the automotive dealers to enter the fuel type information when registering the vehicle, which can be a source of error. To minimize this source of error, the Pennsylvania DMV is currently working to move to a VIN-based software that will decode the VIN in order to obtain vehicle-specific information such as fuel type.

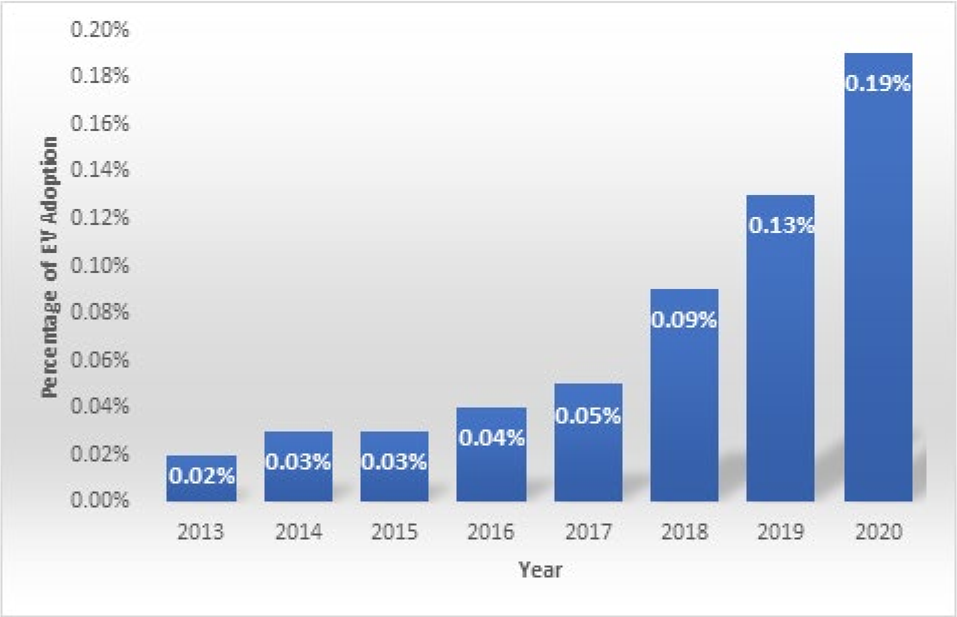

Figure 29. Pennsylvania EV Adoption Rate, 2013-2020[57]

C.2.2 Projected EV Adoption Trends

The PA EV Roadmap[58] that was released in February 2019 outlined four possible scenarios for EV deployment based on high and low levels of technology support and policy support to estimate items such as energy use, GHG emissions, criteria pollutant emissions, societal impacts, and cost-benefit results. The goal for this memo was to update these scenarios based on the latest information available with a focus on the GHG and criteria pollutant impacts. However, it became evident that at least 2 of the scenarios used in the PA EV Roadmap would not be easily replicable since they were based off independent studies that have not been updated since they were released.

The percent EV adoption ranges presented in the PA EV Roadmap vary widely based on the source of information for each scenario. For example, the PA EV Roadmap shows the 2033 projected EV sales percentage for the most conservative scenario 1 at 10%, compared to the most aggressive scenario 4 at 79%. This wide range of EV adoption projections demonstrates the uncertainty in estimating future EV uptake. It should also be noted that medium and heavy-duty vehicle electrification has already begun and could accelerate rapidly in the coming years.

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[57] Source: PennDOT Driver & Vehicle Services
[58] https://files.dep.state.pa.us/Energy/OfficeofPollutionPrevention/StateEnergyProgram/PAEVRoadmap.pdf

In an effort to simplify and update the process used in the PA EV Roadmap, two scenarios were modeled using Pennsylvania vehicle registration data as a basis. Descriptions of the two scenarios are shown below:

- Scenario 1: The first scenario is based off the projected EV adoption trendline using actual registration data from 2013-2020. A best fit polynomial trendline was developed for future years to project a more status quo rate of EV adoption.
- Scenario 2: The second scenario projects a more aggressive adoption rate trajectory assuming that PA adopts more EV-supportive policies such as California's ZEV standard[59]. By signing the ZEV MOU[60], PA will commit to fleet EV adoption goals that they will try to achieve in future milestone years. Using goals that similar ZEV states have set, it was assumed that PA would reach 5% total passenger vehicle EV registrations by 2025, 8.9% by 2030, 14.7% by 2040, and 20.6% by 2050[61]. Using these milestone targets by year, a trendline was projected from the baseline year of 2020.

Figure 30 shows projections for each scenario through 2033. Since vehicle registration data was used to develop a trendline for scenario 1, years 2013-2020 are included in the curve as actual values. The values shown after 2020 are projections based on the scenarios described above. Scenario 2 starts at the actual 2020 data point and quickly accelerates compared to scenario 1 to hit the ZEV MOU targets in horizon years 2023, 2028, and 2033.

