PENNSYLVANIA ELECTRIC VEHICLE ROADMAP

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MEISTER CONSULTANTS GROUP | A CADMUS COMPANY

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PENNSYLVANIA ELECTRIC VEHICLE ROADMAP

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Message from Governor Tom Wolf

Climate change is the most critical environmental threat confronting the world. In Pennsylvania, greenhouse gas emissions are creating significant challenges ranging from devastating floods in our homes and towns to costly crop losses and air pollution that exceeds federal standards and is linked to respiratory diseases. Left unchecked, these emissions would create a high risk of severe, irreversible impacts.

In January 2019, I signed an Executive Order establishing the first statewide goal to reduce carbon pollution in Pennsylvania. The commonwealth will work to permanently reduce greenhouse gas emissions 26 percent by 2025 and 80 percent by 2050, compared with 2005 levels. The Executive Order also established the Green Government Council to achieve quantitative state agency performance goals in energy conservation, renewable energy procurement, and clean transportation.

This includes replacing 25 percent of the state government passenger car fleet with electric cars and electric hybrid cars by 2025. As their battery costs fall and mileage range increases, these zero-emission vehicles have the potential to provide significant benefits for our health, economy, and environment.

Commonwealth agencies must lead by example, demonstrating commitment to environmental and fiscal stewardship. I commend the Departments of Environmental Protection, General Services, and Conservation and Natural Resources; PennDOT; and the Public Utility and Turnpike Commissions for partnering with other statewide experts to develop *Pennsylvania's Electric Vehicle Roadmap*—a set of strategies to increase electric vehicle use within two years, within five years, and beyond.

Pennsylvanians' quality of life depends on the careful stewardship of resources and development of technologies to enable economic growth while protecting the environment. If implemented, strategies in the *Roadmap* will help ensure that we begin soon to leverage the benefits of electric transportation for all Pennsylvanians, while advancing toward a vibrant future for the commonwealth.

Tom Wolf
Governor

Message from Secretary Patrick McDonnell

As the source of 20 percent of greenhouse gas emissions in Pennsylvania, the gasoline- and diesel-powered transportation sector is a key area for clean energy innovations. If more Pennsylvanians chose electric vehicles (EVs), which generate zero emissions, we could make great strides in reducing greenhouse gases statewide. By 2023, in fact, each mile driven by a new EV would emit 50 percent less greenhouse gas than a new gasoline-powered car.

Increased EV use would bring other significant benefits: reduced asthma and other respiratory disease, jobs in EV manufacturing and infrastructure installation, consumer cost savings from greater fuel efficiency and lower maintenance, and lower costs for ratepayers through improved efficiency in the electricity grid (for example, adding new load at night, when grid use is lower).

Pittsburgh, Philadelphia, and a few other parts of the state are avidly pursuing EV initiatives. We know from applications to the Driving PA Forward and Alternative Fuel Incentive grant programs that some businesses, schools, hospitals, and municipalities are interested in EV use and charging stations. Still, EV use lags in Pennsylvania.

The Department of Environmental Protection formed the Drive Electric PA Coalition—a statewide partnership of state agencies and industry, community, and academic leaders—in 2016 to conduct a research-grounded analysis of the best ways to overcome barriers to great EV use in Pennsylvania. The result is *Pennsylvania's Electric Vehicle Roadmap*, which lays out 13 strategies to tap the great potential of EVs, from increased public education to EV-ready building code amendments and financing programs.

To reap the benefits of electric transportation, Pennsylvania will require more intensive leadership, investment, and recognition of the long-range economic and environmental benefits. I'm proud of the leadership DEP and our partners are providing on this important aspect of Pennsylvania's transportation mix. If you'd like to join us on the road to a cleaner, healthier Pennsylvania, I invite you to turn the page. Further, I encourage you to consider how this valuable work might inform your transportation decisions.

Patrick McDonnell
Secretary
Department of Environmental Protection

EXECUTIVE SUMMARY

This roadmap was developed on behalf of the Pennsylvania Department of Environmental Protection (DEP) and in collaboration with the Drive Electric Pennsylvania Coalition. The purpose of this roadmap is to review the state of the electric vehicle (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.

EVs have the potential to transform Pennsylvania's transportation system and provide significant benefits for the environment, economy, and society. Some of the primary potential benefits include greenhouse gas reduction, air pollutant reduction, consumer cost savings, benefits to the electricity grid, and economic development benefits. Though many areas in Pennsylvania's transportation system could benefit from increased electrification, this roadmap focuses solely on the light-duty vehicle market, currently the most cost-effective market for EVs. Furthermore, though other alternative fuel technologies, such as fuel cell electric vehicles are in the early phases of market commercialization, this roadmap focuses solely on battery electric and plug-in hybrid electric vehicles.

In 2017, Pennsylvania ranked 24th nationwide for total sales of EVs. Major metropolitan regions have seen a slightly higher share of EV registrations than other parts of the state, with Philadelphia experiencing two times the share of EV registrations compared to smaller metropolitan regions and rural parts of the state. Pennsylvania has over 395 publicly listed electric vehicle supply equipment (EVSE), or charging stations, and 910 total plugs, most of which are Level 2 chargers.

Pennsylvania currently has a breadth of local, regional, and state initiatives designed to support EV deployment. The 13 strategies laid out in this roadmap expand or augment those preexisting initiatives in the state and are intended to be implemented in the near-, medium-, or long-term (0-2 years, 2-5 years, or more than 5 years in the future). The strategies cover goals and targets, pricing-based policies, public planning and investment actions, education and outreach initiatives, enabling regulations, and financing models. Together, the proposed strategies address barriers facing EV drivers, single family home residents, multi-family home residents, workplaces, fleets, utilities, dealers, and other key stakeholders. The strategies proposed in this roadmap are intended to increase consumer and dealer confidence in EVs, encourage utility participation in expanding the EV charging infrastructure, improve consumer economics, and expedite processes for installing and expanding EV infrastructure across the state. Within each strategy, suggestions for implementation pathways are provided. The implementation pathway for each strategy can be adapted to lower or higher levels of effort as EV technologies, costs, and the commonwealth's policy and political context change over time.

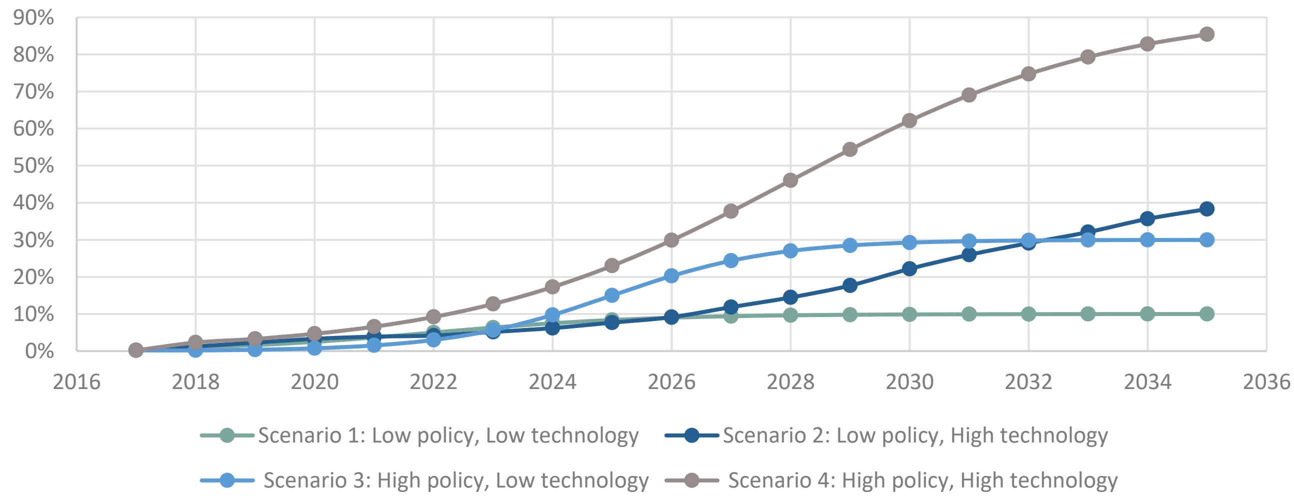
The strategies recommended for Pennsylvania are illustrated in Table 1.

Table 1: Timeline of recommended strategies to support EV adoption in Pennsylvania

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			■

To provide an understanding of the range of potential energy, environmental, and economic impacts of increased EV and EVSE adoption in Pennsylvania, four EV adoption scenarios were modeled. These four scenarios represent the intersection of low- or high-policy support and low- or high-technology advancement. For each scenario, the following assessments were conducted: energy impacts; greenhouse gas and criteria pollutant emissions impacts; and economic impacts on future EV consumers, non-EV consumers, and on society with and without environmental benefits. Figure 1 illustrates the EV sales adoption curve for each of the four scenarios.

Figure 1: Scenario modeling of projected EV sales shares, 2017-2035



The EV sales scenarios in Figure 1 show a range of EV adoption over time. In Scenario 1 (low policy, low technology), EVs represent 10 percent of total sales by 2033, whereas Scenario 4 (high policy, high technology) has EV's representing 79 percent of total sales by the same year.

Those EV sales scenarios manifest into fleet penetration in different ways. In Scenario 1 (low policy, low technology), EVs represent 7 percent of the total light-duty fleet by 2033, whereas Scenario 4 (high policy, high technology) forecasts that EVs will represent 31 percent of the light-duty fleet. As the scenarios become more aggressive, they result in greater reductions in gasoline consumption, greenhouse gas emissions, air pollution, and future social and environmental costs. Based on the data and assumptions adopted for this analysis, it is estimated that all four scenarios may be cost-effective to society and to the future EV consumer by 2033. However, Scenario 3 (high policy, low technology) is not anticipated to be cost effective for society if environmental benefits are not considered or for non-EV consumers (see SECTION 4 for greater detail). The results of these four scenario models can be utilized by the commonwealth to understand the range of potential impacts of the various policy options in the roadmap and of an increased EV market in the state.

As entities in Pennsylvania work together with the commonwealth or the Drive Electric Pennsylvania Coalition to implement the strategies laid out in this roadmap, conducting pilot tests and evaluating the impact of these policies as they are implemented will be important to ensure the strategies are having the desired impact of increasing EV adoption. Furthermore, it is recommended that these strategies be revisited periodically to adjust to the changing and growing EV market in Pennsylvania.

ROADMAP GLOSSARY

AEO – Annual Energy Outlook published by the Energy Information Agency used for several projections in this roadmap.

AFIG – Alternative Fuel Incentive Grant program that funds a variety of alternative fuel vehicle programs.

AFDC – Alternative Fuels Data Center, a resource of the U.S. DOE's Vehicle Technologies Office.

AFLEET – Alternative Fuel Life-Cycle Environmental and Economic Transportation tool created by Argonne National Labs and used for emissions modeling and cost inputs for benefit-cost analysis in this roadmap.

AFV – Alternative fuel vehicle

BCA – Benefit-cost analysis

BEV – Battery electric vehicle (e.g., Nissan Leaf)

CD mode – Charge depleting mode, or when a plug-in hybrid electric vehicle is dependent on the energy in its battery pack.

CO – Carbon monoxide

CS mode – Charge sustaining mode, or when a plug-in hybrid electric vehicle is running primarily on its gasoline engine.

DEP – Pennsylvania Department of Environmental Protection

DOE – United States Department of Energy

DVRPC – Delaware Valley Regional Planning Commission

EIA – Energy Information Agency

EREV – Extended range electric vehicle

EV – Electric vehicle, meaning a vehicle powered, at least in part, by electricity. Unless otherwise noted, EV refers to all plug-in vehicles in this report.

ESCO – Energy Services Company

eVMT – Electric vehicle miles traveled

EVSE – Electric Vehicle Supply Equipment, or electric vehicle charging infrastructure.

GVWR – Gross vehicle weight rating

HDV – Heavy-duty vehicle, which refers to vehicles that weigh over 26,000 lbs. GVWR. Examples include transit buses, refuse trucks, and long-haul tractor trailers.

HOA – Home Owners' Association

ICEV – Internal combustion engine vehicle

kWh – Kilowatt-hour

LDV – Light-duty vehicle, which generally refers to vehicles that weigh less than 10,000 lbs. GVWR. LDVs are the primary focus of this report, which is further broken down to light-duty cars and trucks.

Light-duty car – Includes subcompact, compact, midsize, and large cars. Also referred to as passenger cars.

Light-duty truck – Includes SUVs, vans, and pick-up trucks. Also referred to as passenger trucks.

Level 1 EVSE – AC Level 1 EVSE (often referred to simply as Level 1) provides charging through a 120-volt (120V) AC plug. 8 hours of charging at 120V can replenish about 40 miles of electric range for a mid-size PEV.[1]

Level 2 EVSE – AC Level 2 EVSE offers charging through 240V (typical in residential applications) or 208V (typical in commercial applications) electrical service. For every 1 hour of charging, Level 2 EVSE can provide 10-20 miles of range.

DCFC – Direct-current (DC) fast charging equipment, sometimes called DC Level 2 (typically 208/480V AC three-phase input), enables rapid charging. For every 20 minutes of charging, DCFC can provide 60-80 miles of range.

MDV – Medium duty vehicle, which generally refers to vehicles that weigh 10,000-26,000 lbs. GVWR and include vehicles like cargo vans and delivery trucks).

MPGe – Miles per gallon equivalent, often used to communicate the equivalent fuel economy of an EV.

MPO – Metropolitan Planning Organzation

MSA – Metropolitan Statistical Area. When MSAs referenced include jurisdictions from multiple states, the analysis only includes areas within Pennsylvania.

NESCAUM – Northeast States for Coordinated Air Use Management, a nonprofit association of air quality agencies in the Northeast.

NHTSA – National Highway Traffic Safety Administration

NOx – Oxides of Nitrogen

NREL – The National Renewable Energy Laboratory

OEM – Original Equipment Manufacturer

PCT – Participant Cost Test, a standard cost-effectiveness test for utility energy efficiency programs measuring the costs and benefits of participants in a program.

PEV – Plug-in electric vehicles

PHEV – Plug-in hybrid electric vehicle (e.g., Chevrolet Volt)

PJM – The regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia, including Pennsylvania.

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[1] EVSE definitions adapted from AFDC.gov: https://www.afdc.energy.gov/fuels/electricity_infrastructure.html#dc

$PM_{2.5}$ – Fine particulate matter

PM_{10} – Large particulate matter

PSC – Public Service Commission

PUC – Public Utility Commission

RIM – Ratepayer Impact Measure, a standard cost-effectiveness test for utility energy efficiency programs measuring the costs and benefits of non-participants in a program.

SCT – Societal Cost Test, a standard cost-effectiveness test for utility energy efficiency programs measuring the total societal costs and benefits of a program, typically including the estimated monetary costs of environmental and social impacts.

SOx – Sulfur oxides

TCI – Transportation and Climate Initiative, an initiative of the Georgetown Climate Center working with Northeastern states and stakeholders to address carbon emissions from the transportation sector.

TCO – Total cost of ownership, comprising vehicle purchase cost, infrastructure costs, and operations and maintenance costs, less any residual value recovered at the time of sale.

TRC – Total Resource Cost test, a standard cost-effectiveness test for utility energy efficiency programs measuring the total societal costs and benefits of administering a program.

The Coalition – The Drive Electric Pennsylvania Coalition

TOU rates – Time of Use electricity rates that typically trade higher on-peak rates for lower off-peak rates. They can be designed for residential customers in general, or specifically for EV charging.

V2G – Vehicle to grid, which describes the potential for electric vehicles to provide value to the electric grid through selling power from their batteries back to the grid, or by participating in demand response programs.

VMT – Vehicle miles traveled

VOC – Volatile organic compounds

VW – Volkswagen

Well-to-wheels – A complete vehicle fuel-cycle analysis that includes the emissions associated with fuel mining, transport, and production (well-to-tank), as well as vehicle operation (tank-to-wheels).