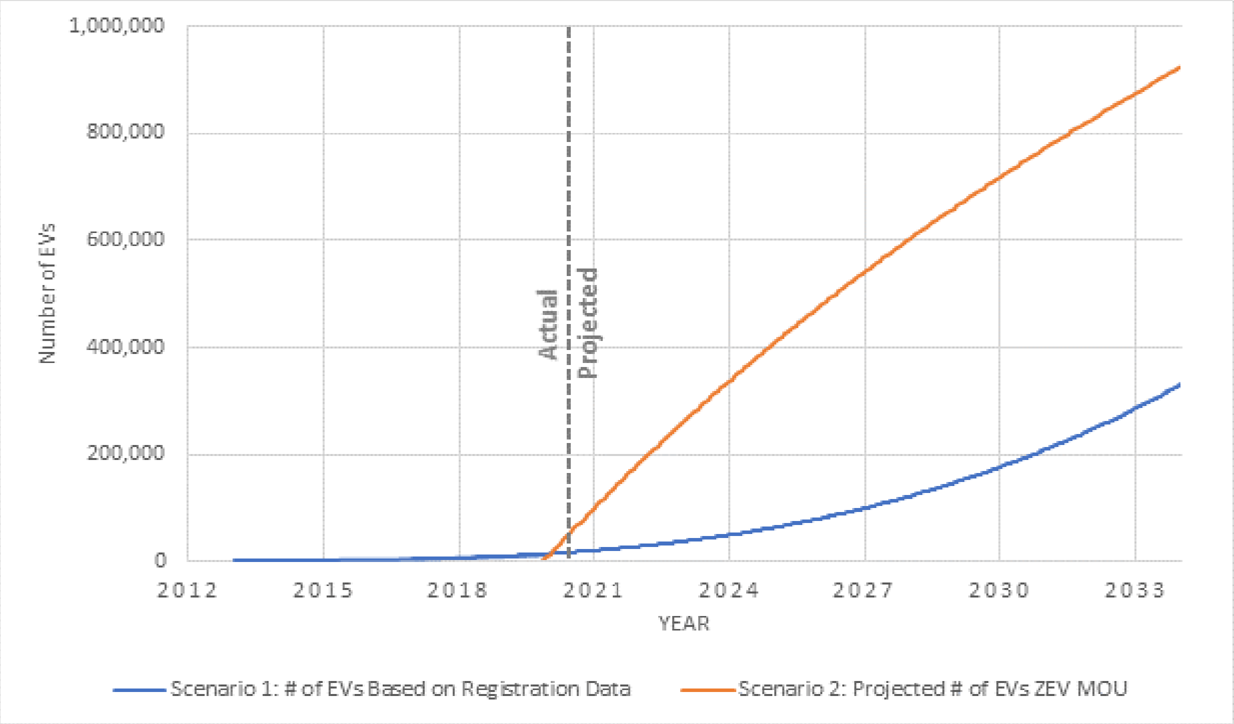

Figure 30. Projected Pennsylvania EV Adoption by Scenario

[59] https://ww2.arb.ca.gov/sites/default/files/2022-03/%C2%A7177%20States%20%283-17-2022%29%20%28NADA%20sales%29.pdf

[60] Pennsylvania has already adopted California's LEV program that sets limits for tailpipe pollution for auto manufacturers, meaning it requires manufacturers to deliver new light- and medium-duty vehicles to the Pennsylvania market that produce lower emissions of greenhouse gas and other air pollutants.

[61] https://mjbradley.com/sites/default/files/NE_PEV_CB_Analysis_Methodology.pdf

C.2.3 GHG and Air Quality Benefits

The methodology for estimating the GHG reduction and air quality benefits uses the same Argonne National Laboratory tool called AFLEET that was used in the PA EV Roadmap. Assumptions used to estimate the GHG and air quality benefits using the AFLEET tool are shown below:

- Since the most current vehicle registration data available is from 2020, the same year was used to establish a baseline to compare future year benefits.
- It was assumed that the overall number of light duty passenger vehicles will remain roughly the same through 2033.
- The AFLEET analysis was only looking at gasoline and all electric passenger vehicles for the analysis (the PA Bureau of Motor Vehicles data does not differentiate between BEVs and PHEVs, although moving to a VIN-based decoder will minimize errors and make this possible).
- The default AFLEET annual vehicle mileage of 12,400 miles was used for both ICE passenger vehicles and EVs in the analysis.
- The default AFLEET fuel economy of 30.9 MPG was used for passenger vehicles and 106.2 MPGGE (miles per gasoline gallon equivalent) was used for BEVs.
- It was assumed that the number of EVs adopted between 2020 and 2033 remain in the vehicle fleet in Pennsylvania[62].

Even though BEVs do not emit tailpipe emissions like internal combustion engine vehicles, the electricity that is generated to charge BEVs produces GHGs. The emissions factor for the electricity generation in Pennsylvania is from the Reliability First Corporation (RFC) region as defined by the North American Electric Reliability Corporation (NERC) shown in Figure 31.

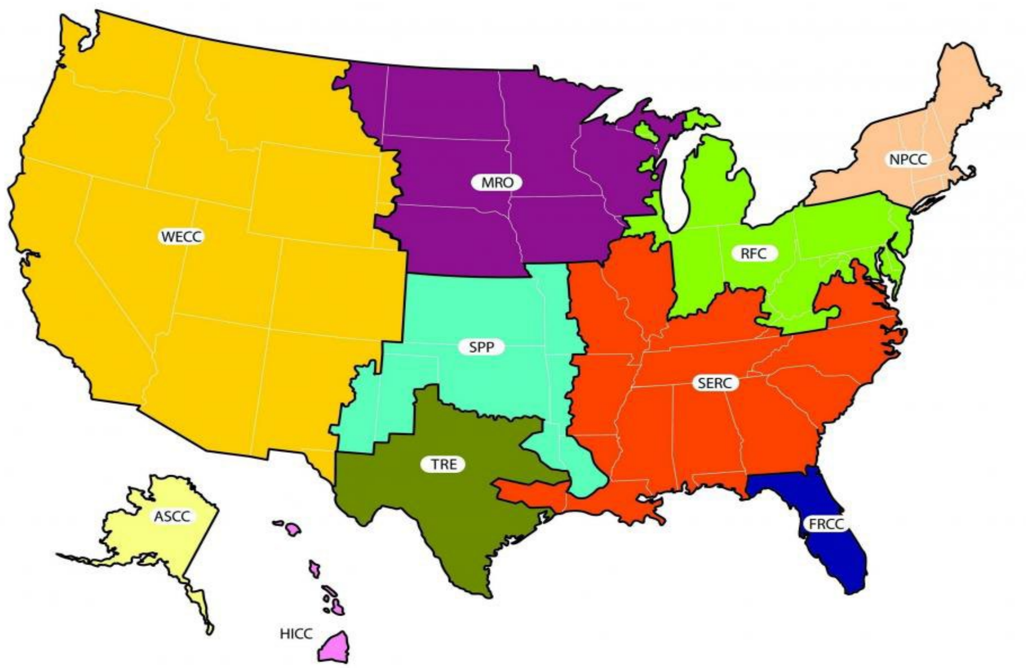

Figure 31. NERC Region Map

[62] The average life of a vehicle is now 12.1 years (https://www.statista.com/statistics/738667/us-vehicles-projected-age/)

Additionally, BEVs will reduce, but not eliminate pollution from fine and particulate matter, known as PM2.5 and PM10 pollutants. Vehicles emit these particles from two primary sources, the ICE exhaust system, and from non-exhaust sources including break wear, tire wear, and road wear / dust. BEVs will continue to emit particles due to non-exhaust sources, largely through brake and tire wear.

GHG and air quality modeling could be further refined by adding variables such as:

- Using a VIN decoding method for vehicle registration data to determine fuel type
- Adjusting the regional grid emissions factor by year and/or project future year emission factors
- Projecting vehicle efficiency assumptions for both EVs and ICEVs (e.g., CAFE standards)
- In addition to light duty vehicles, also including medium and heavy-duty vehicles
- Obtaining VMT data by county to estimate trip distance (e.g., drivers in rural areas typically drive further than those in urban areas)

However, it should be cautioned that refining these inputs to calculate GHG and air quality benefits may not always be a worthwhile exercise due to some of the more broad, unavoidable assumptions that are needed to estimate these reductions on a statewide or even regional level.

C.3 Emissions and Air Quality Results

The following section discusses the Pennsylvania statewide emissions and air quality results based on the two scenarios for years 2020, 2023, 2028, and 2033 using the AFLEET tool. As discussed earlier, since scenario 2 is assumed to be starting in 2020 and projecting a more aggressive adoption trend from there, scenarios 1 and 2 have the same values for year 2020.

C.3.1 Estimated GHG Results

Table 6 shows the estimated baseline year of 2020 at 34.7 million metric tons of GHGs for both scenarios. As expected, as more BEVs with no tailpipe emissions are adopted into the statewide vehicle fleet, reductions in GHGs increase. And it should be noted that the GHG benefits will almost certainly be greater than what is shown in the table since the emissions factor used for the RFC region is likely to continue to decline as more renewable generation sources come online (i.e., the emissions factor remains constant in this analysis through year 2033). In fact, this is one of the main environmental benefits of BEVs when compared to ICE vehicles.

Since a BEV's operating GHG emissions are directly related to how clean the electric grid is for charging the vehicle, it is likely that a BEV will get 'cleaner' over time as the grid transitions away from coal, whereas an ICEV will only pollute more over time as the engine wear decreases the vehicle's efficiency.

C.3.2 Estimated Criteria Pollutant Results

Table 7 estimates the criteria pollutants by scenario and year using data from AFLEET. For 2020, each criteria pollutant is shown in million pounds, with the projected percent change in future years. In all cases, the adoption of EVs will reduce criteria pollutants, even accounting for PM2.5 and PM10 while an EV is in operation due to brake and tire wear. Under the more aggressive scenario 2, criteria pollutants such as CO, NOx, VOCs, and SOx, each of which can have health and environmental consequences, are estimated to decrease by over 10% from the current 2020 baseline.

C.4 Conclusion

Pennsylvania has an opportunity to improve air quality and combat the contributors of climate change through the adoption of EVs. As seen in the estimated scenario results, providing incentives for EVs, and implementing stronger standards such as California's ZEV program will strongly benefit the environment and health of Pennsylvania's residents, especially those in disadvantaged communities.

Appendix D Equity Considerations Memorandum

D.1 Introduction

The purpose of this memo is to document best practices and considerations for making EVs a viable option for transportation in disadvantaged and underserved communities and for those with disabilities. Equity acknowledges that each person's needs and circumstances differ and therefore the allocation of resources (in this case, access to EVs/EV chargers) will differ for all populations to reach similar outcomes. The final report will use these best practices to develop recommendations specific to PennDOT's EV goals and objectives and the goals of the Justice40 initiative.

Equity considerations for EVs include:

- Accessibility – location of convenient charging
- Affordability – user-friendly subsidization for carsharing, incentivization for ownership, and lowering the cost of electric power
- Practicality – addressing the specific mobility needs of the community

At the center of the equity discussion surrounding EVs is EJ. The term itself dates to the 1980s, but the idea is based upon justice for racist policies and decisions, particularly in the early- to mid-20th century, that led to disproportionate environmental quality in communities of color across the United States. Over the years, the term has expanded to include unequal environmental outcomes across many groups including disadvantaged groups.

In the U.S., low socio-economic status (SES) communities generally experience lower air quality because of higher exposure to traffic and air pollution. Supporting the replacement of vehicles that burn fossil fuels with clean energy vehicles, such as EVs, will support positive public health impacts in low-SES neighborhoods.

The United States Department of Transportation (USDOT) defines the disadvantaged and underserved communities as follows[63]:

- *Disadvantaged* communities are communities that experience disproportionately high and adverse health, environmental, climate related, economic, and other cumulative impacts
- *Underserved* communities are populations sharing a particular characteristic, as well as geographic communities, that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life, as exemplified by the list in the preceding definition of equity.

This plan specifically addresses the needs of high minority communities, low-income communities, and people with disabilities. These include both disadvantaged and underserved communities. EJ communities by race are defined as census tracts where more than 30% of the population identifies as a non-white minority. EJ communities by income level are identified as a census tract where 20% or more of people live at or below the federal poverty level.

[63] USDOT Equity Action Plan. (2022).

D.2 State of Equity in EVs

The state of equity in EVs has been a developing topic within state governments over the course of the last several years. States like Colorado and California are leading the way in successful pilot programs and long-term equity EV programs and infrastructure developments. States in the Midwest are beginning to iron out electrification opportunities that also promote equitable services.[64]

D.2.1 Use Cases

Equity considerations are needed for each use case to ensure that all users have access to convenient charging infrastructure to meet their needs. Potential use cases for EV charging include:

- Direct current fast charger (DCFC) corridor charging (all power levels)
- DCFC corridor charging (150 kW+ and above), because the FHWA corridor funding is tied to 150kW+ connectors
- Public or community (Level 2/L2 and DCFC)
- Workplace (all power levels)
- Single family home (all power levels)
- Multi-unit dwelling (all power levels)
- Opportunity charging for medium- and heavy-duty freight and delivery trucks

Regardless of the use case, agencies and developers should consider user safety in EV charging location design, such as providing security cameras and security lighting for users who may need to access the chargers at night.

D.2.2 Economic Equity

Initial deployment of EVs was limited to high-end new vehicles, typically inaccessible to middle and low-income consumers. As more EVs move into the used vehicle market and affordability of new EVs improves, focus is needed on how to ensure economic equity in the areas of accessibility and practicality.

- The economic forecast for EVs shows that in the next 5-10 years that the affordability for low-income households would represent some price parity between purchasing a used gasoline vehicle versus a used EV[65]
- Low-income communities would benefit from the lower cost of operating EVs, but there also needs to be an equal investment in the charging infrastructure in these communities. Widespread access to chargers and an adequate local power distribution network/grid will impact the ability of these neighborhoods to have charging infrastructure. States are recommended to promote equitable access through the following steps:[66]
    - Directing electric power utilities to address equity issues in their transportation electrification plans (such as grid preparation, local power distribution, and EV charging infrastructure).

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[64] Regional Electric Vehicle Midwest Coalition Memorandum of Understanding. (2021).