ZEV – Zero emissions vehicle

SECTION 1 INTRODUCTION

1.1 THE NEED FOR ELECTRIC VEHICLE DEPLOYMENT NATIONWIDE AND IN PENNSYLVANIA

Electric vehicles (EV) have the potential to transform Pennsylvania's transportation system and provide significant benefits for the environment, economy, and society. As battery costs continue to fall and vehicle range increases, EVs are becoming a cost-effective and viable option for consumers and fleets alike. Still, EV deployment continues to lag market forecasts due to a range of barriers. To unlock the potential benefits of EVs for Pennsylvania, policymakers and key stakeholders have begun to work together to identify policies and programs designed to overcome these barriers and increase EV adoption rates. Some of the primary potential benefits of EVs for Pennsylvania include:

- Greenhouse gas reductions: Governor Wolf recently signed a new executive order establishing the first statewide goal to reduce carbon pollution in Pennsylvania, which is contributing to climate change. The goal states that the commonwealth will work to achieve a 26 percent reduction of greenhouse gas emissions by 2025 and an 80 percent reduction by 2050, from 2005 levels. Additionally, the state monitors the impacts and economic opportunities associated with climate change.[2] In 2013, transportation made up 23 percent of Pennsylvania's net greenhouse gas emissions (20 percent of gross emissions, see Figure 2), 65 percent of which were from gasoline-powered vehicles and 26 percent of which were from diesel-powered vehicles.[3] By 2023, each mile driven by an EV passenger car compared to a gasoline-powered vehicle would emit 50 percent less greenhouse gases based on the anticipated regional electricity mix. These emissions reductions are anticipated to grow over time as Pennsylvania's electricity sector becomes cleaner.
- Air pollutant reduction: As of 2018, several counties in Pennsylvania consistently exceed EPA human-health and environmentally based standards for 8-hour ozone and for fine particulate matter ($PM_{2.5}$), which both have significant negative human health impacts.[4] The burning of higher carbon fossil fuels, including gasoline and diesel, in high traffic intensity areas is a substantial source of air pollution. According to the 2014 National Emissions Inventory, 53 percent of statewide NOx emissions and 10 percent of $PM_{2.5}$ emissions are from mobile sources.[5] With zero tailpipe emissions,

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[2] Pennsylvania Department of Environmental Protection. (2016, August). *2015 Climate Change Action Plan Update*. Retrieved from http://www.depgreenport.state.pa.us/elibrary/GetDocument?docId=5342&DocName=FINAL 2015 Climate Change Action Plan Update.pdf

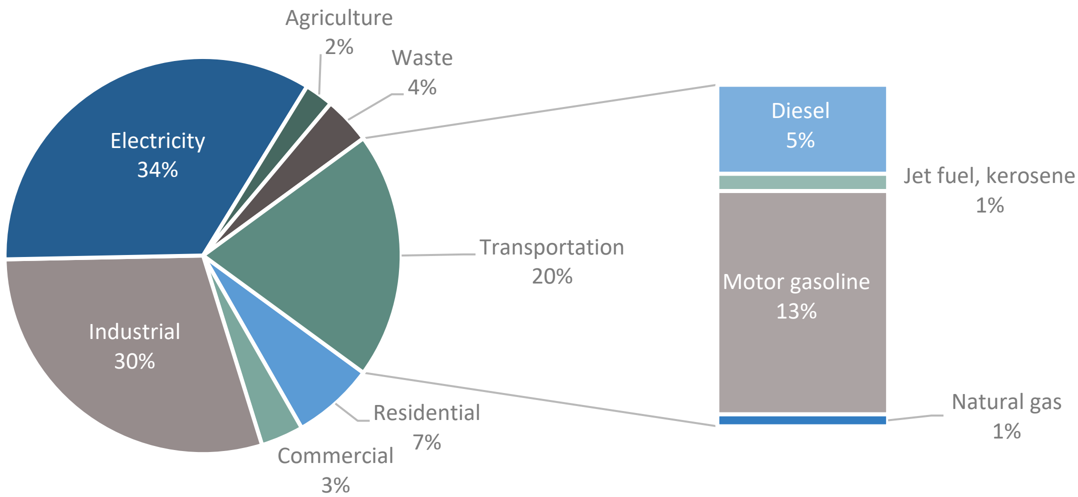
[3] *Pennsylvania Greenhouse Gas Inventory 2016*. (2017, January). Retrieved from http://files.dep.state.pa.us/Air/AirQuality/AQPortalFiles/Advisory%20Committees/CCAC/Docs/Inventory-2016_1-18-17_(final).pdf

[4] The counties out of attainment for 8-hour ozone are Lancaster, Pittsburgh-Beaver Valley, Reading, Allentown-Bethlehem-Easton, and Philadelphia; and for $PM_{2.5}$ are Lebanon County, Allegheny County, and Delaware County. https://www3.epa.gov/airquality/greenbook/ancl2.html

[5] EPA. (2018, March). Air Emissions Inventories. *2014 National Emissions Inventory (NEI) Data*. Retrieved from https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data

EVs have the potential to reduce the burden on communities near highways, ports, and other high traffic zones, and improve quality of life and public health outcomes.

Figure 2: 2013 Pennsylvania Gross Greenhouse Gas Emissions by Sector



(Source: DEP 2016 GHG inventory)

- Consumer cost savings: Due to the greater fuel efficiency and lower maintenance requirements of EVs, it is anticipated that consumers and fleets that switch to EVs from gasoline-powered vehicles will save on maintenance and fuel costs over the lifetime of their vehicle. Maintenance costs for EVs have been found to be lower than conventional vehicles due to less wear on brakes and fewer moving parts.[6] While most EVs have greater upfront costs compared to their gasoline-powered counterparts, ongoing reductions to battery costs suggest the cost premium will decline over time and savings will grow.
- Benefits to the electricity grid: Widespread electrification of vehicles could improve the load factor of the grid, i.e., increase the overall efficiency or utilization rate of the grid. Because the electric grid typically operates below peak capacity, by strategically adding new electric load at the right times (e.g., at night when grid use is lowest), EV adoption in Pennsylvania can help drive down costs for ratepayers, support increased renewable energy integration, and improve reliability to consumers. In addition, with managed EV charging and bidirectional vehicle-to-grid (V2G) charging, EVs could potentially support increased renewable energy generation and integration as well as grid stability through frequency regulation, reduced curtailment, and by providing reserve capacity during peak demand periods. Bidirectional charging gives EVs the potential to balance variable electricity

[6] Palmer, K., Tate, J., Wadud, Z., Nellthorp, J. (2017, November 4). Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan. *Applied Energy, 209)*. Retrieved from https://www.sciencedirect.com/science/article/pii/S030626191731526X

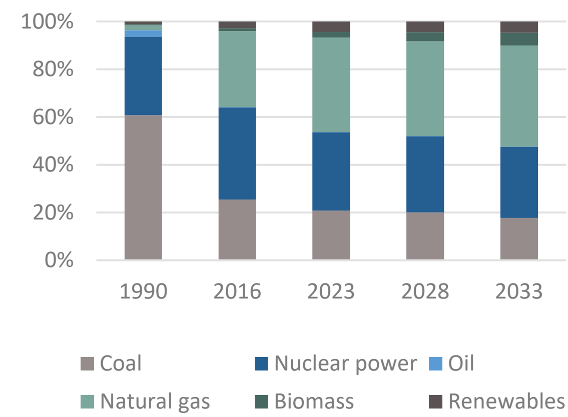
production from intermittent renewable sources and store excess energy, thus reducing curtailment of renewable sources.[7]

- **Economic development benefits:** By beginning to transition its transportation system to run on electricity, Pennsylvania can decrease its reliance on foreign oil and increase its reliance on domestic fuels and an electricity sector that brings greater economic impacts to the local economy.[8] Additionally, Pennsylvania could benefit from job growth in EVSE installation, EV parts or vehicle manufacturing, as well as related EV/EVSE services including education and training of EV mechanics.[9]

Some of these benefits—air pollution reduction, greenhouse gas emissions reductions, and consumer cost savings—are anticipated to grow over time. Increasingly, Pennsylvania is powering its electricity grid with cleaner sources, meaning each mile converted to electric mobility will yield greater greenhouse gas and air quality benefits.

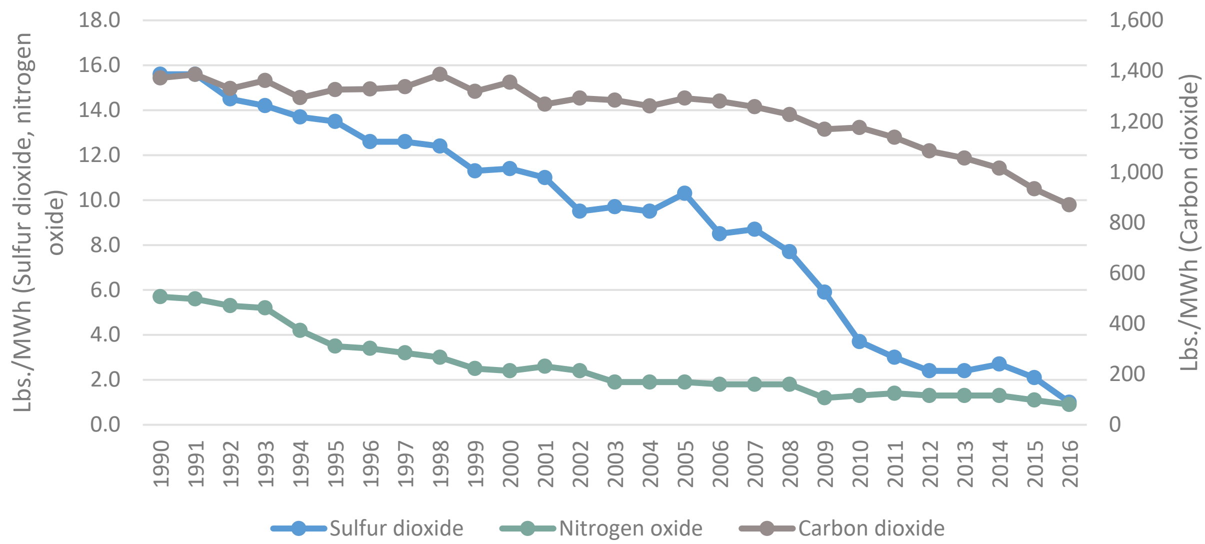
For example, as illustrated in Figure 3, between 1990 and 2016, the share of electricity generated by coal in the state fell from 61 percent to 25 percent and is expected to fall further to 19 percent by 2033. Over the same period, total annual statewide electricity sector emissions decreased 22 percent and emissions intensity (greenhouse gas emissions per unit of electricity produced) fell 37 percent (see Figure 4).[10]

Figure 3: Historical and projected electricity grid mix in PA (Source: EIA)



[7] IRENA. (2017, February). *Electric Vehicles Technology Brief*. Retrieved from http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/IRENA_Electric_Vehicles_2017.pdf
[8] National Renewable Energy Laboratory. (2017, April 20). *Connecting Electric Vehicles to the Grid for Greater Infrastructure Resilience*. Retrieved from https://www.nrel.gov/news/program/2017/connecting-electric-vehicles-to-the-grid-for-greater-infrastructure-resilience.html
[9] Todd, J., Chen, J., Clogston, F. (2013). *Creating the Clean Energy Economy: Analysis of the Electric Vehicle Industry*. Retrieved from https://www.iedconline.org/clientuploads/Downloads/edrp/IEDC_Electric_Vehicle_Industry.pdf
[10] U.S. Energy Information Administration. (2018, January 25). *Electricity*. Pennsylvania State Electricity Profile 2016. Retrieved from https://www.eia.gov/electricity/state/pennsylvania/

Figure 4: PA Greenhouse gas and criteria pollutant electricity emissions intensity, 1990-2016



(Source: EIA)

Moreover, advances in battery technology have resulted in battery costs declining by 73 percent between 2010 and 2016, which has driven subsequent reductions in upfront costs for EVs.[11] As a result, EVs are anticipated to become increasingly cost-effective for consumers on a total cost of ownership (TCO) basis as costs for batteries and other EV components continue to fall.

Importantly, while not an issue at low levels of EV deployment, increased levels of EV adoption could impact gas tax revenues that fund road and bridge maintenance. Transportation experts agree a new revenue solution for transportation infrastructure is needed regardless of EV uptake, as increasing fuel economy fleetwide and other factors erode gas tax revenues. As EV deployment increases, it will be important to determine revenue replacement options for gas taxes, and to determine how EVs contribute to that system.

While EVs have the potential to positively transform Pennsylvania's transportation system, widespread deployment is unlikely to happen—and the potential benefits are unlikely to be maximized—without policymakers and other key stakeholders implementing a range of enabling policies, programs, and market interventions. To date, EV deployment in Pennsylvania has represented a small share of the overall vehicle market (0.56 percent in 2017 for both battery electric vehicles [BEVs] and plug-in electric vehicles [PHEVs]), and market growth has been slower than many peer states. This roadmap is designed to jumpstart the EV market in Pennsylvania and to help residents, fleet owners, and businesses realize the benefits of transportation electrification for the state.

[11] Curry, C. (2017, July 5). *Lithium-Ion Battery Costs and Market.* Retrieved from https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF-Lithium-ion-battery-costs-andmarket.pdf

1.1.1 NOTABLE NATIONAL AND REGIONAL EV INITIATIVES

Notable national and regional initiatives designed to increase EV adoption that have also informed the development of this roadmap include:

Zero Emission Vehicle states: California has unique authority under the Clean Air Act to adopt stricter vehicle emission regulations than federal government standards, and other states are also eligible to adopt California's standards. California's Zero Emission Vehicle (ZEV) legislation requires that 14 percent of the vehicles auto manufacturers deliver and sell to the state of California must be zero emission vehicles (electric or hydrogen), rising to 22 percent by 2025. Nine other states—Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont—have adopted California's ZEV program. In addition to the ZEV sales mandate for manufacturers, participating states in the ZEV Memorandum of Understanding have also agreed to coordinate on several actions to support ZEV deployment, such as adoption of EV-friendly building codes and laws, setting EV purchase targets for government fleets, and implementing incentives for EV drivers. The program is considered one of the strongest policies driving EV adoption in the United States.

Drive Change. Drive Electric:[12] The Northeast States for Coordinated Air Use Management (NESCAUM) has collaborated with the Association of Global Automakers and the Alliance of Automobile Manufacturers to launch the 'Drive Change. Drive Electric' Campaign, a joint effort of major automakers and states, including New York, Connecticut, Massachusetts, New Hampshire, Rhode Island, Vermont, and New Jersey. The goal of the campaign is to raise consumer awareness and understanding of zero emission vehicle technologies by developing a website, social media outreach, advertising materials, and events.

Northeast Electric Vehicle Network: The Northeast Electric Vehicle Network, run by Georgetown Climate Center's Transportation and Climate Initiative, is "an effort to coordinate electric vehicle infrastructure planning and deployment throughout the Northeast and Mid-Atlantic regions. The Network refers to more than just physical infrastructure; it includes partnerships and connections necessary for a successful transition to cleaner and more efficient electric transportation."[13] The Network is a partnership of state governments, utilities, charging infrastructure providers, private companies, nonprofits, universities, and local governments.

Northeast Corridor Strategy: NESCAUM's recently released Northeast Corridor Strategy is a collaborative effort of Northeast states from D.C. to Maine aimed to facilitate EV travel through the highly connected region. The strategy includes a joint vision and recommendations for funding and building a regional charging network, and ensuring investments are aligned with regional goals.

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[12] Drive Change Drive Electric. *About 'Drive Change. Drive Electric.'*. Retrieved from https://driveelectricus.com/about-us/

[13] Transportation & Climate Initiative of the Northeast and Mid-Atlantic States. *Northeast Electric Vehicle Network.* Retrieved from http://www.transportationandclimate.org/content/northeast-electric-vehicle-network

1.2 ROADMAP OVERVIEW AND PURPOSE

1.2.1 DRIVE ELECTRIC PENNSYLVANIA COALITION

In 2016, the Pennsylvania Department of Environmental Protection (DEP) Energy Programs Office began collaborating with a broad range of stakeholders with the goal of increasing EV adoption in Pennsylvania. These stakeholders now form the Drive Electric Pennsylvania Coalition (the Coalition), which includes state and municipal government officials, U.S. Department of Energy's (DOE) Clean Cities Coalitions, EV businesses and consultants, transportation organizations, electric utilities, environmental groups, auto companies, and other interested stakeholders. The Coalition meets quarterly and participation is open to the public. The Coalition seeks to increase the acceptance and adoption of EVs by state government agencies, local governments, businesses, industry, and the public in Pennsylvania. The Coalition has formed the following three subcommittees to further define plans, goals, and activities related to these important areas:

- The Education and Outreach Committee is focused on developing and implementing a statewide education and communications strategy that increases awareness and understanding of EVs for all Pennsylvania citizens, businesses, and governmental entities.
- The Infrastructure Committee is focused on helping to increase demand for EVs by supporting cost-effective and robust planning and investment in EVSE to promote consistent access and charging experiences for all Pennsylvania citizens, businesses, and governmental entities.
- The Procurement Committee is working to accelerate the adoption of EVs in Pennsylvania fleets by providing educational resources, tools, goals, and promotions that address the needs of state, municipal, private fleets, and consumer purchases.

1.2.2 ROADMAP PURPOSE

This document serves as the Commonwealth of Pennsylvania's EV roadmap and has been structured to achieve the following goals:

- Expand the knowledge base of the Coalition and other Pennsylvania entities via information gathering from a broader base of stakeholders.
- Document a baseline of information regarding the deployment of EVs and EVSE in Pennsylvania to date.
- Identify EV policies, plans, and programs that can support EV deployment in Pennsylvania and draw from best practices around the U.S. and internationally.
- Develop a consistent and robust roadmap by leveraging the expertise of Coalition stakeholders, EV thought leaders from different sectors, and experts in EV policy and planning.

1.2.3 ROADMAP FOCUS AND STRUCTURE

This roadmap explores policy measures and market interventions that can support development of electrified on-road passenger transportation modes in Pennsylvania, with a primary focus on light-duty vehicles (LDV), including both light-duty cars (passenger cars such as sedans and hatchbacks) and light-duty trucks (vehicles like SUVs, vans, and pick-up trucks). Altogether, light-duty cars and trucks comprise 89 percent of on-road vehicle miles traveled in the state (PennDOT Highway Statistics 2016).

When discussing strategies to increase adoption of EVs, the report includes both full BEVs as well as plug-in hybrid electric vehicles (PHEV). Though traditional hybrids and other alternative fuel vehicles, such as fuel cell electric vehicles, are also important potential strategies for Pennsylvania's transportation sector, this report does not address those vehicle types. The roadmap has been informed by several facilitated workshops engaging Coalition members, a literature review, EV policy research, interviews with national EV experts, and targeted modeling. More details about the process for developing this roadmap and a literature review of EV deployment planning documents can be found in Appendix A.

The remainder of the roadmap is structured as follows:

- SECTION 2: State of the EV Market in Pennsylvania: This section provides an overview of progress and trends with respect to deployment of EVs and EVSE in Pennsylvania to date, as well as an assessment of key market barriers affecting the deployment of EVs in Pennsylvania.
- SECTION 3: Next Generation EV Strategies: This section describes best practices in EV policies, programs, and other types of strategies from around the country, provides a benchmark of current state and local policies and programs in Pennsylvania, and recommends a set of priority policies and programs to increase EV deployment in Pennsylvania.
- SECTION 4: Pennsylvania EV Market Penetration Scenarios: This section documents the methodology and results of the scenario modeling, which describes the potential economic, environmental, and energy sector impacts across a range of EV deployment scenarios.
- SECTION 5: Conclusions and Next Steps: This section summarizes the key conclusions of the report and outlines next steps, timelines, and stakeholder roles and responsibilities to implement policy and program recommendations.

SECTION 2 STATE OF THE EV MARKET IN PENNSYLVANIA

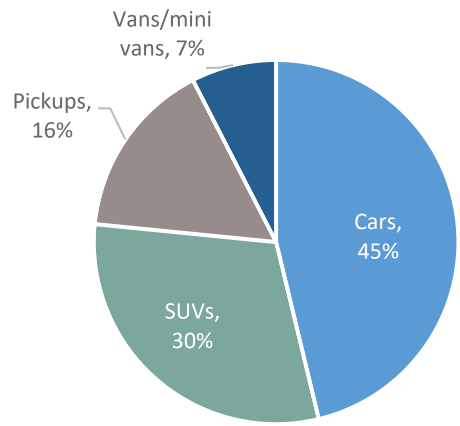
2.1 EV AND EVSE DEPLOYMENT IN PENNSYLVANIA

This section provides a snapshot of Pennsylvania's progress to date in deploying EVs and EVSE, considering trends in EV sales, geographic distribution of EV registrations, and progress in EVSE installations. It also benchmarks Pennsylvania's progress in EV deployment against other state and regional markets.

2.1.1.1 Available EV technology

Since 2011, the number of distinct EV models available has grown from under 5 to over 53, increasing the available options for consumers.[14] Thus far, available EV models are primarily light-duty cars (such as sedans and hatchbacks), while SUVs, vans, and pick-up trucks are just beginning to become available in PHEV models, and BEV models are anticipated to become available in the future (see Table 2 for sample models of available EV models). Today, 53 percent of registered light-duty vehicles in Pennsylvania are SUVs, pick-up trucks, or vans. Given that available EVs are primarily sedans and hatchbacks, the dominance of the other LDV platforms in PA could present a barrier for EV adoption in the coming years (see Figure 5).[15]

Figure 5: Registered vehicles in PA by vehicle type



[14] Office of Energy Efficiency & Renewable Energy. *Find Electric Vehicle Models.* Retrieved from https://www.energy.gov/eere/electricvehicles/find-electric-vehicle-models

[15] Auto Alliance Driving Innovation. (2015). *State Facts: Autos Drive Pennsylvania Forward.* Retrieved from https://autoalliance.org/in-your-state/PA/

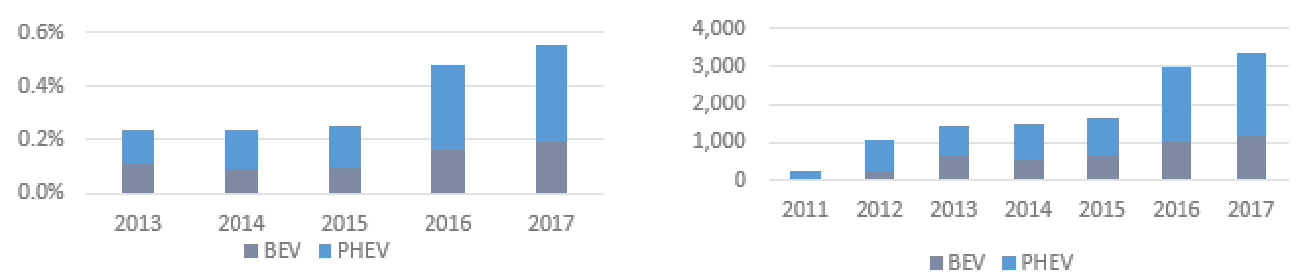
Table 2: Vehicle types and available BEV and PHEV models[16]

	Vehicle type	BEV sample models	PHEV sample model
Light-duty cars	Compact and subcompact cars	**Ford Focus Electric** *(MSRP $29,200; Range 115 miles)*	**Chevy Volt** *(MSRP $33,200; Range 53 miles)*
	Mid-size and large cars	**Nissan Leaf** *(MSRP $29,990; Range 151 miles)* **Tesla Model 3** *(MSRP $35,000; Range 310 miles)*	**Prius Prime** *(MSRP $27,100; Range 25 miles)* **Ford Fusion Energi** *(MSRP $33,400; Range 21 miles)*
Light-duty trucks	SUV	*No models currently available. Toyota, BYD, VW, Tesla, Mitsubishi, Volvo, Audi, etc. have all announced SUV, Van, or Pick-up models to be released by 2020.*	**Mitsubishi Outlander** *(MSRP $34,600; Range 22 miles)*
	Van		**Chrysler Pacifica** *(MSRP $40,000; Range 33 miles)*
	Pick-up		**Workhorse W-15** *(MSRP $50,000, Range 80 miles)*

Among medium and heavy-duty vehicles, electric transit buses are the most widely available and commercialized vehicle type, with electric school buses, refuse trucks, delivery trucks, and some drayage trucks in various phases of pilot, demonstration, and early commercialization phases. Analysts anticipate that medium- and heavy-duty vehicle fleets that primarily serve local and regional routes will be prime candidates for widespread electrification, whereas long-haul trucking electrification may prove more difficult.[17]

2.1.1.2 Benchmarking Pennsylvania's EV deployment progress relative to other states

Figure 6: Market share of Zero Emission Vehicles in Pennsylvania, 2013-2017 (left) and Annual sales of Zero Emission Vehicles in Pennsylvania, 2011-2017 (right)



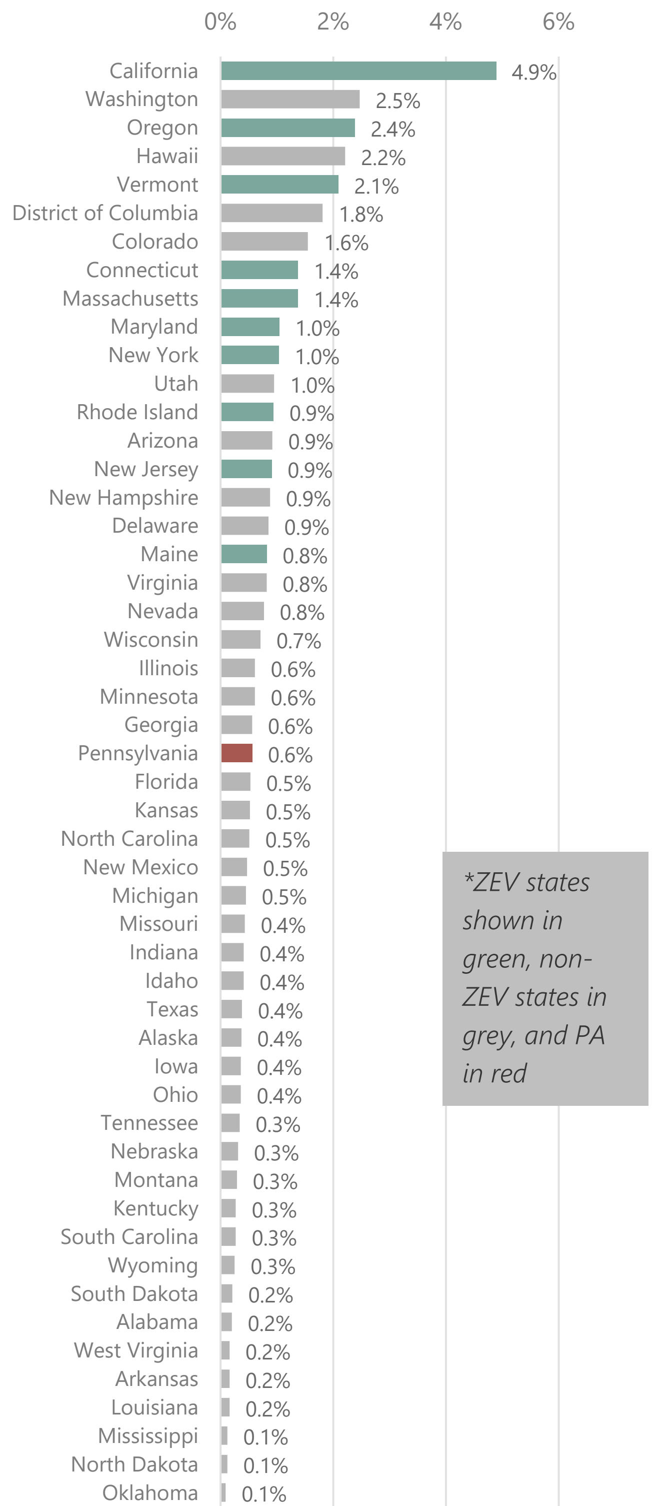
(Source: Auto Alliance Advanced Technology Vehicle Sale Dashboard.)

[16] Information from https://www.energy.gov/eere/electricvehicles/find-electric-vehicle-models, http://www.plugincars.com/cars

[17] Moultak, M., Lutsey, N., Hall, D. (2017, September). *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles.* Retrieved from https://www.theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf

In 2017, Pennsylvania ranked 19th out of 50 states in PHEV market share, and 32nd in BEV market share. For both EV types combined, Pennsylvania's market share of 0.6 percent of new sales falls in the middle nationwide (24th), though remains lower than states that are part of the ZEV mandate. Figure 7 highlights EV market share amongst ZEV and non-ZEV states in 2017.[18] EV sales in the light-duty vehicle market have been growing at an average annual rate of 36 percent between 2011 and 2017 (see Figure 6).[19] During that period, PHEV sales exceeded BEV sales in Pennsylvania. The market share of EVs is still very small but growing, capturing 0.55 percent of new vehicle sales in 2017, up from 0.24 percent in 2013 (see Figure 6).

Figure 7: EV sales share by state in 2017



2.1.1.3 Geographic Distribution of EV Deployment

Major metropolitan regions like Philadelphia have seen a greater share of battery EV registrations than other parts of the state, while smaller metropolitan regions and rural parts of the state have experienced somewhat lower adoption rates (see Table 3).[20] To date, there have been more substantial local and regional EV policies and initiatives in the Philadelphia and Pittsburgh regions, which collectively represent about 45 percent of the state's vehicle fleet. While the six metropolitan statistical areas (MSA) studied for this roadmap and highlighted in Table 3 represent a majority of the state's vehicle market, 38 percent of vehicles are registered outside these areas, indicating a need for a statewide strategy in addition to targeted regional initiatives.

[18] Data is from the Auto Alliance Advanced Technology Vehicles Sales Dashboard, and includes both BEV and PHEV sales in 2017.

[19] Based on data from the Auto Alliance Advanced Technology Vehicle Sales Dashboard.

[20] PennDOT has data only for BEV registrations, while PHEVs are included with hybrid vehicles.

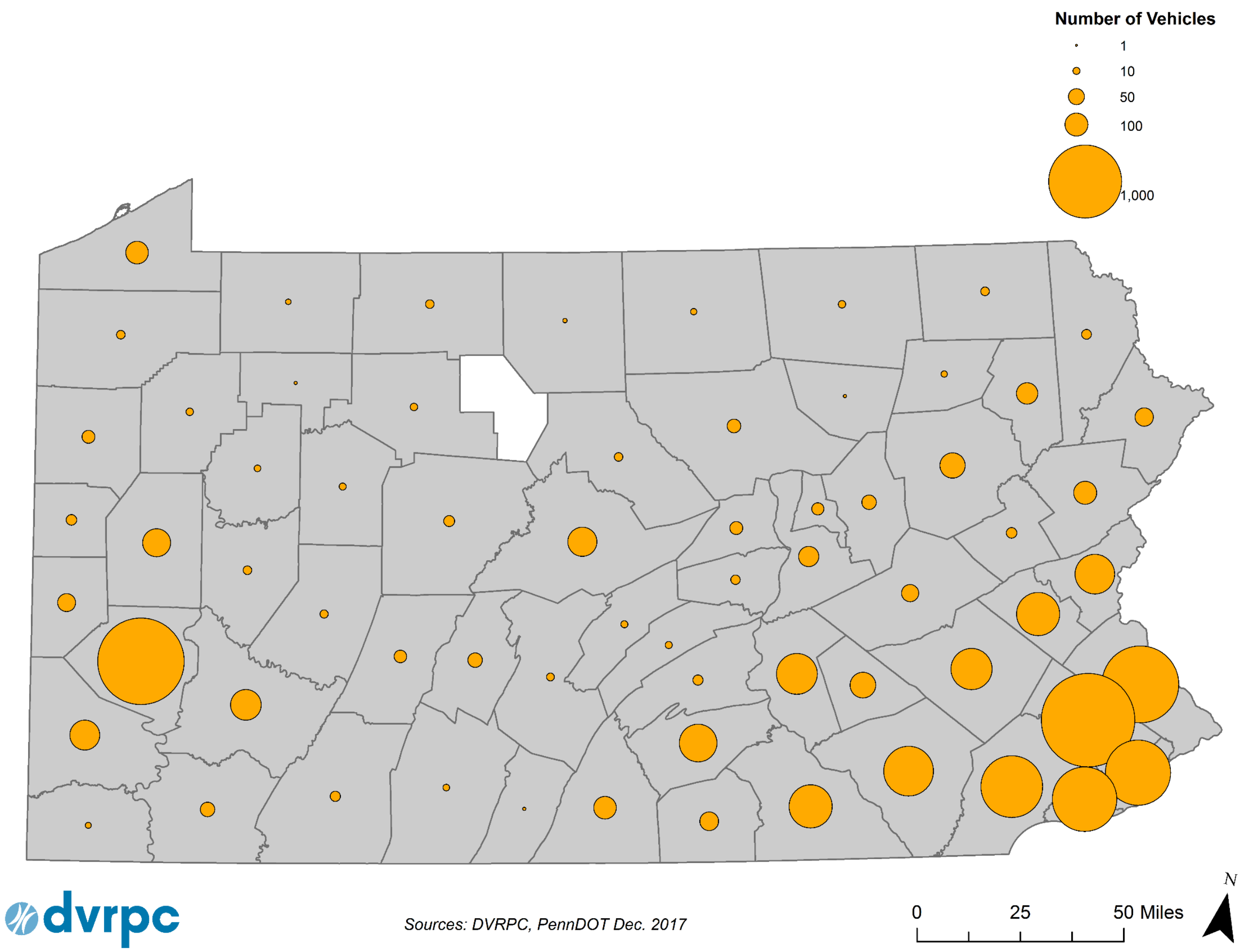
Table 3: 2017 Regional distribution of registered EVs in Pennsylvania (Source: DVRPC and PennDOT[21])

Metropolitan Statistical Area (MSA)[22]	BEVs	PHEVs	EVs	Total registered vehicles	EV share of MSA total	Share of state LDVs in MSA
Allentown-Bethlehem-Easton, PA-NJ	75	311	386	313,023	0.12%	4.0%
Harrisburg-Carlisle, PA	147	473	620	379,154	0.16%	4.8%
Lancaster, PA	116	359	475	332,975	0.14%	4.2%
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	1,536	2,839	4,375	2,049,753	0.21%	26.1%
Pittsburgh, PA	721	1,351	2,072	1,446,415	0.14%	18.4%
Scranton-Wilkes-Barre, PA	71	153	224	352,477	0.06%	4.5%
Rest of the state	885	2,310	3,195	2,968,093	0.11%	37.8%
TOTALS	3,551	7,796	11,347	7,841,890	0.14%	**100%**

[21] Commonwealth of Pennsylvania Department of Transportation Bureau of Motor Vehicles. (2017). *Report of Registrations*. Retrieved from http://www.dot.state.pa.us/public/dvspubsforms/BMV/Registration%20Reports/ReportofRegistration2017.pdf. Updated data from DVRPC and PennDOT became available in May 2018, which is included in Table 3. The fleet modeling undertaken in Section 4 was completed with previous PennDOT EV registration data and was not updated; it was only utilized to inform the initial adoption curves and likely has a minimal impact on the overall results.

[22] Analysis of MSAs that span multiple states only includes counties within Pennsylvania.

Figure 8: Registered EVs in Pennsylvania (2018 PennDOT data processed by DVRPC)



2.1.1.4 EV fleet deployments in Pennsylvania

The Coalition Procurement Committee has focused on strategies to support fleet transitions to EVs.[23] Though fleet vehicles make up a relatively small share of Pennsylvania's total vehicle inventory, fleet electrification can be an important strategy for several reasons:

- **Predictable routes and charging:** Fleets are often operated from central depots where EVSE can be easily sited, and tend to have more predictable routes, allowing vehicle selection to match range requirements.
- **Greater return on investment:** Fleet managers are more likely than individual consumers to consider life cycle costs when making purchasing decisions. Higher utilization of some fleet vehicles can mean higher operations and maintenance savings and shorter payback periods, making a strong case for EVs in some fleets.

[23] Public and commercial fleet vehicles can include both light-duty, as well as medium- and heavy-duty fleet vehicles, though this roadmap primarily focuses on light-duty vehicles.

- Raising awareness: Incorporating EVs into consumer-facing fleets such as rental cars, taxis, or rideshare/car-share vehicles has an additional benefit of providing more consumers with direct experience with EVs.
- Emissions impact: Some fleet vehicles like delivery trucks and buses are often driven further than private vehicles and operate in densely populated urban areas, and may have a more substantial impact on air quality and greenhouse gas emissions.

Table 4 summarizes Pennsylvania's approximate on-road inventory of commercial and government fleets, indicating the electrification potential of focusing efforts on different fleets. Commonwealth and municipal government vehicles include a range of light-duty as well as medium- and heavy-duty trucks.

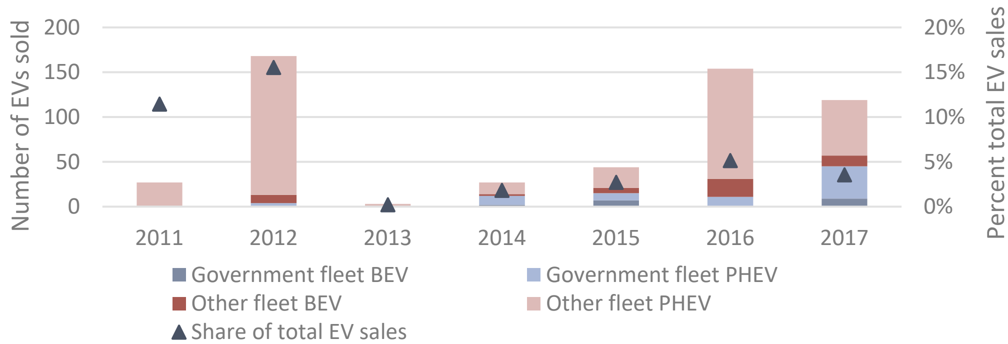
Table 4: Fleet vehicle electrification potential in Pennsylvania (Source: PennDOT[24])

	Fleet vehicle type	Number registered (2017)
Government fleet vehicles	School buses	31,500
	Transit buses	6,700
	Commonwealth vehicles	35,900
	Municipal government vehicles	110,300
Commercial fleet vehicles	Taxis	2,600
	Limousines	2,600
	Light-duty trucks	1,730,000
	Medium-duty trucks	109,300
	Heavy-duty trucks	92,800

In recent years, EV fleet deployments by government and private fleets in Pennsylvania reached about 15 percent of total EV sales, while in other years fleet deployments represented a very minor share (see Figure 9). Most EV fleet deployments have been in private fleets thus far, though government EV investment has been more substantial in recent years.