[65] Bauer, G., Hsu, C.W., Lutsey, N. (2021). When Might Lower-Income Drivers Benefit from Electric Vehicles? Quantifying the Economic Equity Implications of Electric Vehicle Adoption. *International Council on Clean Transportation.*

[66] Huether, P. (2021). Siting Electric Vehicle Supply Equipment (EVSE) with Equity in Mind. *American Council for an Energy-Efficient Economy.*

- Developing charging infrastructure evaluation criteria which considers equity needs in terms of pollution, economic condition, tribal status, etc., in addition to income.
    - Developing common performance measures for success which will improve evaluation by the state and communication between utility commissions.
    - Setting minimum funding levels for underserved communities for utility investments.
- In addition to Departments of Transportation, public utilities need to have early buy-in to support EV charging infrastructure in disadvantaged and underserved communities. Electric utility investment in underserved communities more than doubled in 2020 from 2019 levels to an investment of $766 million.[67] In 2020, utility commissions across the country approved $1.2 billion in transportation electrification investments.[68]
    - The 2020 investments were largely contributions by Southern California Edison and a majority of investor-owned utilities in New York State.
    - Several utilities in California, Florida, Maryland, Massachusetts, Ohio, Pennsylvania, and Washington contributed a combined $28 million total program investment and $3.4 million dedicated investment for underserved communities.
    - Arizona, California, Colorado, New Mexico, New York, and Oregon have all implemented state laws or utility commission orders directing or encouraging utilities to consider underserved communities in distribution of EV supply equipment.[66]
- Payment options are needed that enable access to charging services for users who are unbanked or underbanked, such as cash-based payment options. These payment options should also include card- or fob-based access (similar to a reloadable transit fare card), rather than requiring smartphone apps to unlock chargers.
- Agencies can also prioritize small business and minority-owned site locations for EV chargers as an economic equity driver.
- The Oregon Department of Transportation's *Transportation Electrification Infrastructure Needs Analysis*[69] identified these charging needs of disadvantaged communities:
    - "Drivers in disadvantaged communities are more likely to need fast charging stations for two reasons. First, these drivers often live in multi-unit dwellings (MUD) without dedicated parking where they can access a reliable slow charge overnight. Second, many drivers for TNCs, like Uber and Lyft, live in these communities, and TNC drivers need to be able to charge quickly to maximize their driving time."

D.2.3 Geographic Equity

It is important to consider differing charging needs in different types of communities across Pennsylvania. For example, differences in needs for drivers in rural areas include:

- **Longer travel distances** in rural areas than urban drivers, with charging stations that are likewise more widely spaced. As a result, these charging stations generally require larger power capacity to deliver a faster charge.
- A wider **variety of use cases**, from long-distance travelers passing through, to farmers needing to charge up specialized farming equipment.
- **Rural towns may have charging needs (and opportunities) that differ from rural corridors.** For example, public Level 2 charging ports can be in rural communities near

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67 Smith, Conner. (2020). Utilities Investing $766 Million in Underserved Communities. *EV Hub.*

68 Electric Utility Filing Bi-Annual Update. (2021). *Atlas Public Policy.*

69 Transportation Electrification Infrastructure Needs Analysis. (2021). *Oregon Department of Transportation.*

restaurants, shopping, tourist destinations, etc., to encourage the support of local businesses. Today, charging stations along major corridors throughout the state mostly serve long-distance travelers with light-duty vehicles who need a fast charge, so these charging stations are typically high-speed Direct Current Fast Charge (DCFC) with large power requirements. Travelers also typically need access to amenities when they are stopped to recharge, so the availability of restaurants, convenience stores, and restrooms is important.

- **Limited availability of EV trucks and Sport Utility Vehicles**, which are the more heavily used vehicle types in rural environments.
- More **expensive to install charging infrastructure**, partly due to the necessity of running electrical power to rural locations. Agencies may consider policies to incentivize investment in charging deserts in rural areas.

Providing equal access to chargers is the best way to make a whole and complete EV roadmap from rural to urban areas.[71]

Rural EV charging infrastructure solves the issue of range limitations to create a national network of EV infrastructure. The following list includes examples for expanding EV charging infrastructure while providing equitable EV charging access in rural areas.

- Locally owned electric utility departments may be able to establish equitable rebates or subsidies to support EV charging infrastructure in disadvantaged and underserved areas.
- Local agencies can support EV infrastructure by electrifying their own fleets, facilitating e-micromobility deployments, streamlining the EV permitting and construction processes, adopting EV-ready building codes and parking ordinances, partnering and coordinating with local utility service providers, and encouraging the installation of public charging stations (including 110-volt outlets).[70]
- Expansion of EV and charging infrastructure into rural communities would be an investment and benefit to the areas, including serving as a stable source of additional revenue, strengthening the local economy, boosting local businesses that have charging stations, and increasing commerce from travelers with EVs.[71]
- EV charging infrastructure has been installed successfully in small towns with the assistance of non-profit power-supplier cooperatives.[72] For example, The Tri-State Generation and Transmission Association is committing nearly $2m in public EV charging across member service areas and promoting EVs in rural areas.

The BIL allocated $7.5 billion in federal funding for EV infrastructure. Formula funding will be distributed to states for designated Alternative Fuel Corridors, particularly along the Interstate Highway System. Pennsylvania could receive up to $171,514,120 of this $5 billion formula funding. The BIL also allocates $2.5 billion for a Discretionary Grant Program for Charging and Fueling Infrastructure. The discretionary funding will be split between $1.25 billion to fill gaps along designated Alternative Fuel Corridors and $1.25 billion to strategically deploy publicly accessible EV charging or alternative fuel infrastructure in rural and underserved and disadvantaged communities.

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[70] Are you ready for the Electric Vehicle Revolution? (2022). *Kittelson & Associates, Inc.*
[71] How Rural Towns Can Prepare for EV Charging and Why Do It. (2021). *EV Connect.*
[72] Tri-State Responsible Energy Plan 2020 Progress Highlights. (2021). *Tri-State Generation and Transmission Association.*

P3s will play an integral role in establishing EV infrastructure in rural towns and require coordinated planning and funding efforts. Localities will now have the opportunity to apply for grant funding for charging infrastructure that can be distributed through P3s.[73]
Alliances or coalitions offer less-formal options for partnerships when partners do not want to legally commit themselves to project funds or take on project risks. The common interests of these partnerships can be outlined in memorandums of understanding (MOUs).[74]

D.2.4 Disability Equity

Accessibility for EV charging infrastructure varies for drivers with disabilities. EV charging could pose some challenges for drivers with varying disabilities.

- Agencies such as the U.S. Department of Energy and the Minnesota Pollution Control Agency have provided guidance in compliance with the ADA requirements for EV charging installation for persons with disabilities.[75,76] The compliance documents cite special design guidelines to accommodate people with disabilities, although the ADA does not provide design standards for EV charging stations.

PennDOT's new EV Equity Guiding Principles addresses disability equity, by recommending they "Certify public charging investments address the Americans with Disabilities Act (ADA) standards and includes safety and security accommodations. Consider a standard of amenities including sufficient lighting, regular staffing, security on site, and steady foot traffic that allow comfortable access for persons with disabilities and people with personal safety concerns."

D.2.5 Home Charging Equity

EV charging for multi-unit dwellings provide property owners, managers, and lessors a unique way to contribute and benefit to environmentally sustainable communities. In addition, EV charging in multi-dwelling units helps attract and retain tenants. EV charging in multi-dwelling units can pose unique challenges as it relates to cost absorption for electrical services billing as well as potential legal issues.