[24] Commonwealth of Pennsylvania Department of Transportation Bureau of Motor Vehicles. (2017). *Report of Registrations*. Retrieved from http://www.dot.state.pa.us/public/dvspubsforms/BMV/Registration%20Reports/ReportofRegistration2017.pdf. PennDOT's data by county only includes BEVs, while PHEVs are included in the hybrid category.

Figure 9: PA EV fleet deployments, 2011-2017



(Source: Auto Alliance Advanced Technology Vehicle Sales Dashboard)

Several public and private fleets across the state have begun to deploy EVs, which helps familiarize employees with the technology and serves as advertising and education for other drivers. Table 5 highlights recent fleet EV deployments in Pennsylvania.

Table 5: Pennsylvania electric fleet vehicle deployment highlights to date

Fleet		Description of fleet deployment
Public transit fleets	SEPTA	SEPTA will soon have the largest fleet of electric buses on the East Coast, with 25 electric buses scheduled to be delivered.
	Port Authority of Allegheny County	The Port Authority of Allegheny County will buy its first electric bus with a federal grant to test the technology for potential use on its BRT route opening in 2020.[25]
	Berks Area Regional Transportation Authority	In 2013, the Berks Area Regional Transportation Authority received the first 2 electric paratransit buses in the country— Ford E-450-based buses with a 100-mile range.[26]
Government fleets	Commonwealth of Pennsylvania	The state fleet is currently undertaking a pilot program for plug-in hybrid and battery EVs, with 8 vehicles deployed by the Department of Conservation of Natural Resources and 17 by the Department of Environmental Protection.[27]
	City of Pittsburgh	Pittsburgh has ordered 4 EVs for its city fleet.[28]
	Philadelphia Parking Authority	The Philadelphia Parking Authority received funds through the AFIG program to purchase 4 EVs.
	City of Philadelphia	The City of Philadelphia has 21 Ford Fusion Energi's in operation (with 8 additional Fusion Energi's on order) and 16 Chevy Bolts on order.
	Penn State	Penn State has several EVs in its fleet, and has added 3 public charging stations to its campus.[29]
Utility fleets	Duquesne Light Company	Duquesne has committed 5% of annual fleet purchase to EVs, and so far has 9 EVs, 4 PHEV bucket trucks, and 3 electric forklifts.[30]
	PECO	PECO has 2 Chevy Volts in its fleet, 22 hybrid bucket trucks, 1 heavy-duty aerial truck and 1 splicer truck.
	PPL Electric utilities	PPL Utilities has 15 Chevy Volts, and has battery-operated buckets on 48 of its trucks, which reduces emissions from idling.[31]
Other commercial fleets	Sheeren Insurance Group	Sheeren Insurance Group received funds through the AFIG program to purchase 2 Nissan Leaf battery-electric vehicles.
	Uber	In Pittsburgh, Uber and Duquesne Light recently partnered to deploy 50 EVs in Uber's regional fleet, along with 5 charging stations.[32]

[25] Blazina, E. (2017, September 24). *Port Authority to Buy First Electric Bus.* Retrieved from http://www.post-gazette.com/news/transportation/2017/09/24/Port-Authority-Pittsburgh-first-electric-bus-2020/stories/201709240043

[26] Metro. (2013, August 12). *First U.S. Electric Paratransit Vehicle Deployed to Pa. Fleet).* Retrieved from http://www.metro-magazine.com/accessibility/news/290838/pa-receives-electric-paratransit-bus

[27] Green Fleet. (2017, September 15). *Pa. Launches Fleet Electrification Pilot*. Retrieved from http://www.government-fleet.com/channel/green-fleet/news/story/2017/09/pa-launches-fleet-electrification-pilot.aspx

[28]U.S. News. (2017, June 20). *Pittsburgh Begins to Adopt Electric Cars for City Fleet.* Retrieved from https://www.usnews.com/news/best-states/pennsylvania/articles/2017-06-20/pittsburgh-begins-to-adopt-electric-cars-for-city-fleet

[29] PennState. (2018, May 8). *Electric vehicle charging stations now available at Nittany Deck.* Retrieved from http://sustainability.psu.edu/spotlight/electric-vehicle-charging-stations-now-available-nittany-deck

2.1.2 TRENDS IN EVSE DEPLOYMENT IN PENNSYLVANIA

2.1.2.1 Public EVSE Deployment in Pennsylvania

Pennsylvania has over 395 publicly listed EVSE stations and 910 total plugs, according to the U.S. DOE's Alternative Fuels Data Center. While listed publicly, not all stations are equally accessible to all EV drivers, with some restricted to customers of an establishment or to drivers of certain types of vehicles. Table 6 provides a summary of different types of public EVSE in Pennsylvania based on their accessibility.

Types of EVSE

Level 1 EVSE *–Provides charging through a 120-volt (120V) AC plug. Most, if not all, plug-in electric vehicles (PEVs) come with an AC Level 1 EVSE cordset, so no additional charging equipment is required. AC Level 1 is typically used for charging when there is only a 120V outlet available, but can easily provide charging for all of a driver's needs. For example, 8 hours of charging at 120V can replenish about 40 miles of electric range for a mid-size PEV.*

Level 2 EVSE *– Offers charging through 240V (typical in residential applications) or 208V (typical in commercial applications) electrical service. Most homes have 240V service available, and because AC Level 2 EVSE can charge a typical EV battery overnight, they will commonly be installed at EV owners' homes for home charging or are used for public charging equipment. For every 1 hour of charging, Level 2 EVSE can provide 10-20 miles of range. AC Level 2 equipment uses the same SAE J1772 connector and charge port that Level 1 equipment uses.*

DCFC *– Direct-current (DC) fast charging equipment, sometimes called DC Level 2 (typically 208/480V AC three-phase input), enables rapid charging. There are three types of DC fast charging systems, depending on the type of charge port on the vehicle: a J1772 combo, CHAdeMO, or Tesla. For every 20 minutes of charging, DCFC can provide 60-80 miles of range.*

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[30] Duquesne Light Company. (2017). *Electric Vehicles.* Retrieved from https://www.duquesnelight.com/energy-money-savings/electric-vehicles

[31] PPL Electric Utilities. *Our Drive for Green.* Retrieved from https://www.pplelectric.com/landing-pages/electric-vehicles/our-drive-for-green.aspx

[32] Aupperlee, A. (2018, February 28). *Uber, Duquesne Light to add electric vehicles, charging stations in Pittsburgh.* Retrieved from http://triblive.com/business/technology/13362782-74/uber-duquesne-light-to-add-electric-vehicles-charging-stations-in-pittsburgh

Table 6: Publicly listed EVSE in Pennsylvania, as of 2/21/18 (Source: AFDC.gov)

EVSE type	Level 1/ Level 2	DCFC	Total
Public plugs: Available to all EV drivers	458	82	**540**
Semi-public plugs: Available only to EV drivers with restrictions, such as being a customer, visitor, or employee of an establishment	27	0	**27**
Tesla plugs: Available to Tesla drivers only	86	62	**148**
Total	**571**	**144**	**715**

2.1.2.2 Geographic Distribution of EVSE Deployment

Table 7 highlights where public EVSE has been installed in Pennsylvania to date, and indicates that the majority of EVSE are currently located in the Philadelphia and Pittsburgh regions, coincident with where most EVs have been registered so far.

Table 7: Regional distribution of public EVSE plugs in Pennsylvania (Source: AFDC.gov)

Metropolitan Statistical Area (MSA)[33]	Level 1/ Level 2 EVSE	DCFC	Total
Allentown-Bethlehem-Easton, PA-NJ	16	0	16
Harrisburg-Carlisle, PA	15	3	18
Lancaster, PA	15	5	20
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	206	24	230
Pittsburgh, PA	170	36	206
Scranton-Wilkes-Barre, PA	5	0	5
Rest of state	31	14	45
TOTAL	458	82	540

The map in Figure 10 includes the locations of public Level 2 and direct current (DCFC) charging stations by the number of plugs per station.[34] The map in Figure 11 includes the locations of public, semi-public, and Tesla charging stations in Pennsylvania by the number of plugs per station. Many existing charging stations are located at university campuses, car dealerships, shopping centers, hotels, and transportation hubs like airports and highway service plazas. Five Pennsylvania Turnpike service plazas now have public charging stations, including Level 2 chargers at Oakmont Plum, New Stanton, Bowmansville, Peter J. Camiel, and King of Prussia Service Plaza. Existing DCFC stations are located at Bowmansville, Peter J.

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[33] Analysis of MSAs that span multiple states only includes counties within Pennsylvania.
[34] According to AFDC.gov as of February 2018.
https://www.afdc.energy.gov/stations/#/analyze?region=PA&fuel=ELEC&ev_levels=all

Camiel, and the King of Prussia Service Plaza. Turnpike stations were jointly funded by a grant from Pennsylvania DEP to Car Charging Group, a private company, with contributions from the Turnpike Commission. This partnership demonstrates the potential for public-private partnerships to enable charging station deployment.

Figure 10: Map of public EV charging stations in Pennsylvania, as of 2/21/2018 (Source: AFDC.gov)

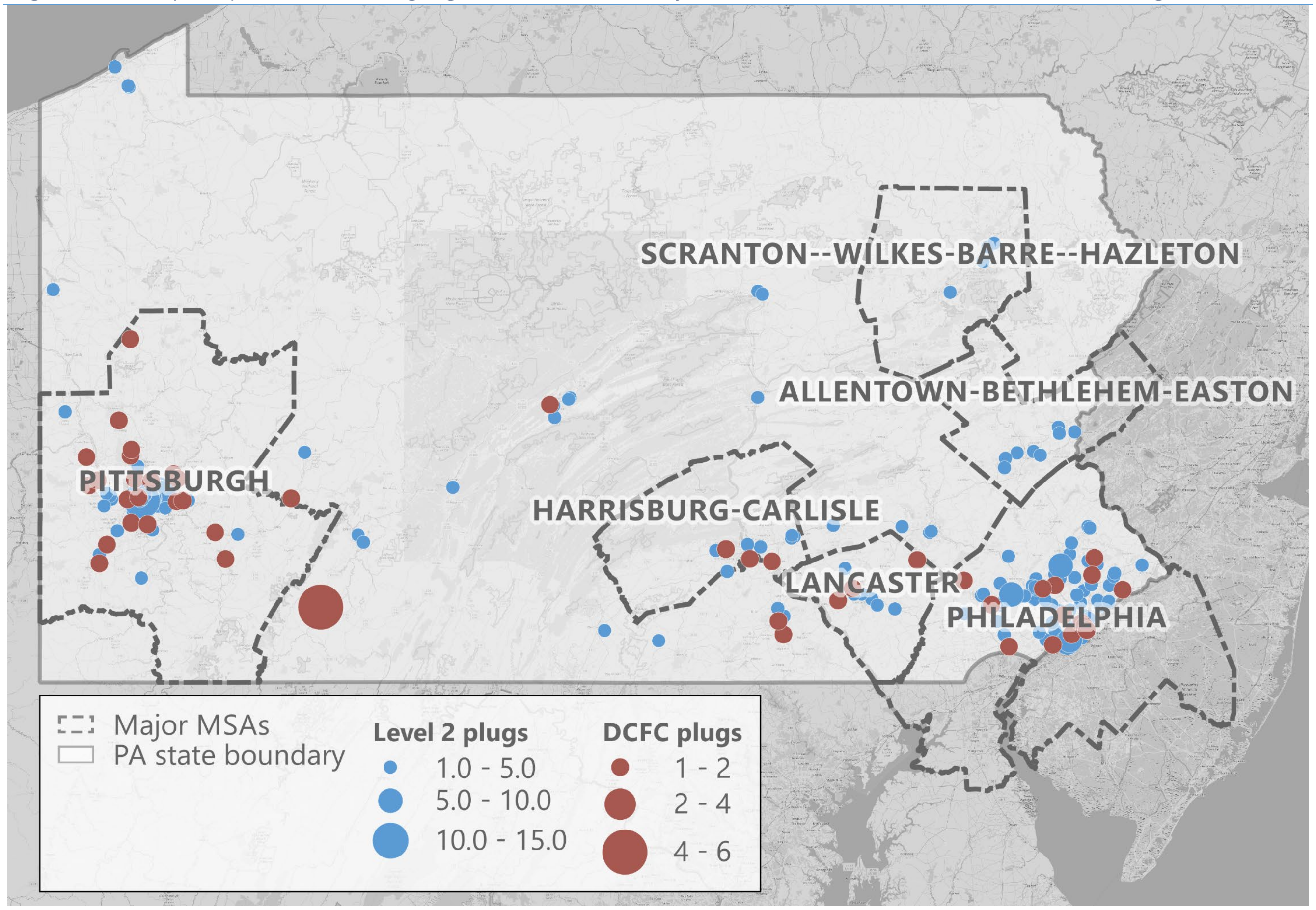
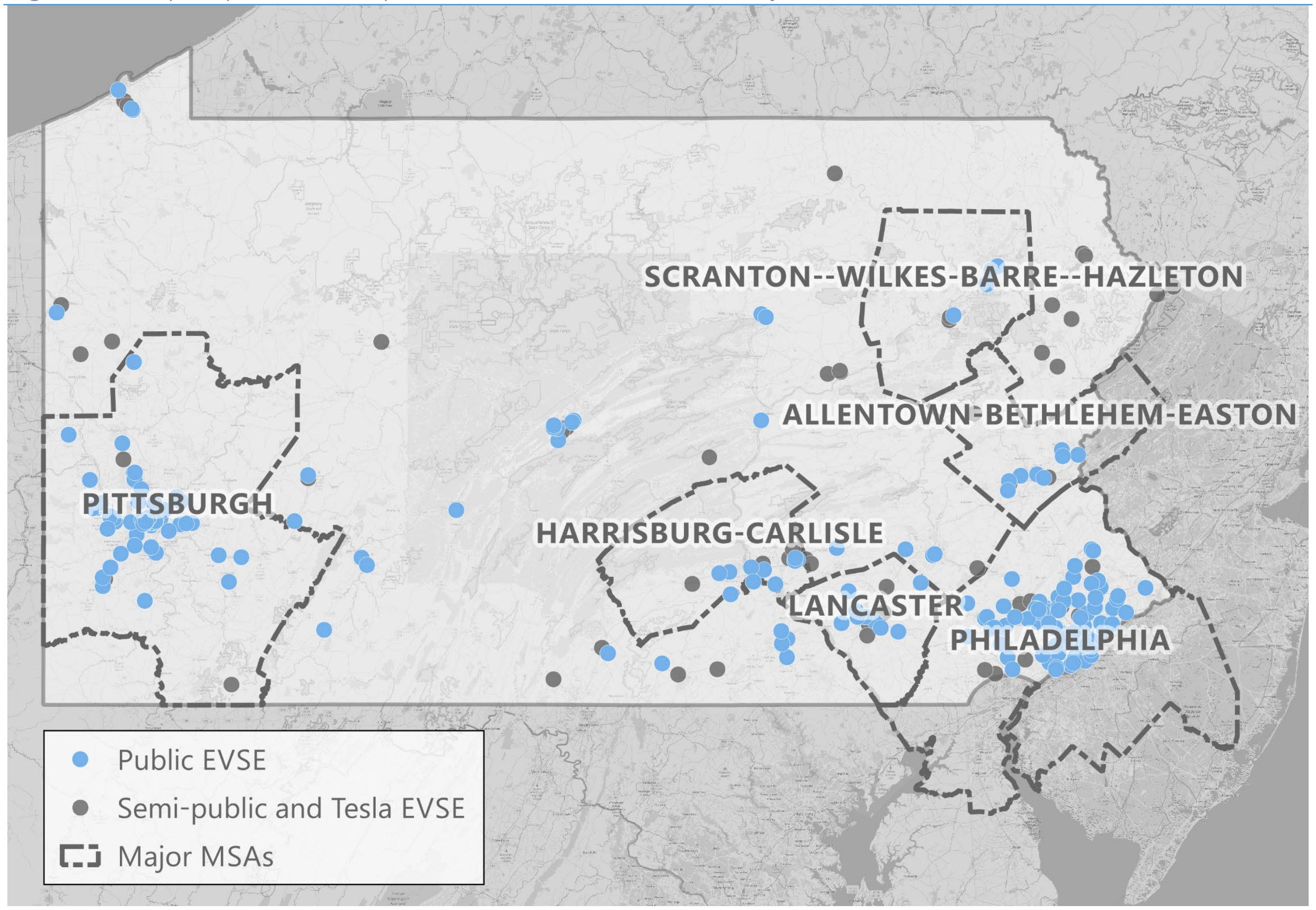


Figure 11: Map of public, semi-public, and Tesla EVSE in Pennsylvania, as of 2/21/2018



2.1.2.3 Benchmarking Public EVSE Availability in Pennsylvania

Multiple researchers have found the availability of EVSE in a market area has a strong relationship with EV adoption, suggesting that public EVSE plays a role in enabling EV market acceleration. While researchers estimate that 82-88 percent of EV charging will take place at home, the availability of chargers is important for increasing consumers' confidence in being able to recharge on-route when necessary.[35] A variety of studies have sought to estimate EVSE needs to support EV adoption, both by observing EVSE availability in high EV adoption markets, as well as forecasting EVSE needs through scenario analysis. While the ideal number of publicly available EVSE is uncertain given the limited deployment of EVs to date, by setting a benchmark, the commonwealth may track its progress in EVSE deployment, and assess its impact on EV adoption in future analyses. The following section highlights two approaches to benchmarking EVSE availability, including observations of per capita availability in leading EV markets, as well as forecasts of needed EVSE per EV as adoption rises.

[35] Wood, E., Rames, C., Muratori, M., Raghavan, S., Melaina, M. (2017, September). *National Plug-In Electric Vehicle Infrastructure Analysis*. Retrieved from https://www.nrel.gov/docs/fy17osti/69031.pdf

EVSE plugs per capita: A literature review by the International Council on Clean Transportation surveyed the ratio of public EVSE per capita for major EV markets around the world to indicate EVSE needs at higher levels of adoption.[36] The researchers found that among the 50 largest U.S. metro areas, *275 plugs per million residents* is a benchmark identifying leading U.S. EV markets. As of 2017, Pennsylvania's available EVSE plugs per capita is far below this benchmark across all regions at 43 public plugs per 1M residents overall, indicating a need for greater focus on EVSE deployment to help support EV market penetration. Table 8 highlights Pennsylvania's current EVSE availability per capita.

Table 8: Benchmarking EVSE per capita and per BEV (Sources: AFDC, PennDOT)

Metropolitan Statistical Area (MSA)[37]	Plugs per 1M residents
Allentown-Bethlehem-Easton, PA-NJ	22
Harrisburg-Carlisle, PA	33
Lancaster, PA	39
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	57
Pittsburgh, PA	87
Scranton-Wilkes-Barre, PA	9
Rest of state	11
TOTAL	43

EVSE per EV forecasted: Multiple government agencies and researchers have attempted to forecast the future requirements for EVSE needed to support increased EV adoption. In 2017, the National Renewable Energy Laboratory (NREL) published its National Plug-in Electric Vehicle Infrastructure Analysis, in which it explored the distribution of EVSE required to support a goal of reaching 20 percent EV market share by 2030, as well as a range of sensitivities. The study projected that Pennsylvania would need 13,600 Level 2 workplace chargers, 9,200 Level 2 public chargers, and 810 DCFC chargers by 2030 to support this level of adoption. As of 2018, Pennsylvania has installed about 6 percent of its estimated needed Level 2 public plugs (including semi-public plugs), and about 18 percent of its estimated needed DCFC plugs (including Tesla) to reach a 20% EV market share by 2020. The number of workplace plugs is not currently tracked by any government agency.

A recent report by the Edison Electric Institute summarized these projections by NREL, as well as projections by the Electric Power Research Institute (EPRI) about future EVSE needs for workplace and public charging (see Table 9), which are utilized later to estimate EVSE needs at different levels of EV adoption in the scenario modeling for this roadmap.[38]

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[36] Wood, E., Rames, C., Muratori, M., Raghavan, S., Melaina, M. (2017, September). *National Plug-In Electric Vehicle Infrastructure Analysis*. Retrieved from https://www.nrel.gov/docs/fy17osti/69031.pdf

[37] Analysis of MSAs that span multiple states only includes counties within Pennsylvania.

[38]Cooper, A., Schefter, K. (2017, June). *Plug-in Electric Vehicle Sales Forecast Through 2025 and the Charging Infrastructure Required.* Retrieved from http://www.edisonfoundation.net/iei/publications/Documents/IEI_EEI%20PEV%20Sales%20and%20Infrastructure%20thru%202025_FINAL%20(2).pdf

Table 9: Estimated charge plugs needed by vehicle type and location per 1,000 EVs

Charger location and type	**NREL** (Charge plugs per 1,000 PHEVs)	**NREL** (Charge plugs per 1,000 BEVs)	**EPRI** (Charge plugs per 1,000 EVs)
Workplace	**334**	**332**	**270**
Public	**3**	**11**	**72**
Level 1	*0.5*	*0.4*	-
Level 2	*2.4*	*10.1*	*67*
DCFC	*0*	*0.5*	*5*

2.2 BARRIERS TO EV DEPLOYMENT IN PENNSYLVANIA

This section describes barriers to widespread adoption of EVs across consumer types and market segments in Pennsylvania, drawing on the literature as well as the work of the Coalition subcommittees. Barriers to market penetration of a new technology are usually interrelated and typically fall into one of these six consumer issues: 1) awareness barriers, 2) decision-making barriers, 3) economic barriers, 4) policy and regulatory barriers, 5) technical barriers, and 6) supply chain barriers. The following section describes each type of barrier in greater detail.

- Awareness barriers are those that hinder the awareness of consumers, fleet owners, dealers, policymakers, and other key stakeholders regarding various aspects of EV technologies. Examples of barriers in this category include a lack of knowledge of the capabilities or costs of EV technology, the available incentives, or the environmental and other benefits of EV technology.
- Decision-making barriers are those that complicate or hinder the ability to choose to invest in EV or EVSE technology. Even if consumers or fleets are aware of EV technology, other barriers may affect their decision to invest in EVs, such as a lack of confidence in the technology's range or availability of charging stations, uncertainty about the consistent availability of incentives, or split incentives between landlords and tenants or fleet managers and owners.
- Economic barriers refer primarily to 1) high upfront costs for electric technologies, and 2) insufficient operating cost savings that together hinder cost-effectiveness of investing in EVs for consumers and fleet owners. Examples that impact capital costs include high EV and EVSE upfront costs, inadequate or unavailable financial incentives to help with the upfront cost, and lack of affordability for low-income populations. Barriers impacting the potential for operating cost savings include, for example, a lack of favorable EV electricity rate options; increasing efficiency of gasoline vehicles and low gas prices that diminish the cost advantage of EVs; and insufficient utilization (mileage) for fleet vehicles that hinders return on investment. Economic barriers are some of the most critical obstacles to enabling EV investment, and have thus been a key focus of policymakers' efforts.
- Policy and regulatory barriers can refer to the absence or limitations of overarching policies like targets, standards, or incentive programs that can drive investment in cleaner technologies. Examples include a lack of sufficient and sustainable funding for incentives or a lack of overarching mechanisms to drive investment in EVs, such as a sales target or pricing of externalities (i.e., air

pollution and greenhouse gases). These barriers can also take the form of regulations that complicate investment, installation, or other aspects of implementation. Examples of regulatory barriers include restrictions on public procurement methods that might hinder fleet EV investment or a lack of EV readiness codes for buildings and parking areas increasing installation costs of EVSE. While not an issue at low levels of EV deployment, there is a concern that increasing electrification will impact gas tax revenues that fund road and bridge maintenance. Some states have addressed this by levying a fee on EV drivers, but this could serve as an early disincentive and create an additional barrier. Transportation experts agree a new revenue solution for transportation infrastructure is needed, and as EV deployment increases, it will be important to determine revenue replacement options for gas taxes, and to determine how EVs contribute to that system.

- Technical and infrastructure barriers refer to limitations in EV technology or infrastructure needs that limit the ability for EVs to serve as a replacement for conventional technologies. Examples include range limitations, lack of available electric models for some vehicle classes, loss of range in cold weather due to heating loads, and the challenges of providing infrastructure for drivers without a garage or dedicated parking. Some of these barriers may diminish over time as EV technology continues to improve. For example, as range increases, EVs become a viable option for an increasing share of drivers and their daily travel patterns.
- Supply chain barriers refer to limitations in access to EV and infrastructure technologies for consumers and fleet owners. Examples include a lack of available EV models at dealerships and a lack of trained technicians for vehicle maintenance, EVSE maintenance, and EVSE installations. Some research has found EV model availability to be an important factor affecting EV adoption, and in states without a sales mandate like Pennsylvania, model availability tends to be limited.[39] Limited vehicle availability has led some states, like Connecticut, to experiment with dealer incentives for EV sales.

2.2.1 SUMMARY

The barrier categories and examples discussed in this section will be further discussed in SECTION 3 to inform the development of policy options that may spur EV deployment in Pennsylvania, and ensure key barriers are comprehensively addressed. Table 10 highlights these key barrier categories with examples of each, though it does not represent a comprehensive list.

[39] Lutsey, N., Searle, S., Chambliss, S., Bandivadekar, A. (2015, July). *Assessment of leading electric vehicle promotion activities in United States cities.* Retrieved from https://www.theicct.org/sites/default/files/publications/ICCT_EV-promotion-US-cities_20150729.pdf

Table 10: Summary of EV market barriers

	Barrier categories	Examples of specific barriers to EV deployment
Motivation Barriers	**Awareness barriers**	• Lack of awareness of EV technology availability, performance, and costs • Lack of awareness of co-benefits of EV technology • Lack of awareness of EV incentives and other supportive policies
	Decision-making barriers	• Lack of confidence in EV technology (e.g., range anxiety) • Lack of confidence in EVSE coverage • Lack of OEM and dealer EV market confidence • Competing financial priorities and capital constraints • Barriers and complications for installing EVSE on rented commercial or residential property or common-interest developments such as HOAs
Capability Barriers	**Economic barriers**	• High EV and EVSE upfront costs • Low-cost effectiveness of public EVSE investments at low EV adoption levels • Lack of affordability for low-income populations • Available electricity rates limit potentially greater fuel savings • Increasing efficiency of gasoline vehicles and/or low gas prices limit savings • Low utilization hinders savings/payback
	Policy/ Regulatory barriers	• Sufficient sustainable funding for EV/EVSE incentives • Lack of policy incentive to invest in clean vehicles • Public procurement methods inhibit EV investment • Lack of EV-friendly codes increase installation costs
Implementation/Results Barriers	**Technical/ Infrastructure barriers**	• Change in customer refueling experience • Range limitations • Lack of EVSE standardization • Insufficient EVSE coverage to enable certain trips • Insufficient electrical capacity for EVSE installation • Providing EVSE for drivers without dedicated parking (e.g., multifamily)
	Supply chain barriers	• Lack of available EV models and inventory • Lack of trained EV/EVSE maintenance, EVSE installation technicians • Inefficient supply chain compared to competitors

SECTION 3 NEXT GENERATION EV STRATEGIES

This section begins with an overview of Pennsylvania actions to advance EV adoption to date, and details strategies developed with the support of DEP and the Coalition to advance EV adoption in Pennsylvania in the coming years. The strategies identified are intended to address key indicators of leading EV markets, including increasing public EVSE access, EV model availability, access to financial incentives, and awareness across multiple key market segments. Together these strategies are intended to represent a feasible yet high impact pathway to overcome key barriers and accelerate EV market development in Pennsylvania.

3.1 EV DEPLOYMENT STRATEGY CATEGORIES

This section introduces the various categories of policies, programs, or other market interventions that stakeholders may pursue to accelerate EV adoption, with a description of Pennsylvania's actions to date related to that category. National examples of each strategy category can be found in Appendix B.

3.1.1 GOALS AND TARGETS

Goals and targets refer to aspirational goals or binding targets to achieve certain levels of EV deployment, performance, or emissions reductions by certain dates. These types of interventions help demonstrate commitment to EV market development and provide a stable policy environment, sending a clear message that can overcome market awareness and confidence barriers to enable vehicle manufacturers, car dealerships, utilities, and other market stakeholders to invest in EVs. Examples include the Zero Emission Vehicle (ZEV) mandate in California, other state, public or private fleet electrification goals or targets, and legislative directives for investor-owned utilities to invest in transportation electrification.

In Pennsylvania: Governor Wolf's recent Executive Order 2019-01 requires the state government to replace 25% of the state passenger car fleet with battery electric and plug-in electric hybrid cars by 2025. Pennsylvania is not part of the ZEV market program, but has opted into California's car standards, which are slated to increase fuel efficiency substantially over the next several years, though are not likely to be sufficient to drive EV purchases alone since conventional vehicles can meet those standards. At the local level, the City of Pittsburgh also has a voluntary target to achieve a 100 percent fossil fuel free city fleet by 2030.

3.1.2 PRICING-BASED POLICIES

Pricing-based policies refer to strategies that seek to overcome economic barriers by improving the cost-effectiveness of EVs, such as incentives, new electricity rate structures, and pricing of driving externalities. Examples include EV-specific electricity rate designs, EV rebate programs, EVSE installation incentives, as well as non-monetary incentives that otherwise increase the value of EVs to consumers like access to HOV lanes or to priority parking spaces.

In Pennsylvania: Pennsylvania offers a variety of programs designed to support Alternative fuel vehicle deployment, including:

- Alternative Fuels Incentive Grant: This grant program awards approximately $5M in grants for public, non-profit, or business entities to cover the incremental cost of retrofitting or purchasing new alternative fuel vehicles for fleets, installing fueling infrastructure, or to fund research, development, and demonstration of new alternative fuel vehicle technologies.
- Pennsylvania FAST Act Corridor Infrastructure Grant: This grant program made $1 million available to local governments, non-profits, and corporate entities to install public alternative fuel vehicle fueling stations along Pennsylvania highways, and requires a 50 percent match on grant funds.
- Alternative Fuel Vehicle Rebates: This grant program provides eligible residents rebates of $750-$1750 per plug-in vehicle depending on battery size. The program has been growing over time; between 2016 to 2017, 792 vehicles received rebates totaling $1.3 million, up from 434 vehicles between 2014 and 2015, and 616 vehicles between 2015 and 2016.

Table 11: AFIG rebates July 1, 2016-June 30, 2017[40]

Vehicle type	Number of rebates	Total Grant Funding
Electric motorcycles	6	$3,000
BEVs	499	$964,000
PEVs	287	$387,000
Total	792	$1,354,000

In addition to the above programs from the state, PECO currently offers EV drivers $50 per vehicle for alerting the utility when they have purchased an EV and installed a charger at their home. Pricing-based policies can also include other forms of incentives that reduce costs for drivers or increase their convenience, such as discounted tolls or parking. Pennsylvania so far has few examples of EV driver incentives, though Philadelphia did have a program that allowed EV drivers to apply for a permit for a dedicated parking space and charger on their street, called the Electric Vehicle Parking Space Program. Though the program was designed to help EV drivers without a garage or other dedicated parking where they could charge a vehicle, it was nevertheless controversial, highlighting the inherent challenges in finding solutions for more urban areas where drivers are less likely to have their own parking space.

3.1.3 ENABLING REGULATIONS

Enabling regulations refer to strategies that are designed to overcome regulatory barriers and ease deployment of and access to EVs and EVSE. By easing investment and deployment, these strategies can also help lower the cost of EV investment for consumers and fleets. Examples include the adoption of EV-

[40] Pennsylvania Department of Environmental Protection. (2018, February). 2016-2017 Annual Report to the Pennsylvania Legislature. *Alternative Fuels Incentive Act Fund.* Retrieved from http://www.depgreenport.state.pa.us/elibrary/GetDocument?docId=4928&DocName=2016-2017%20ALTERNATIVE%20FUELS%20INCENTIVE%20ACT%20FUND%20ANNUAL%20REPORT.PDF%20

readiness building codes, ordinances, zoning requirements, or expedited permitting processes to facilitate the deployment of EVSE. Additionally, this strategy can include initiatives that ensure open access to public EVSE for all consumers, and regulations that anticipate barriers to EVSE installation in multi-family or cooperative ownership dwellings by ensuring that Home Owners' Associations (HOAs) or other entities cannot block EVSE installation by a resident.

In Pennsylvania: A barrier to enabling third-party charging provider business models has been the inability to re-sell electricity in most states, as that ability tends to be restricted to utilities only. In November 2018, the Pennsylvania Public Utility Commission unanimously approved a policy statement aimed to ensure a more uniform ability for third-party charging providers to re-sell electricity across utility service areas throughout the commonwealth, a step that will help remove barriers for emerging EVSE business models.

3.1.4 FINANCING AND BUSINESS MODELS

Financing and business model strategies refer to initiatives that facilitate development of new business models that increase access to EVs or strategies to enable access to financing for EVs or EVSE. Examples may include support for accessible financing for EVs or EVSE, supporting market development for public EVSE business models, or partnerships with shared use mobility companies to expand electric mobility options.

In Pennsylvania: With grant funding limited and sometimes uncertain from year to year, many jurisdictions have turned to affordable financing options to create a more durable approach to funding clean energy and vehicle investments. The Alternative and Clean Energy Program is an example of a financing program in Pennsylvania that can be used for alternative fuel vehicles, infrastructure, or manufacturers. The program provides loans and loan guarantees for clean energy projects and AFV fueling stations; however, public EVSE is not currently eligible. Pennsylvania has taken an innovative step in applying an energy efficiency financing mechanism—Energy Service Performance Contracting (ESPC)—to transportation projects, which enables investment in cleaner fleets. The Delaware Valley Regional Planning Commission (DVRPC) worked with the Rose Tree Media School District and an energy services company (ESCO) to invest in energy efficiency upgrades for its buildings, combined with converting a portion of its school bus fleet to natural gas.

3.1.5 PUBLIC PLANNING AND INVESTMENT

Public planning and investment strategies refer to local, state, or utility-led efforts to plan for and invest in EV infrastructure and technology. Examples include providing technical assistance to fleets or other entities to support deployment, or directly investing in government-owned EVs or utility-owned EVSE.

In Pennsylvania: There are several examples of public planning and investment in EV and EVSE deployment at the state, regional, and local levels in Pennsylvania. Another part of the AFIG program, the Alternative Fuels Technical Assistance Program, provides technical assistance through DEP to eligible organizations to support deployment strategies for alternative fuel vehicles. Additionally, some jurisdictions have done extensive planning work to support EV deployment. The DVRPC created its own "Ready to Roll" regional EVSE action plan using U.S. DOE funding to compile regional demographic data for assessing future EV market penetration and EVSE needs. Additionally, Philadelphia's Electric Vehicle Policy Taskforce released a draft set of policy recommendations to increase EV deployment in the city, which relate to increasing public EVSE, expanding electric bus deployment, increasing education and awareness, and expanding access to electric shared mobility like e-bikes.

Pennsylvania has been allocated $119 million from the Volkswagen (VW) Settlement Funds to create the Driving PA Forward program, through which up to 15 percent of which can go to light duty EVSE, while the rest must support NOx reducing technologies (see box).