- California developed guidelines for EV charging infrastructure for multi-unit dwellings. [77]
- Multi-Unit dwelling case studies reflect success stories in installation of charging stations.
    - Atlas Public Policy's report about EV chargers at multi-family dwellings discusses important recommendations including requiring the equipment is capable of separate metering or submetering in order to bill the EV drivers directly based on usage and administering different rates based on the time of use. [78]
    - Minneapolis's Green Rock Apartments considered networked Level 2 charging units which would have allowed for payment to use the unit but opted against this and installed a non-networked system. The units are primarily used to charge the

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[73] How the Infrastructure Bill Can Begin Funding State and Local Projects. (2021). *JLL.*
[74] NCHRP Report 924: Foreseeing the Impact of Transformational Technologies on Land Use and Transportation. (2019). *National Academies of Science.*
[75] ADA Requirements for Workplace Charging Installation. (2014). *U.S. Department of Energy*.
[76] Installation Requirements for Electric Vehicle Charging Stations. (2021). *Minnesota Pollution Control Agency.*
[77] Plug-in Electric Vehicle Charing Infrastructure Guidelines for Multi-unit Dwellings. (2013). *California Plug-in Electric Vehicle Collaborative.*
[78] EV Charging at Multi-Family Dwellings. (2021). *Atlas Public Policy.*

company's EVs but are also available to tenants for free as well as the general public in an emergency.[79]

- Home charging can be a challenge at any residence that does not have parking garage access where power outlets are located near the vehicle parking spot. This can include single-family homes, townhomes, or apartments with on-street parking.
  - One solution is to install EV charging infrastructure at the curb next to on-street parking spaces. This can be done in residential and commercial areas, such as New York City's curbside Level 2 chargers.[80]

D.2.6 Environmental Equity

Transportation-related air pollutants can have significant impact to public health conditions including asthma, reduced lung capacity, heart disease, and cancer that are especially harmful in densely populated areas. These areas often have higher concentrations of minority and low-income communities. The project team will explore this further in a separate memorandum titled "Examine Impact on Climate-Air Quality".

- EVs have zero tailpipe emissions and can drastically improve ambient air quality, particularly in dense urban environments.
- A 2016 study by the Denver Colorado Department of Environmental Health[81] found that EVs effectively eliminated emissions of volatile organic compounds (VOCs) and significantly reduced Nitrogen Oxides (NOx) and greenhouse gas (GHG) emissions compared to new gasoline vehicles. As the electric grid gets cleaner over time, EVs will provide even greater air quality and emissions benefits.
- The American Lung Association released a report in 2020 that estimates Pennsylvania could avoid $2.3 billion in health costs, 206 premature deaths, 2,400 asthma attacks, and 10,814 lost workdays per year by 2050 if there is a widespread transition to zero emission transportation.[82]
- Zero Emission Vehicles reduce emissions, which will lessen the impacts of climate change and air pollution in Pennsylvania.

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[79] Multi-Unit Dwelling Procurement Case Study: Green Rock Apartments. (2019). *U.S. Department of Energy*

[80] New York City Installs First Curbside Electric-Vehicle Charing Station. (2021). *The Wall Street Journal.*

[81] Opportunities for Vehicle Electrification in the Denver Metro Area and Across Colorado. (2016). *City and County of Denver, Department of Environmental Health.*

[82] The Road to Clean Air | Benefits of a Nationwide Transition to Electric Vehicles. (2020). *The American Lung Association.*

D.3 Implemented Programs and Strategies

There are several states that have documented the processes of successful implementation of equitable EV programs. States like California, Ohio, Colorado, and Georgia have used dedicated state funding or funds from settlements (e.g., the Volkswagen class action lawsuit) to begin studies, pilots, and/or expand existing EV subsidies, car sharing, and infrastructure installation in disadvantaged and underserved communities or for disabled persons. Independent evaluations of programs are limited, but where available, findings from such evaluations are noted.

- A comparative analysis of the Federal and Georgia state EV tax incentives suggests spreading the tax credit over multiple years (as was done in Georgia) results in a higher percentage of households qualifying for the full tax credit.[83]
- The Colorado Public Utilities Commission approved Xcel Energy's $110m electrification plan to install 20,000 EV chargers and offer rebates to lower income consumers.[84]
    - 15% of the total program budget will go toward supporting transportation electrification for income-qualified customers and communities with high emissions levels.
    - The EV Equity Rebate pilot program offers specific rebates to income-qualified customers for the purchase of EVs.
- DriveOhio's EV Study recommended the following actions for implementation:[85]
    - Educate members on the need for local policies and equity measures to operate the service(s).
    - Conduct outreach and education with state agencies, local government, MPOs, utilities, and key stakeholders.
    - Identify and conduct outreach in high priority areas, including proposed equity zones; identifying site hosts who would be interested in applying for funding and assistance.
- California has developed a multi-pronged approach to reach zero emissions from transportation activities.[86]
    - Development of a map to assist policy and program managers in identifying disadvantaged and underserved communities.
    - Ensure civic leaders who represent disadvantaged and underserved communities are included in stakeholder discussions.
- A review of California's various clean transportation programs identified the following ways to uphold equity standards for clean mobility programs.[87]
    - Emphasizing anti-racist solutions;
    - Prioritizing multi-sector approaches;
    - Delivering intentional benefits;
    - Building community capacity;
    - Being community driven; and,

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[83] Liu, H., Guensler, R., Rodgers, M. O. (2020). Equity Assessment of Plug-In Electric Vehicle Purchase Incentives with a Focus on Atlanta, Georgia. *Center for Transportation, Equity, Decisions and Dollars.*

[84] Manescu, Larisa. (2021) Colorado Approves $110 Million Electric Vehicle Charging Program with Major Equity Provisions. *Sierra Club.*

[85] Zehnder, K. O, Lowry, S., Ramos, S., Spofforth, S., Conley, A. (2020). Electric Vehicle Charging Study. *DriveOhio.*

[86] Brown, A. L, Sperling, D., Austin, B., DeShazo, JR, Fulton, L., Lipman, T., et al. (2021). Driving California's Transportation Emissions to Zero. *UC Office of the President: University of California Institute of Transportation Studies.*

[87] Clean Mobility Equity: A Playbook. (2021). *The Greenlining Institute.*

- Establishing paths toward wealth-building.
- Greenlining has also introduced an equity toolkit based on lessons learned from California's programs.[88]
- Los Angeles Cleantech Incubator (LACI) successfully ran a pilot for an EV car share for the under-resourced communities of San Pedro and Pacoima.[89]
    - Community members used it with grant-based subsidies and reported it was less expensive than regular use of non-EV based rideshare services such as Uber or Lyft.
    - The San Pedro pilot's monthly revenue exceeded operating expenses after 12 months and continued as a self-sustained program following the end of the pilot phase.
- As recently as September 2021, an MOU for the Regional Electric Vehicle Midwest Coalition of states (Illinois, Indiana, Michigan, Minnesota, and Wisconsin) was established to "create a regional framework to accelerate vehicle electrification int the Midwest." An isolated component of this program is to promote equity in disadvantaged and underserved communities to foster a healthy, sustainable, and clean environment where people in these groups live, work, and play.[64]
- Baltimore City has seen a range of options to support charging for city residents who do not have access at their residence.[90]
    - City owned parking garages have EV charging stations.
    - Some street parking has EV charging stations.
- Gas station provider Royal Farms has included EV charging stations at newly remodeled or newly built gas stations across Delaware, Maryland, Pennsylvania, and Virginia.[91]
- Many cities across the country have adopted EV-readiness ordinances. The ordinance that was passed in Chicago[92] requires new construction of residential (five or more units) and commercial buildings of certain sizes to have at least 20% of parking spaces be ready for EV charging equipment to be installed, with provisions for accessibility for people with disabilities.