Driving PA Forward

In January 2016, Volkswagen and several of its subsidiaries (VW) were sued for violating federal and California laws by installing defeat devices on diesel passenger vehicles sold in the U.S., which resulted in vehicles emitting 9 to 40 times the allowable amount of oxides of nitrogen (NOx) during on-road operation. The settlement of this lawsuit established $2.925 billion in environmental mitigation trust funds to be divided among the participating States and Indian Tribes to mitigate offending vehicle emissions. Pennsylvania could leverage its allocated $118.5 million in State Mitigation Trust funds to support its EV adoption goals, which it must expend within 10 years. Through Driving PA Forward, Pennsylvania plans to spend the maximum allowed 15 percent ($17.7 million) of these funds on light duty vehicle EVSE, with the remainder pledged to fund cleaner on-road and non-road heavy duty vehicles. DEP estimates that its plans for these funds could reduce lifetime NOx emissions by 27,700 tons.

Additionally, Electrify America, which is also deploying a separate $2 billion in zero emission vehicle charging infrastructure nationwide as part of the VW Settlement, selected Philadelphia as one of 17 cities where Electrify America will invest in charging infrastructure networks in communities and along highways as part of its Cycle 1 funding commitment.

Pennsylvania is also participating in a regional effort called the Transportation Climate Initiative (TCI). TCI is a regional collaboration of 12 Northeast and Mid-Atlantic states and the District of Columbia that seeks to improve transportation, develop the clean energy economy and reduce carbon emissions from the transportation sector.

3.1.6 MARKETING, OUTREACH, AND EDUCATION

Marketing, outreach, and education strategies include initiatives designed to overcome social and institutional barriers by improving EV awareness, confidence, and commitment from consumers and fleet operators. Examples include advertising campaigns, educational initiatives, web site and social media resources, collateral materials development, ride-and-drive events, and other outreach initiatives such as cooperative purchase programs that combine education with achieving price reductions for consumers.

In Pennsylvania: The Eastern PA Alliance for Clean Transportation and the Pittsburgh Region Clean Cities Coalition have hosted several EV/EVSE demonstration and education events around the state, often in conjunction with other alternative fuel vehicle-oriented outreach. Additionally, I-95, I-80, I-376, I-90, I-79, and I-76 have been designated as Electric Vehicle Charging Corridors through the Federal Highway Administration, and will have signage helping EV drivers locate charging stations and to build awareness for non-EV drivers. The Education and Outreach subcommittee of the Coalition is in the process of developing plans to increase EV marketing, outreach, and education work statewide, starting with a centralized website and set of materials where drivers and key stakeholders can come for important information about EVs.

3.1.7 SUMMARY

Thus far, Pennsylvania has implemented several local, regional, and state initiatives designed to support AFV and EV deployment, which the commonwealth can build on to jumpstart EV adoption levels. Table 12 summarizes state and local examples of each strategy category in Pennsylvania.

Table 12: Summary of Pennsylvania initiatives to support EVs to date

CATEGORY	STATE AND LOCAL PENNSYLVANIA INITIATIVES
Goals and targets	⦿ Must replace 25% of state vehicles with BEVs or electric plug-in hybrids by 2025. ⦿ California car standards (Section 177 state) (PA DEP) ⦿ Local voluntary target for Pittsburgh fleet (City of Pittsburgh)
Pricing-based policies	⦿ AFIG AFV rebate program (PA DEP) ⦿ Philadelphia Electric Vehicle Parking Space Program *(likely to be discontinued)* (City of Philadelphia)
Enabling regulations	⦿ PUC enabled third party re-sale of electricity (PA PUC)
Financing and business models	⦿ Transportation performance contract for school buses (DVRPC)
Public planning and investment	⦿ AFIG technical assistance funds and EVSE grants (PA DEP) ⦿ DVRPC "Ready to Roll" plan (DVRPC) ⦿ Philadelphia Electric Vehicle Policy Taskforce plan (City of Philadelphia) ⦿ Transportation Climate Initiative
Marketing, outreach, and education	⦿ EV/EVSE demonstration events (Clean Cities Coalitions) ⦿ Interstate EV Charging Corridor designations (PA DEP, PennDOT) ⦿ Centralized website and materials *(in development)* (The Coalition)

The following sections describe proposed strategies identified by the Coalition that can be deployed in the coming years to accelerate EV adoption in Pennsylvania. For each strategy, the Coalition has described 1) key market barriers addressed by the strategy, 2) objectives and high-level description of the strategy, 3) best practices (or lessons learned) from other jurisdictions, 4) pathway to implementation in Pennsylvania, and 5) key collaborators who may work together to implement the strategy. Coalition members also organized strategies into near-term, medium-term, and long-term categories for deployment.

3.2 NEAR-TERM STRATEGIES FOR EV DEPLOYMENT IN PENNSYLVANIA (0-2 YRS)

3.2.1 STRATEGY – STATEWIDE EV SALES GOALS

Category: Goals and targets

Barriers addressed: Lack of available EV models and inventory; lack of consumer awareness of EV technology; lack of market confidence from original equipment manufacturers (OEMs), dealers, and suppliers

Objectives: Increase market confidence by signaling a clear direction towards investment in EVs in the state, increase awareness by increasing EV model availability and marketing activity by dealers and other actors, and set a benchmark by which to measure progress.

Description: This strategy involves setting statewide EV sales or deployment goals by a certain date. Primarily, this strategy could focus on private light duty vehicles, though other sales goals could be set for state, municipal, and commercial fleets. In the future, Pennsylvania could consider adopting or joining a binding target like the ZEV mandate program that requires automakers to sell a certain share of ZEVs per year in states that have joined the program.

Best practices: Experts interviewed for this roadmap stressed that setting an aspirational target is essential, as a too-low target could stymie adoption levels. Examples of EV deployment targets in other states that are not part of the ZEV mandate include:

- Colorado's Electric Vehicle Action Plan sets a goal to increase light duty EV adoption to reach 940,000 EVs deployed by 2030, a figure in line with the states' earlier planning efforts' high EV growth scenarios.[41]

[41] State of Colorado. (2018, January). *Colorado Electric Vehicle Plan*. Retrieved from https://www.colorado.gov/governor/sites/default/files/colorado_electric_vehicle_plan_-_january_2018.pdf

- Washington State's 2015 Electric Vehicle Action Plan adopted a goal of increasing the number of EVs on the state's roads from 10,000 in 2014 to 50,000 by 2020. Progress towards the goal is tracked through the Results Washington dashboard.[42]

Pathway to implementation: This strategy could be implemented via administrative or legislative action that sets EV deployment goals for certain horizon years for different fleets, including private vehicles, the state fleet, municipal and other public fleets, and commercial fleets. The Pennsylvania legislature or an administrative agency may establish realistic but accelerated adoption targets relative to the baseline scenario modeled in this roadmap (SECTION 4), and consider ways to incentivize stakeholders to reach those targets, such as providing incentives to dealers, fleet owners, and other key stakeholders who reach certain sales metrics. Furthermore, the commonwealth may consider a replacement to the gas tax for EVs, once EV deployment has reached the selected sales target, or another market penetration goal.

Key collaborators and stakeholders: DEP, Drive Electric Pennsylvania Coalition members, PA Governor's office, dealers, fleets, and municipalities.

3.2.2 STRATEGY – UTILITY TRANSPORTATION ELECTRIFICATION DIRECTIVE

Category: Goals and targets; Public planning and investment

Barriers addressed: Lack of sufficient, sustainable funding for EV/EVSE incentives; Low-cost effectiveness of public EVSE investments at low EV adoption levels, lack of available electricity rate options designed for EV charging

Objective: Enable and encourage utilities to leverage their expertise and relationship to customers to jumpstart the EV market in a way that maximizes benefits to ratepayers and society.

Description: This strategy could enable and encourage utilities to invest in transportation electrification. This strategy is designed as a precursor to several of the following strategies (e.g. EVSE investment, EV rates, and marketing and outreach), serving as a foundation to encourage utility participation in advancing the EV market in a manner that complements and supports the competitive EV charging market. As an example, the legislature could direct the Pennsylvania Public Utility Commission (PUC) to open a proceeding asking utilities to submit proposals to increase adoption of EVs in their service area.

Best practices: Nearly all EV experts interviewed for this roadmap expressed that it is essential to grant utilities latitude to invest in transportation electrification to help jumpstart the EV market. Interviewees provided multiple reasons for giving utilities a strong role in transportation electrification, including: their existing role in serving public interests; knowledge of installing and maintaining electricity infrastructure; stable business structure that continues to be involved in electric distribution for the long-term; and cost recovery mechanisms that allow for the installation of chargers where there is the greatest demand rather

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[42] Buell, T. (2015, February). *Washington State Electric Vehicle Action Plan 2015-2010*. Retrieved from http://www.wsdot.wa.gov/NR/rdonlyres/28559EF4-CD9D-4CFA-9886-105A30FD58C4/0/WAEVActionPlanFebruary2015Print.pdf, Results Washington. *Electric Vehicles.* Retrieved from https://data.results.wa.gov/reports/Copy-of-G3-1-1-c-Electric-Vehicles--1

than where there is greatest profit. Interviewees also noted utilities' unique ability to reach customers for marketing and awareness. Examples of other states that have directed or provided the option for utilities to invest in transportation electrification include:

- Maryland: The Public Service Commission (PSC) has required investor-owned utilities to participate in grid modernization proceedings and provided the option to file an EV-specific proposal through a formal PSC hearing process. The PSC has been conducting a stakeholder process to inform utilities' filings, through which it has engaged ratepayer advocates, environmental advocates, charging providers, retail electricity providers, and the Department of Transportation, among others.
- Washington State: ESHB 1353 authorized the state Public Utilities Commission to enable utilities to invest in EVSE and receive a rate of return. The PUC first gathered stakeholder feedback to develop a policy statement that is intended to guide utility proposals.
- California: SB350 in California declares transportation electrification to be in the public interest, directing investor-owned utilities to develop plans for investing ratepayer funds to advance transportation electrification. All plans are then reviewed and approved by the PUC. The proposals from the three largest utilities in California total investments worth $1 billion through a variety of projects designed to accelerate EV deployment for a variety of vehicle classes. The proceedings have started with a set of smaller pilot priority review projects, and will be followed by larger standard review projects.
- Oregon: In 2016, the Oregon legislature passed a bill requiring their PUC to direct electric utilities to file applications for transportation electrification programs.

Pathway to implementation: This strategy could be implemented through the passage of legislation (such as HB1446; see side box for more information), or through a PUC directive like in Maryland that makes EV proposals optional or begins with pilot projects.

> **About HB1446**
>
> *HB1446, the Pennsylvania Clean Transportation Infrastructure Act, was proposed before the Pennsylvania legislature in 2017. If enacted, the bill would have established a goal to increase transportation electrification, i.e., electricity use to power cars and other vehicles, by at least 50 percent by 2030 above market forecasts, and would charge electric utilities and EVSE providers with developing and implementing plans, which would be approved and overseen by the PUC, to invest in EVSE in their service territories.*

Key collaborators/stakeholders: Legislature, PUC, utilities, third party charging providers, Drive Electric Pennsylvania Coalition.

3.2.3 STRATEGY – EXPANDED AND IMPROVED AFIG REBATE PROGRAM

Category: Pricing-based policies

Barriers addressed: Competing financial priorities and capital constraints; high EV and EVSE upfront costs; lack of OEM/dealer EV market confidence

Objective: Support higher levels of EV market share by helping consumers afford the incremental cost of EVs.

Description: This strategy could seek to expand and improve the AFIG rebate program by increasing the total program budget, thereby allowing for a larger number of rebates than in past years, and improving the program in several ways. Currently, approximately 25 percent of EVs sold in the state per year receive rebates, while leading ZEV states provide rebates to about 50 percent of EVs sold. The current rebate level of $1,750 per year could be held constant. Improvements to the existing program could include 1) altering PA's program to be like Connecticut's "dealer assignment" where the rebate is directly applied at point of sale and reimbursed to the dealer and 2) providing a share of the rebate to dealers. Ensuring durability of the incentives should be considered, including consideration of utility involvement through the transportation electrification proceedings. While the program could primarily be for light duty vehicles, as the EV market matures, it could be evaluated by DEP to update the targeting of the rebates to different market and vehicle segments. The strategy could prioritize applications where EV technology is commercially available but needs support to increase deployment, and where EV adoption can expose consumers to EV technology such as car rental and shared mobility fleets.

Best practices: Rebates and other direct financial incentives for consumers (like tax credits) have had measurable impacts on EV adoption. Researchers at NREL found that a $1,000 increase in tax credit value for EVs resulted in a 7 percent increase in per capita EV registrations.[43] In the most recent survey of Pennsylvania AFIG rebate recipients, 32 percent of respondents said they would not have purchased an EV without the rebate.

Pathway to implementation: The commonwealth, via DEP or the Coalition, could continually evaluate and review the targeting and funding of the AFIG program, and make recommendations for future targeting and funding sources to enable the program to grow over time. This may involve legislative action to increase the size of the program. The strategy could be continually revised, targeting vehicle types that are most poised for growth. For example, once a vehicle class reaches cost parity in the market, rebates could shift to other vehicle classes that are becoming more commercially ready but need assistance. The rebate program should be developed with strong ties to education and outreach efforts to consumers and dealers.

Key collaborators and stakeholders: DEP, Drive Electric Pennsylvania Coalition, dealers.

3.2.4 STRATEGY – CONSUMER MARKETING AND EDUCATION CAMPAIGN

Category: Marketing, education, and outreach

Barriers addressed: Lack of awareness of technology availability, performance, and costs; lack of awareness of incentives and other supportive policies

[43] Clinton, B., Brown, A., Davidson, C., Steinberg, D. (2015, February). *Impact of Direct Financial Incentives in the Emerging Battery Electric Vehicle Market: A Preliminary Analysis*. Retrieved from https://www.nrel.gov/docs/fy15osti/63263.pdf

Objective: Increase consumer awareness of EV technology, costs, performance, and available incentives.

Description: This strategy could include the consumer-oriented educational programs identified by the Coalition. Principally this strategy could include 1) creating and maintaining a Drive Electric Pennsylvania Coalition centralized website, branded materials, social media presence, and potential media campaign informed by consumer survey research, and 2) supporting Ride and Drives and other events designed to increase exposure to EVs.

Best practices: Numerous studies have found low awareness of EVs, incentives, or experience driving EVs among consumers, suggesting the importance of awareness-raising programs. Recent research has found that most potential EV buyers can't name a single EV model, haven't driven one, aren't aware of incentives, and don't know how or where they would charge an EV.[44] Among educational and awareness-raising efforts, ride and drive events are found to be particularly effective and affordable to implement. In three separate years, EV sales went up 13 percent, 21 percent, and 24 percent the month after National Drive Electric Week when ride and drive events are held across the country, and numerous surveys have measured significant increases in EV purchase interest after consumers participated in ride and drive events.[45] Massachusetts' Drive Clean Mass program is a state-run ride and drive program that has seen positive results from surveying participants, and is able to integrate this educational outreach with their state-run rebate program. A recent program evaluation found that 12.5 percent of follow-up survey respondents had leased or purchased an EV within six months of their test drive, 74 percent said they would probably make an EV their next purchase, and 82 percent had spoken with others about their experience.[46] In 2015, the Mass Drive Clean program recommended a goal for 3,000 test drives and 8,000 vehicle exposures to help the state reach their 300,000 EV deployment goal by 2025.[47]

Pathway to implementation: DEP and the Coalition could oversee the implementation and maintenance of a central website, branded materials, and social media presence, and could identify key partners to host Ride and Drives and other outreach events. A target for participation in outreach events could be developed by DEP and the Coalition based on the EV sales goal set. The Coalition could continue to meet to identify other key educational programs to increase consumer awareness and confidence in EVs. The Coalition could also identify whether the ongoing programs and efforts can be accomplished through partnerships and in-kind contributions from Coalition members, or whether additional funding will be needed.

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[44] Singer, M. (2016, January). *Consumer Views on Plug-In Electric Vehicles – National Benchmark Report*. Retrieved from http://www.afdc.energy.gov/uploads/publication/consumer_views_pev_benchmark.pdf

[45] Plug In America. (2016, October). *Evaluating Methods to Encourage Plug-in Electric Vehicle Adoption.* Retrieved from https://pluginamerica.org/wp-content/uploads/2016/11/PEV-Incentive-Review-October-2016.pdf

[46] Plug In America, Reach Strategies. (2016). Mass Drive Clean: on the road to clean air. *2016 Final Report.* Retrieved from https://www.mass.gov/files/mdc-2016-final-report-final_1.pdf

[47] Plug In America, Reach Strategies. (2015). Mass Drive Clean: on the road to clean air. *2015 Campaign Results: Mobilizing Massachusetts ZEV Adoption & Fostering a Sustainable Market.* Retrieved from https://www.mass.gov/files/documents/2016/08/xn/mass-driveclean-final-report-2015.pdf

Key collaborators and stakeholders: DEP, Drive Electric Pennsylvania Coalition, Clean Cities Coalitions, utilities, dealers.

3.2.5 STRATEGY – DEALER OUTREACH AND SUPPORT PROGRAM

Category: Marketing, education, and outreach

Barriers addressed: Lack of OEM/dealer EV market confidence; lack of available EV models and inventory

Objective: Engage, educate, and encourage car dealers to raise consumer awareness and EV sales

Description: This strategy could involve creating a statewide dealer outreach, education, and support program to provide tools and resources needed for dealers to sell more EVs, with an initial goal to recruit at least 10 dealerships across several key participating regions of Pennsylvania, both in urban and rural areas. This program could be closely integrated with the EV Sales Goals (3.2.1) and AFIG Rebate strategies (3.2.3), by providing incentives to dealers who reach certain sales percentages or goals. The program could also provide technical assistance by developing a specialized sales tool kit for dealers.

Best practices: Connecticut has one of the most highly integrated EV deployment policy with dealerships, in which EV rebates are processed by dealers, who receive a share of the EV rebates. A recent program evaluation found that perceptions of the program among participating dealership employees to be very positive: 74 percent reported that the dealer incentive has made them more open to EVs as a real alternative to conventional vehicles, and 63 percent reported believing that just a few or none of their customers would have purchased an EV without the rebate program.[48] Overall, employees reported feeling much more motivated to spend time educating consumers about EV technology and its benefits. The program was designed and is being implemented in partnership with the Connecticut Automotive Retailers Association, which has helped to encourage dealer participation in the program. During its launch, the program included substantial dealer outreach and training. As the program continues, outreach, webinars, and other assistance is provided to dealers on an ongoing basis.

Pathway to implementation: The commonwealth could work with interested dealers, associations of dealers, and other key stakeholders to design a program to support and incentivize dealers to increase EV sales and participate in the AFIG rebate program. The state could partner with Plug In America's PlugStar program to help connect potential customers to designated EV dealerships.

Key collaborators and stakeholders: DEP, Drive Electric Pennsylvania Coalition, Department of General Services (DGS), auto dealers, automakers.

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[48] Johnson, C., Williams, B., Anderson, J., Appenzeller, N. (2017). *Evaluating the Connecticut Dealer Incentive for Electric Vehicle Sales*. Center for Sustainable Energy. Retrieved from https://energycenter.org/sites/default/files/docs/nav/research/CT-Dealer-IncentiveEvaluation-CSE-2017.pdf

3.2.6 STRATEGY – FLEET EDUCATION, COOPERATIVE PURCHASE, AND TECHNICAL ASSISTANCE PROGRAM

Categories: Marketing, education, and outreach; Public planning and investment

Barriers addressed: Lack of awareness of technology availability, performance, and costs; lack of confidence in EV technology performance; lack of available EV models and inventory

Objective: Increase fleet EV adoption levels to increase environmental benefits from vehicles with high vehicle miles traveled (VMT) rates; increase consumer awareness by electrifying fleets that are consumer-facing such as carshare, car rental, or shared mobility company fleets.

Description: A fleet education, cooperative purchase, and technical assistance program could include a variety of programs to support public and private fleet investment in EVs and infrastructure, including:

- Outreach to fleet managers, including Ride and Drive events for fleet operators
- Development of specialized tools, procurement guides, procurement templates, sample RFP language, and other materials to support fleet EV and EVSE procurement
- Engagement with DGS
- Increased EV options to COSTARS members by promoting COSTARS participation by contracted EV vendors, as well as connecting municipalities with other EV/EVSE procurement options such as the National Joint Powers Alliance (NJPA) Purchasing Cooperative.

Best practices: Multiple existing efforts to support AFV fleet procurement, such as Clean Cities efforts in PA, as well as national AFV joint procurement efforts like Fleets for the Future can be built upon to identify the best strategies for PA.

Pathway to implementation: The commonwealth may design a program to provide technical support to a variety of Pennsylvania fleets, and may identify whether the ongoing programs and efforts can be accomplished through partnerships, or whether additional funding will be needed. The existing Alternative Fuels Technical Assistance Program, in which DEP grants consulting services to applicants to support alternative fuel vehicle strategies, could be adapted or expanded to implement this strategy. Over time, this strategy should be updated to refine the types of vehicles and EVSE offered through COSTARS.

Key collaborators and stakeholders: DEP, Drive Electric Pennsylvania Coalition, Clean Cities Coalitions, DGS, DVRPC and other MPOs, federal cooperative purchasing programs, public and private fleets, dealers, OEMs.

3.2.7 STRATEGY – STATEWIDE EVSE NETWORK PLANNING, INVESTMENT, AND COMMUNICATIONS PROGRAM

Category: Public planning and investment

Barriers addressed: Insufficient EVSE coverage to enable certain trips; lack of confidence in EVSE coverage

Objective: Ensure adequate EVSE coverage for critical corridors and destinations, particularly those that may not be covered by other EVSE deployment strategies, and increase consumer awareness and confidence in EVSE availability.

Description: Through this strategy, the state could lead planning efforts to ensure an adequate statewide public EVSE network to enable long distance travel on major corridors and to key destinations and tourist attractions such as state parks throughout the state. The state transportation agency could create a statewide public EVSE network plan that fills any gaps left by local and regional EVSE investment and develop an investment plan leveraging VW settlement or other available funds to fill those gaps. The agency could also establish a uniform signage and state EVSE route designation program to advertise and communicate public EVSE availability to drivers and complement federal Interstate highway designations.

Best practices: The other strategies in this roadmap for investing in EVSE infrastructure may leave gaps in long distance travel or other key destinations. It will be important for a state planning and investment effort to fill those gaps to help build consumer confidence in the ability to reach all parts of the state with an EV. Other states have adopted uniform signage standards for EVSE to help build awareness and provide confidence to EV owners about the distribution of charging infrastructure. While there is a federal route designation program, there is no current program for state routes.

Pathway to implementation: This strategy could be implemented by expanding the AFIG FAST Act Corridor Infrastructure Grant program to include a state route EVSE designation program, and developing a network plan and investment strategy. VW settlement funds may also be able to be leveraged for this strategy, through commitment of the Mitigation Trust Fund (total of $17.7M), designed to fund DCFC and Level 2 chargers.

Key collaborators and stakeholders: DEP, Drive Electric Pennsylvania Coalition, PennDOT, utilities, third party charging providers, DVRPC, and other MPOs.

About the FAST Act

The FAST Act is a funding and authorization bill for federal surface transportation spending that was passed in 2015. One element of the bill created a program to designate alternative fuel corridors as "sign-ready", which means routes where drivers currently have access to alternative fuel stations (including EVSE) are made eligible for signs alerting alternative fuel drivers where they can find fueling stations, like currently exist for gas stations on federal highways. Part of Pennsylvania's AFIG grant program has focused on providing a 50 percent reimbursement for public EVSE on the state's designated corridors: I-76, I-276, I-476, I-95, and I-80.

3.3 MEDIUM-TERM STRATEGIES FOR EV DEPLOYMENT IN PENNSYLVANIA (2-5 YRS)

3.3.1 STRATEGY – RESIDENTIAL AND COMMERCIAL EV RATE DESIGNS

Category: Pricing-based policies

Barriers addressed: Some current electricity rates inhibit fuel savings; lack of awareness of co-benefits

Objectives: Maximize grid benefits, reduce costs for ratepayers, reduce charging costs for EV owners that charge during off-peak times, and remove barriers to DCFC deployment

Description: This strategy encourages the development of specialized EV rates across Pennsylvania utilities and electricity suppliers, with special attention given to tailoring rates separately for residential applications and commercial applications. This strategy could also encourage the deployment of advanced meters and other hardware and software technologies that may be needed to enable lower rates for off-peak charging. Some utilities are beginning to offer specialized EV rates, such as:

- Time-of-use rates (TOU) to encourage residential charging overnight
- Rates tailored to public EVSE, which tends to be utilized during the day
- Rates and demand charges tailored for DCFC, which draw electricity from the grid at a higher capacity.

TOU rates for residential charging encourage EV owners to charge during off-peak times, drive down operating costs for EV owners via lower rates, and can enable reduced costs for all ratepayers. DCFCs often incur high demand charges, hurting the business model for charging infrastructure providers or the cost effectiveness for EV drivers. This strategy could involve pursuing solutions to mitigate high demand charges, such as pairing stationary storage with DCFC or introducing new rate designs.

Best practices: In places where utilities have offered residential TOU rates, customers have demonstrated a willingness to shift charging times to off-peak periods. In a pilot project in San Diego, 78 to 85 percent of EV owners on a TOU rate plan programmed their charging for super-off-peak hours. Additionally, survey responses indicated that 59 percent of EV drivers nationally would participate in a demand-response program from their utility for their EV charging.[49] There are still relatively few examples of rates and strategies for public DCFC, though strategies thus far include minimizing demand charges and pairing energy storage with EVSE. Some California utilities have introduced DCFC rate designs that shift demand charges to volumetric charges and include deep discounts for off-peak/super-off-peak periods.

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[49] The EV Project. (2015, April). *Residential Charging Behavior in Response to Utility Experimental Rates in San Diego.* Retrieved from https://avt.inl.gov/sites/default/files/pdf/EVProj/ResChargingBehaviorInResponseToExperimentalRates.pdf ; Electric Power Research Institute. (2016, February 26). *Plug-In Electric Vehicle Multi-State Market and Charging Survey.* Retrieved from https://www.epri.com/#/pages/product/000000003002007495/

Pathway to implementation: This strategy could be encouraged through the transportation electrification legislative initiatives (Section 3.2.2). Each utility and electricity supplier could be encouraged to analyze and propose rate designs based on their own peak periods, timelines for introducing advanced meters, and other considerations and constraints.

Key collaborators and stakeholders: PUC, utilities, electricity suppliers, third party charging providers.

3.3.2 STRATEGY – PUBLIC AND RESIDENTIAL EVSE INVESTMENT

Category: Public planning and investment; Pricing-based policies

Barriers addressed: Insufficient EVSE coverage to enable certain trips; lack of confidence in EVSE coverage; Low-cost effectiveness of public EVSE investments at low EV adoption levels; high upfront EV and EVSE costs.

Objective: Increase access to public and residential EV infrastructure by enabling and encouraging utilities to invest in EV infrastructure to benefit drivers and the grid, while continuing to enable participation in the EVSE market by third-party charging providers.

Description: Pennsylvania's utilities could be enabled and encouraged to develop a range of programs to deploy different types of EVSE in their respective service territories, including single-family residential, multi-family residential, workplace, fleet, and public charging. Facilitated by the electrification directive in Section 3.2.2, regulators could enable utilities to invest in EVSE and receive a fair and reasonable rate of return on their investment. The programs could be structured to enable utilities to own and operate charging infrastructure, as well as provide incentives that support ownership by site hosts such as workplaces, fleets, multi-family housing complexes, third-party providers, and other stakeholders. The PUC may need to monitor the level of investments that can be rate-based by utilities over time to encourage market acceleration and a fair EVSE marketplace for future growth by other third-party participants.

Best practices: For residential EVSE incentives, a multi-state post-purchase survey of EV drivers revealed that 22 percent would not have purchased an EV without a residential EVSE incentive, and an additional 39 percent reported that it was a very important part of their decision.[50] A post-survey of test drivers found that of those who did not purchase an EV, 54 percent reported that more widespread infrastructure might have persuaded them to purchase an EV.[51] Experts interviewed for this Roadmap stressed the importance of Pennsylvania establishing an "ecosystem of charging" opportunities for prospective EV owners that can build market confidence, and that utilities are a key catalyst for increasing EVSE availability.

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[50] The EV Project. (2015, April). *Residential Charging Behavior in Response to Utility Experimental Rates in San Diego.* Retrieved from https://avt.inl.gov/sites/default/files/pdf/EVProj/ResChargingBehaviorInResponseToExperimentalRates.pdf

[51] Plug-in Electric Vehicle Collaborative, Best. Ride. Ever!. (2016, February 29). *Final Report.* Retrieved from http://www.pevcollaborative.org/sites/all/themes/pev/files/PUBLIC_PEVC%20Best.Ride.EVer%21%202015%20Final%20Report.pdf

- In Washington State, the public utilities commission encouraged a "portfolio" approach, where utilities were asked to design multiple programs to reach various market segments, including direct utility ownership of public EVSE, as well as incentives for workplaces and other potential public and quasi-public EVSE site hosts.
- In Maryland, utilities have proposed to make rebates available that cover a portion of the costs of Level 2 chargers for home charging, rebates for public and workplace charging, as well as funds for direct utility public EVSE ownership.
- To leave room for competition in the EVSE market, Pacific Gas and Electric CompanyMPO has linked the number of chargers they can deploy to 25 percent of the chargers needed to meet state ZEV goals.

Pathway to implementation: Following a legislative directive for transportation electrification, or other directive through the PUC, utilities could work with regional planning agencies and other key stakeholders in their service area to develop a proposal for EVSE investment. Proposals could begin with pilot programs and entail more specific targeting to non-attainment areas for air quality, urban areas with higher shares of residents who lack dedicated parking, or "priority areas" as defined in HB1446. To maintain market competition, the PUC could for example limit the number of public EVSE over time, or limit utility direct ownership and investment to sunset when EV sales reach a certain level. This strategy should also be closely coordinated with VW settlement programs for light duty charging infrastructure and the AFIG grant program for EVSE.

Key collaborators and stakeholders: PUC, utilities, MPOs, third party charging providers, Drive Electric Pennsylvania Coalition.

3.3.3 STRATEGY – WORKPLACE AND MULTI-FAMILY EVSE EDUCATION AND OUTREACH PROGRAM

Category: Marketing, education, and outreach

Barriers addressed: Lack of awareness of technology availability, performance, and costs; lack of awareness of incentives and other supportive policies

Objectives: Increase EVSE investment and availability at workplaces and multi-family residences, and educational outreach to employees and residents.

Description: The commonwealth could conduct outreach and provide technical support for EVSE deployment to organizations such as large employers, higher education institutions, and multi-family property owners or management firms, with a goal to provide direct education and support to 20-30 new organizations annually on topics such as 1) strategies, options, and costs for workplace and/or public charging; 2) policy options and incentives; 3) communication strategies to reach their customer base, employees, or residents; and 4) power management, scheduling and load considerations.

Best practices: The workplace can be an important way to reach potential new EV drivers through peers and through employer leadership. The U.S. DOE Workplace Charging Challenge was a major program with a goal of increasing workplace charging that helped deploy over 5,500 charging stations to over

600 employers by 2015. Based on program participation, the U.S. DOE estimated that employees of the programs' participants were six times as likely to drive an EV as the general population.[52]

Pathway to implementation: The commonwealth may design a program to provide the above support to Pennsylvania's major employers, property owners, and other institutions, and may also identify whether the ongoing programs and efforts can be accomplished through partnerships, or whether additional funding could be needed to implement this strategy. A program could also be developed to encourage commitments from major employers, property owners, and other key stakeholders.

Key collaborators and stakeholders: DEP, Drive Electric Pennsylvania Coalition, Clean Cities, Delaware Valley Regional Planning Commission, major employers, third-party charging providers, higher education institutions, property owners, contractors, and developers.

3.3.4 STRATEGY – MUNICIPAL TECHNICAL ASSISTANCE, PLANNING, AND GRANT PROGRAM

Category: Public Planning and Investment; Marketing, education, and outreach

Barriers addressed: Lack of awareness of technology availability, performance, and costs; lack of knowledge of EV-friendly model ordinances; insufficient electrical capacity for EVSE installation; insufficient funding for EV programs in smaller communities

Objective: Provide centralized resources, funding, and support for local EV-readiness policy and planning

Description: DEP, the Coalition, or another state agency could provide centralized support to municipalities to implement EV-readiness policy, regulations, and planning at the local level. Technical support could encompass development of model EV-ready building permitting and zoning ordinances, parking policies, streamlined EVSE permitting processes, cooperative purchasing programs, and other tools and resources that can be adapted by municipalities statewide. The program could also include a grant program for leading EV Accelerator municipalities to develop, pilot, and document lessons learned, to support the continued improvement of the program and development of new resources. Such a grant program can be administered through a state-driven application process that ensures equitable and proportionate distribution of funds to urban, suburban, and rural communities. Because of the large number of municipalities in Pennsylvania, this strategy focuses on providing replicable, centralized support to further leverage limited resources and create a knowledge-sharing platform for best practices.

Best practices: The North Jersey Transportation Planning Authority partnered with leading municipalities to fund AFV readiness plans that it then synthesized to create a Readiness Guidebook for other

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[52] U.S. Department of Energy. (2015, December). *U.S. Department of Energy's EV Everywhere Workplace Charging Challenge. Workplace Charging Challenge Mid-Program Review: Employees Plug In.* Retrieved from https://www.energy.gov/sites/prod/files/2015/12/f27/105313-5400-BR-0-EERE%20Charging%20Challenge-FINAL_0.pdf

municipalities.[53] Researchers have found that the U.S. DOE PEV Readiness Grant Program, which provided support to cities or regions to conduct charging infrastructure planning, regulatory reforms, and other EV deployment support services, had a significant, positive statistical effect on EV adoption rates in states without other EV incentives.[54] Washington State has also developed a centralized resource for municipalities to promote EV-readiness planning.[55] Solar Benefits Colorado was a joint initiative of Boulder County, Adams County, and the City and County of Denver that worked with solar providers and dealerships to negotiate bulk purchase prices resulting in a 26 percent discount on 2015 Nissan LEAFs. The program increased sales three-fold from 2014-2015 in Boulder County, with just 28 percent of participants reporting they had been considering an EV previously.

Pathway to implementation: Pennsylvania entities could work to identify the needed level of resources to implement this program, and who the lead partners and municipalities could be. For any local grants, a strong evaluation and reporting requirement may be considered to document lessons learned for other municipalities. Resources such as the eCode360 Library of municipal codes and cooperative procurement resources such as Fleets for the Future should be leveraged to seek out best practices that can be adopted by Pennsylvania municipalities.

Key collaborators and stakeholders: DEP, Drive Electric Pennsylvania Coalition, DCED, DVRPC and other MPOs, and municipalities.

3.4 LONG-TERM STRATEGIES FOR EV DEPLOYMENT IN PENNSYLVANIA (5+ YRS)

3.4.1 STRATEGY – EXPLORE DEVELOPMENT OF INNOVATIVE FINANCING FOR EVS/EVSE

Category: Financing and business models

Barriers addressed: High EV and EVSE upfront costs; Competing financial priorities and capital constraints; restrictions on public procurement methods

Objective: Enable more durable financing solution for consumers and fleets to afford incremental upfront costs of EVs and EVSE than direct incentives.

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[53] North Jersey Transportation Planning Authority. *NJTPA and Alternative Fuel Vehicles.* (2018). Retrieved from http://www.njtpa.org/planning/regional-studies/environment/air-quality/alternative-fuels-vehicles

[54] Santini, D., Zhou, Y., Werby, M. (2015, February). *Status and Issues for Plug-in Electric Vehicles and Hybrid Electric Vehicles in the United States.* Retrieved from https://cleancities.energy.gov/files/u/news_events/document/document_url/95/2015_strategic_planning_electric_drive.pdf

[55] Department of Commerce, Puget Sound Regional Council. (2010, July). *Electric Vehicle Infrastructure: A Guide for Local Governments in Washington State.* Retrieved from https://www.psrc.org/sites/default/files/electric-vehicle-guidance.pdf

Description: This strategy could begin with a study of potential innovative financing mechanisms for EV/EVSE deployment with priority focused on identifying solutions for financing residential EVSE, fleet vehicles and EVSE, and/or supporting low income households to afford EV technologies. Financing strategies to investigate could include on-bill repayment, inclusion of fleet conversions in Energy Service Performance Contracting, battery leases, Property Assessed Clean Energy (PACE) for residential EVs/EVSE, etc. Financing programs could be through utilities or an expanded version of the existing Alternative & Clean Energy (ACE) program that provides loans and loan guarantees.