[88] Electric Vehicles for All: An Equity Toolkit. (2021). *The Greenlining Institute.*

[89] From Policy to Action: EV Car Share Success in Two Los Angeles Under-Resourced Communities. (2021). *Los Angeles Cleantech Incubator.*

[90] Electric Vehicle Charging Stations. *City of Baltimore.*

[91] Field, Kyle. (2017) Royal Farms Rolls Out DC Fast Chargers at its Gas Stations to Drive Retail Sales. *Clean Technica*.

[92] Chicago City Council Approves Ordinance to Increase Chicago's Electric Vehicle Readiness Citywide. (2020). *City of Chicago.*

D.4 Progress in Pennsylvania

In February 2022, PennDOT released its EV Equity Guiding Principles:[93]

- Make EVs more affordable.
- Make EV charging more accessible.
- Invest in fleet electrification.
- Invest in traditionally underserved, low-income, persons of color, and otherwise vulnerable population areas.
- Increase EV awareness, education, and technical capacity.

Pennsylvania is making progress in addressing issues of equitable access to EVs and infrastructure to disparate populations. Pennsylvania legislators have proposed legislations for electrification infrastructure. Vehicle grant programs are available for public and private entities. Policy and industry best practice studies have explored ways to successfully integrate equitable EV sales, carsharing, and transit options to low-income and disabled populations.

- The Alternative Fuel Vehicle Rebate Program offered through the Pennsylvania Department of Environmental Protection (DEP) includes an additional $1,000 rebate for the purchase of an alternative fuel vehicle for low-income PA residents whose total household income is below 200 percent of the Federal Income Poverty level.[94]
- PennDOT's DC Fast Charging and Hydrogen Fueling grant program includes scoring criteria for projects located within EJ areas, as defined by the PA DEP.[95]
- Pittsburgh is addressing equity in EVs by using an equity score in its prioritization of deploying EV charging locations.[96] Pittsburgh also produced a Mobility Vision Plan[97] with a goal to "advance mobility justice to redress the infrastructure racism of the past", in part by expanding clean transportation options to every resident of the city.
- PennDOT is monitoring the progress of Pennsylvania Senate draft legislation (SB 435) for statewide EV infrastructure via utilities. The bill is supported by the largest electric utility in the state (PECO). A priority of the bill is social equity – encouraging development in disadvantaged and underserved communities via EVs and electrification of transit serving these communities.[98] PennDOT plans to provide comment on the legislation when requested.

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[93] Electric Vehicle (EV) Equity Guiding Principles. (2022). *Pennsylvania Department of Transportation.*
[94] Pennsylvania Alternative Fuel Rebates for Consumers. *Pennsylvania Department of Environmental Protection.*
[95] DC Fast Charging and Hydrogen Fueling Grand Program. (2021). *Pennsylvania Department of Environmental Protection.*
[96] EV Charging Strategic Plan. (2021). *City of Pittsburgh.*
[97] Envision 2070 | Mobility in a Sustainable Pittsburgh. (2021). *City of Pittsburgh.*
[98] SB 435 – An Act amending Title 66 (Public Utilities) of the Pennsylvania Consolidated Statutes, in restructuring of electric utility industry, providing for transportation fueling infrastructure development. (2021). *Pennsylvania State Legislature.*

Appendix E Additional Maps and GIS Files

These additional maps were prepared to assist with EV planning efforts.

Figure 32. Total EV Registrations by Zip Code, Nov. 2020
Figure 32 identifies EV registrations by zip code as of November 2020. The recommended charging locations are superimposed on this map.

Figure 33. Percentage of EV Registrations by Zip Code, Nov. 2020
Figure 33 identifies the percentage of EV registrations (# EVs per total vehicle registrations) at the zip code level. The recommended charging locations are superimposed on this map.

Figure 34. RoS by AADT Threshold
Figure 34 shows which routes have traffic volumes within each of the five AADT thresholds identified in this plan.

The ArcGIS Pro project file including the geodatabase with all project maps and datasets used for this analysis are available digitally using the following link.

Click here to access the project files.

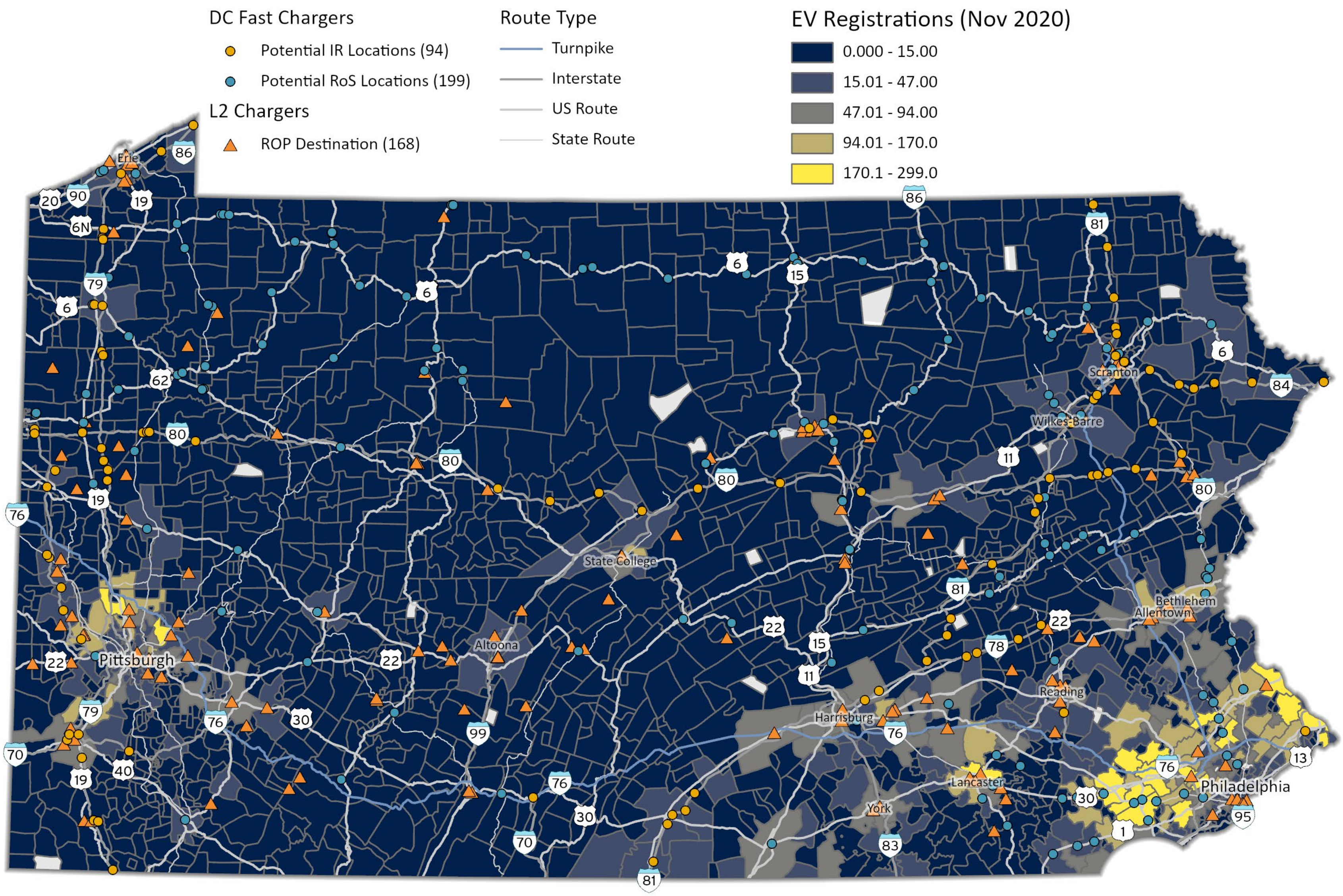

Figure 32. Total EV Registrations by Zip Code, Nov. 2020

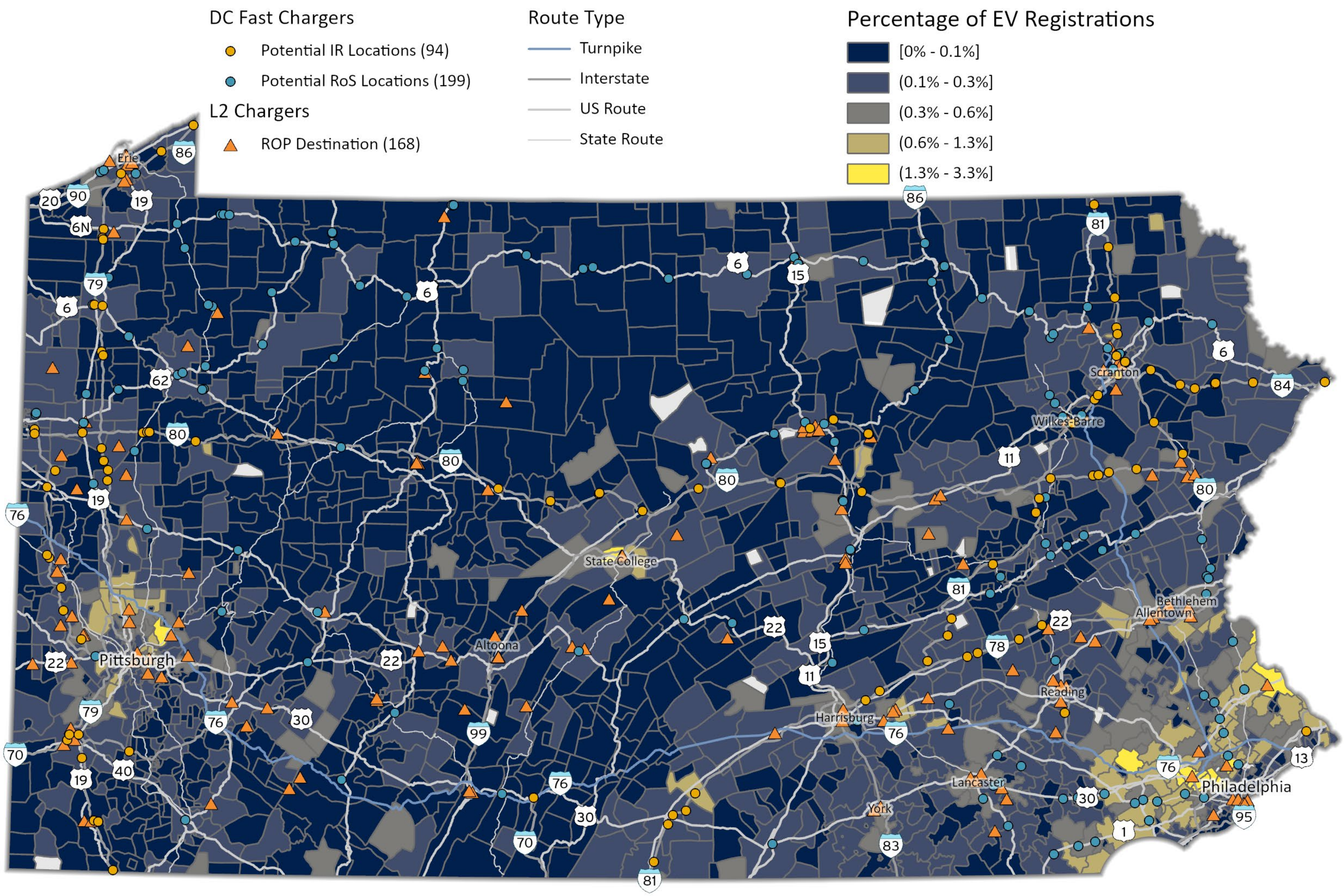

Figure 33. Percentage of EV Registrations by Zip Code, Nov. 2020

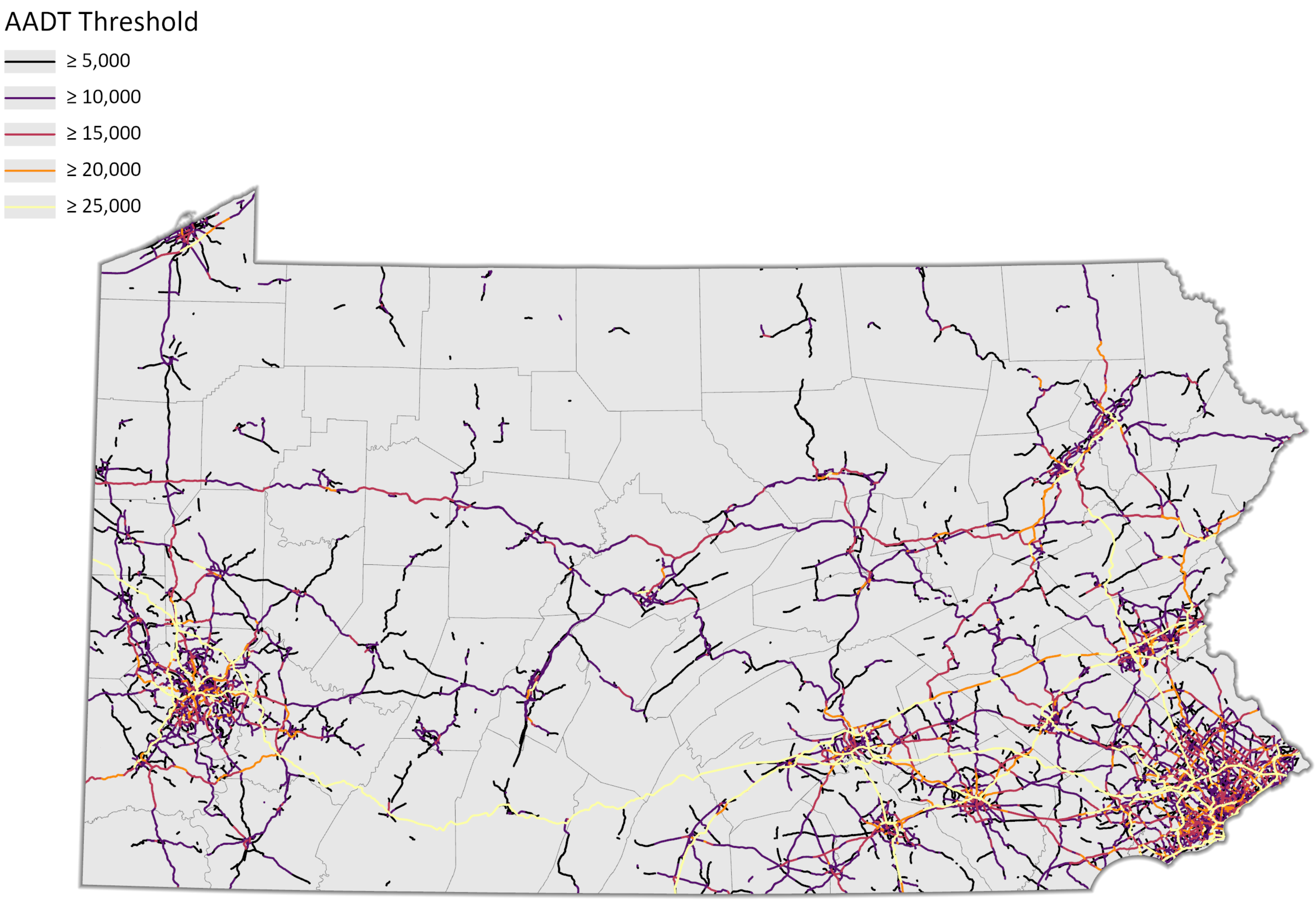

Figure 34. RoS by AADT Threshold

Appendix F PennDOT's EV Equity Guiding Principles

The following are reproduced directly from PennDOT's EV Equity Guiding Principles Document[99].

A. Make EVs More Affordable
    1. Ensure availability of
    2. EV purchase incentives and payment options targeted to underserved, low-income, persons of color, disabled, and otherwise vulnerable consumers.
    3. Verify effectiveness of EV purchase incentive programs at local and state levels by tracking the appropriate metrics (EV registrations, income levels, incentives leveraged, etc.) and adjusting incentive structures as needed.

B. Make EV Charging More Accessible
    4. Ensure sufficient public charging and electrical grid infrastructure in underserved, low-income, persons of color, disabled, and otherwise vulnerable communities, especially in areas with low home-charging access (i.e., high percentage of multifamily dwelling units) and a lack of public transit options.
    5. Support sufficient public charging infrastructure along major highway corridors, including in rural locations that are necessary to fill gaps in the statewide EV charging network, but may not have the critical mass (e.g., of traffic volume, EV registrations, etc.) to be financially feasible in the short-term without public funding.
    6. Certify public charging investments address the ADA standards and includes safety and security accommodations.
        a. Consider a standard of amenities including sufficient lighting, regular staffing, security on site, and steady foot traffic that allow comfortable access for persons with disabilities and people with personal safety concerns.
    7. Ensure equal access to EVSE funding opportunities for all businesses that are interested in hosting public EVSE on their property.
        a. Focus on small and diverse businesses where appropriate.
        b. Support a variety of charging station business models.
    8. Reduce financial barriers for businesses (e.g., demand charges) who are interested in hosting public EVSE on their property by working with electric utility companies to make EV charging both affordable and beneficial to the local distribution networks.
    9. Expand payment options to accommodate drivers that do not have access to a personal banking account, credit cards, and other cashless options (e.g., offering a pre-paid card to charge EVs).

C. Invest in Fleet Electrification
    10. Support fleet electrification funding programs are accessible to transit authorities and school districts that serve predominantly underserved, low-income, minority, and otherwise vulnerable populations.

D. Invest in Traditionally Underserved, Low-income, Persons of Color, and Otherwise Vulnerable Population Areas
    11. Reduce GHG emissions and improve air quality in communities located near Interstates by facilitating the adoption of EVs and support the build-out of an EV charging network statewide.

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[99] https://www.penndot.pa.gov/ProjectAndPrograms/Planning/Documents/EV%20Equity%20Principles_02072022.pdf

12. Commit 40 percent of the overall benefits from EVSE goes towards projects in underserved, low-income, persons of color, disabled, and otherwise vulnerable population areas.
13. Track and report data demonstrating the type and amount of investments in underserved, low-income, communities of color, disabled, and otherwise vulnerable communities.
14. Confirm that EJ metrics are included as part of the scoring system in all EVSE state funding programs.
15. Partner with other state, regional and local agencies, academia, and community-based organizations to draw EV-related industry and workforce to the Commonwealth. Support EV industry job skills, local small business development and educational opportunities for all job-levels.
16. Engage directly with diverse audiences to understand their mobility needs and consider a broad range of electrified transportation including electric bicycles, electric car sharing, and electric taxis and TNCs prior to investment.

E. Increase EV Awareness, Education, and Technical Capacity

17. Provide timely communication and easy-to-use resources about EV/EVSE to the general public, members of the General Assembly, consumers, businesses, planning agencies, EJ advocacy groups, and community-based organizations.
18. Craft consistent signage and messaging related to EV/EVSE.
19. Design and publicly disseminate meaningful opportunities and resources for diverse groups of audiences to participate in the EV infrastructure and policy planning process, including underserved, low-income, persons of color, disabled, and otherwise vulnerable populations

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