Best practices: While there are few examples thus far of the use of financing for EVs and EVSE, financing for energy efficiency and clean energy upgrades in residential and commercial settings proves to be an effective strategy for creating a durable solution to help ease up front cost and capital constraint barriers in the energy sector. Thus far, there are a handful of examples of adaptations of clean energy finance to enable investment in EVs and/or EVSE for consumers and fleets:

- California's Alternative Energy and Advanced Transportation Financing Authority supports the use of PACE financing for residential EVSE by providing a loan loss reserve to mitigate potential risks to mortgage lenders of residential PACE financing. The California Capital Access program also provides loans for EVSE purchase and installation to small businesses.
- The Connecticut Green Bank is offering residents' low-interest loans (0.99 percent) to purchase a new or used EV.[56]

Pathway to implementation: As the commonwealth considers the ability to expand the AFIG program and other incentives over time, they may choose to fund a study to identify promising financing strategies target market segments, and pathways and key stakeholders for implementation. The ACE program, which provides loans and loan guarantees for clean energy projects and AFV fueling stations (though EVSE is not currently eligible) could be explored as an avenue for implementing EVSE financing programs.

Key collaborators and stakeholders: Drive Electric Pennsylvania Coalition, DCED, ACE program, utilities, dealers and OEMs, financing institutions.

3.4.2 STRATEGY – EV-READY BUILDING CODES

Category: Enabling regulations

Barriers addressed: Lack of EVSE-ready requirements increase installation costs; insufficient electrical capacity for EVSE installation; providing EVSE for drivers without dedicated parking

Objective: Remove barriers to and promote installation of EVSE.

Description: This strategy could involve amending the state's building code to ensure EV readiness in new construction (such as pre-wiring for charging stations) is promoted through the building code while retaining local flexibility. While the current building code does not present any explicit barriers to installing

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[56] Connecticut Green Bank. (2017). *Introducing Smart-E for* EV. Retrieved from https://www.ctgreenbank.com/smart-ev/

EVSE, building codes can help make installation simpler and less expensive for residents and site hosts in the future by avoiding expensive retrofits. EV-ready building codes may include requirements such as a percentage of parking spaces in commercial or multi-family developments being made "EV-ready." This means having sufficient electrical capacity to support EV charging, and the installation of wire and conduit to provide electricity to EV charging spaces.

Best practices: Other states that have adopted EV-readiness provisions in their building codes include California, Washington, and Massachusetts. California, through its Green Building Standards, mandates a certain level of EV-readiness statewide, but also provides more ambitious requirements that local jurisdictions are enabled to adopt if they choose. While New Jersey has not changed its building code, the state Division of Codes and Standards provided guidance to municipalities' local code enforcement agencies that residential EVSE installation constitutes "minor work." This helped to streamline the permitting process for installations.

Pathway to implementation: This strategy could involve coordination of EVSE requirements with the state legislature as well as several Pennsylvania agencies and AHJs to add EVSE-ready requirements to the state's recent adoption of the 2015 ICC suite of building codes. In addition, model ordinance language created for use by PA municipalities to include into their local zoning requirements via the Municipal Technical assistance strategy can serve to address similar objectives as changes to the building code may take time.

Key collaborators and stakeholders: Drive Electric Pennsylvania Coalition, DEP, PA Department of Labor and Industry, Review and Advisory Committee, developers, commercial builders, residential builders, and code enforcement officials.

3.5 SUMMARY

The strategies identified in this roadmap and summarized in Table 13 are intended to collectively represent a feasible yet high impact pathway to overcome key barriers and accelerate EV market development in Pennsylvania. Together, the proposed strategies address barriers facing EV drivers, single family home residents, multi-family home residents, workplaces, fleets, utilities, dealers, and other key stakeholders. The implementation pathway for each strategy can be adapted to lower or higher levels of effort as EV technologies, costs, and the commonwealth's policy and political context change over time.

Importantly, research investigating the impact of EV policies have found individual policies to be less effective on their own than in combinations that are complementary to one another. For example, both financial incentives and public EVSE investments have been found to have a statistically significant impact on EV market adoption, yet studies have found each to have limited impact in isolation.[57] The top cities in

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[57] Sierzchula, W., Bakker, S., Maat, K., Wee, B. (2014, May). The influence of financial incentives and other socio-economic factors on electric vehicle adoption. *Energy Policy, 68*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0301421514000822; Lutsey, N., Searle, S., Chambliss, S.,

EV adoption in two separate studies had a combination of awareness campaigns, higher EVSE per capita, greater consumer incentives, and greater model availability.[58]

The strategies identified in this roadmap collectively address key indicators of leading EV markets, including increasing public EVSE availability, increasing EV model availability by working to support and incentivize dealers, expanding the availability of financial incentives for EV purchases, and increasing education levels and awareness amongst multiple market segments. This set of strategies, combined with potential EV technology advancement, is likely to jumpstart Pennsylvania's EV market far beyond its current deployment level.

As DEP, the commonwealth, and the Coalition work to implement these strategies, evaluating the impact of these policies and conducting pilot tests will be important to adapt the strategies over time to the changing EV market. This plan hopes to help the commonwealth seek out a more ambitious pathway towards adoption of EVs.

Bandivadekar, A. (2015, July). *Assessment of leading electric vehicle promotion activities in United States cities.* Retrieved from https://www.theicct.org/sites/default/files/publications/ICCT_EV-promotion-US-cities_20150729.pdf

[58] Zhou, Y., Levin, T., Plotkin, S. (2016, May). *Plug-in Electric Vehicle Policy Effectiveness: Literature Review.* Retrieved from https://energy.gov/sites/prod/files/2017/01/f34/Plug-In%20Electric%20Vehicle%20Policy%20Effectiveness%20Literature%20Review.pdf

Table 13: Summary of Pennsylvania EV roadmap strategies by policy category

Primary category	Strategy	Near-term actions (0-2 years)	Mid-term actions (2-5 years)	Long-term actions (5+ years)
Goals and targets	Establish utility transportation electrification directive	■		
	Establish statewide EV sales goals	■		
Pricing-based policies	Encourage residential and commercial EV rate designs		■	
	Expand and improve AFIG rebate program	■		
	Advance public and residential EVSE investment		■	
Public planning and investment	Strengthen statewide EVSE network planning, investment, and communications	■		
	Establish fleet education, cooperative purchase, and technical assistance program	■		
	Develop municipal support, technical assistance, and grant program		■	
Marketing, education, and outreach	Create EV marketing and education campaign targeted at consumers	■		
	Establish workplace and multi-family EVSE education and outreach program		■	
	Establish dealer outreach and support program	■		
Enabling regulations	Adopt EV-ready building code amendments			■
Financing and business models	Explore development of financing for EVs/EVSE			■

SECTION 4 PENNSYLVANIA EV MARKET PENETRATION SCENARIO MODELING

4.1 MOTIVATION AND METHODS OF SCENARIO MODELING

To provide an understanding of the range of potential energy, environmental, and economic impacts of increased EV and EVSE adoption in Pennsylvania, four EV adoption scenarios were modeled. These four scenarios represent different levels of future EV policy efforts combined with different levels of future technological advancement (and respective cost reductions) for EVs. Put simply, these four scenarios represent the intersection of low- or high-policy support and low- or high-technology advancement (e.g., low-policy support with low-technology advancement, low-policy support with high-technology advancement, etc.). See Table 14 for a summary of each scenario. These combinations of scenarios are intended to illustrate the uncertainty of policy impacts across different market contexts and under different, still-unknown levels of EV technological improvements. As a result, the scenarios ranged from a business-as-usual scenario to a very ambitious EV adoption pathway.

Benefit-cost analyses were conducted for each scenario and the resulting output was used to inform the roadmap policy prioritization process, inform goal-setting for EV deployment, and increase understanding of the environmental, economic, and energy impacts across scenarios. The analysis additionally explores how each scenario could impact the six priority Metropolitan Statistical Areas from an energy, environmental, and economic perspective.

The energy, environmental, and economic modeling utilize a combination of 1) a statewide vehicle fleet penetration model, 2) a benefit-cost model based on utility energy efficiency benefit cost analysis methodologies and 3) open source emissions and energy models built by the United States Environmental Protection Agency (EPA) and Argonne National Laboratory (ANL). The scope of the modeling covered the light-duty passenger vehicle fleet as reported by the Pennsylvania Department of Motor Vehicles.

4.1.1 SCENARIO DEFINITIONS, INPUTS, AND ASSUMPTIONS

The scenarios were structured around 1) varying levels of policy support and 2) varying levels of technology advancement, resulting in four scenarios, as shown in Table 14. Details describing the policy and technology variables—and other key assumptions—are described in the following sections.

Table 14: EV deployment scenarios modeled

		TECHNOLOGY ADVANCEMENT	
		LOW	HIGH
POLICY SUPPORT	LOW	Scenario 1: Low policy, Low Technology	Scenario 2: Low Policy, High Technology
	HIGH	Scenario 3: High Policy, Low Technology	Scenario 4: High Policy, High Technology

Each scenario's projected EV deployment curves were mapped to other widely known projections for EV deployment, but grounded with Pennsylvania's current EV penetration for the first model year. The data sources used to inform fleet penetration curves include:

- Scenario 1: The U.S. Energy Information Administration (U.S. EIA) reference case for EV sales in the U.S. as a whole[59] **for the low-policy support, low-technology scenario**;
- Scenario 2: An average of market research firm projections and EV market expert projections[60] **for the low-policy support, high-technology advancement scenario**;
- Scenario 3: The level of EV sales required for Pennsylvania to meet the level of EV deployment called for by the ZEV MOU Program led by California and adopted by nine other leading states **for the high-policy support, low-technology advancement scenario,**[61] and
- Scenario 4: The level of EV sales required to help the light duty vehicle sector contribute proportionally to a potential 80 percent by 2050 greenhouse gas reduction goal[62] **for the high-policy support, high-technology advancement scenario**.

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[59] U.S. EIA Annual Energy Outlook (AEO) 2017. The AEO 2017 Reference Case projects that the combined BEV and PHEV share of sales will reach 10 percent by 2040 in the light duty fleet. The Reference Case projects sales percentages on a national level. Note that Pennsylvania's EV market share as of 2017 is less than half of the U.S. average; therefore, these estimates may be optimistic as applied to Pennsylvania in the near-term years of the model. For more information on current EV market share, see: https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/

[60] Projections included Bloomberg New Energy Finance EV Outlook 2017, Energy Innovations' Energy Policy Simulator 1.3.1 business as usual case, and Wood Mackenzie's 2017 EV scenarios.

[61] While Pennsylvania is not one of the nine states that have adopted the ZEV program, an ambitious EV sales target such as the ones created for the ZEV Program is interpreted as a strong level of broad policy support that requires multi-pronged, intensive efforts to advance the EV market. By 2025, participating states are committing to aim for roughly 15 percent of new vehicle sales to be ZEVs.

[62] The penetration of EV sales to contribute to an 80 percent reduction in light duty emissions was modeled to range from 80 percent of sales to 97 percent of sales by MJ Bradley among the eight states they analyzed in their 2017 Electric Vehicle Cost-Benefit Analyses. The Consulting Team took the mid-point of this range as the level for our scenario.

These scenarios and their underlying assumptions were reviewed by DEP, U.S. DOT Volpe Center, and the Coalition in late 2017. Scenario results were calculated out to three horizon years: short-term, medium-term, and long-term. The short term was defined as within the next five years (2023), medium term as ten years (2028), and long term as fifteen years (2033). All results shown in the following sections reflect the range of potential impacts from the combined policy and technology scenarios and the assumptions built into those scenarios. The results do not reflect the impacts of the ZEV MOU program or of an 80x50 climate change policy applied to Pennsylvania's context, given the uncertainty of policy impacts across contexts, as well as the uncertainty of how future rates of technology advancement may impact policy effectiveness.

4.1.1.1 Technology Scenarios

Since EV technology advancement trends through the next 15 years are uncertain, the hypothetical cost effectiveness of policy bundles to advance the EV market should be evaluated under conditions in which 1) technology advances rapidly and 2) technology advancement is incremental. Technology advancements and improved economies of scale are anticipated to manifest in a wider selection of vehicle model choices and cost reductions.

In recent years, battery and EV powertrain costs have significantly decreased and vehicle manufacturers have added greater range to newer models of PHEVs and BEVs. For instance, battery unit costs decreased on average 19 percent per year between 2010 and 2015.[63] The degree to which these trends will change in the future will have a significant effect on the cost and desirability of future EVs. Table 15 presents the assumptions embedded within the low and high technology scenarios for our models.

The timing with which the cost of BEV and PHEV vehicles can reach parity with conventional internal combustion vehicles is an important consideration and is subject to numerous assumptions (such as vehicle utilization, fuel prices, dealership profits and pricing decisions, and cost curves for batteries and powertrains). Several sources have recently estimated dates for upfront costs to reach parity and for total cost of ownership to reach parity. A few recent examples include NREL's Electrification Futures Study, which projects 100-mile range BEVs could reach cost parity in 2021 under their Rapid Advancement case, and UBS's Evidence Lab Electric Car Teardown, which projects that BEV total cost of ownership could reach parity by 2025 in the U.S. (using the Chevy Bolt as an example).[64] NREL's National Economic Value Assessment of Plug-In Electric Vehicles does not assume EVs will reach upfront cost parity with EVs through

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[63] Jadun, P., McMillan, C., Steinberg, D., Muratori, M., Vimmerstedt, L., Mai, T. (2017). *Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050.* Retrieved from https://www.nrel.gov/docs/fy18osti/70485.pdf

[64] It is important to note that cost parity is only one of many factors driving consumers' decision processes and furthermore consumers' perception of what a comparable "reference car" to compare an EV against may be different from the assumptions in any of the studies that estimate cost parity. Therefore, these findings should not be interpreted overly broadly.

2045, except for some lower range EVs.[65] In the benefit-cost analysis for individual consumers, the low-technology advancement scenario assumed EIA Reference Case upfront vehicle costs for conventional, BEV, and PHEV cars and light trucks. The high-technology advancement scenario utilized the NREL Electrification Futures Study ratio between their Slow Advancement and Rapid Advancement cases to project BEV and PHEV purchase costs while conventional vehicle costs were held constant.

Table 15: Low- and high-technology scenario summary

Category	Trend	Technology Scenarios - Low	Technology Scenarios - High
Vehicle costs	**Battery cost decrease**	Cost improvements slow considerably (1% per year)	Nearly 75% decrease in battery unit costs per kWh by early 2020s, in line with GM and Tesla predictions
	Powertrain cost decrease	Steady incremental cost improvements	Nearly 75% decrease in powertrain costs per kw, 2016 to 2022, in line with EV Everywhere goal[66]
	EVSE costs	Stable	Stable
Vehicle features	**Increase in PHEV all-electric range**	Most models of PHEV reach 50 miles all-electric by early 2030s	Most models of PHEV reach 50 miles all-electric by early 2020s
	Increase in BEV range	Few new models of BEV available with >200-mile range by early 2020s	Many models of BEV available with >200-mile range by early 2020s
	Increase in availability of crossovers and SUVs as PHEV and BEV	Limited through 2025	Rapid
Fuel costs	**Increased efficiency (MPGe)**	Steady and incremental (1%/year)	Steady and incremental (1%/year)
	Electricity and gasoline prices	Not assumed to vary across scenarios	

4.1.1.2 Policy Scenarios

Low- and high-policy scenarios were developed to generally correspond with low- and high-EV adoption rates, but are not intended to suggest a clear linkage, given the differing impact of policies across contexts.

[65] Melaina, M., Bush, B., Eichman, J., Wood, E., Stright, D., Krishnan, V...McLaren, J. (2016, December). *National Economic Value Assessment of Plug-In Electric Vehicles, 1.* Retrieved from https://www.nrel.gov/docs/fy17osti/66980.pdf

[66] U.S. Department of Energy. (2013, January 31). *EV Everywhere Grand Challenge Blueprint.* Retrieved from https://www.energy.gov/sites/prod/files/2014/02/f8/eveverywhere_blueprint.pdf

The low-policy scenario approximates adoption rates associated with Pennsylvania's current set of EV policies. The high-policy scenario approximates California and other leading states' EV-related policies (see Table 16).

Table 16: Low and high policy scenario summary

Category	Strategy	Policy Scenarios - Low	Policy Scenarios - High
Goals and targets	Statewide EV sales mandate	**No**	**Yes**
	Utility transportation electrification mandate	**No**	**Yes**
Pricing-based policies	Expand and improve AFIG rebate program	**Yes**	**Yes** *Benchmarked to rebates for leading ZEV states*
	Federal tax credit	**No**	**Yes**
	Fleet, public and workplace EVSE incentive programs	**Yes** *Benchmarked to current levels of EVSE per EV in PA*	**Yes** *Benchmarked to recommended levels of EVSE per EV*
	Residential EVSE incentive programs	**No**	**Yes** *Benchmarked to recommended levels of EVSE per EV*
Public planning and investment	Publicly owned or utility-owned EVSE development	**No**	**Yes** *Benchmarked to recommended levels of EVSE per EV*
Marketing, education, and outreach	Statewide Marketing and Education Campaign	**No**	**Yes**

A benefit-cost assessment was conducted to provide a high-level approximation of the overall cost-effectiveness of policies across a range of different stakeholder groups. EV programs can have financial impacts for EV consumers, ratepayers and taxpayers, and the net state economy. Depending on the perspective used to evaluate an EV program, different costs and benefits are considered. For details on which costs and benefits are included in each perspective, please refer to Appendix C. Program financial impacts often vary across perspectives. A program may provide net economic benefits for society in Pennsylvania, but still may not provide an attractive payback for an EV consumer. Therefore, this study incorporates a multi-stakeholder approach, which separately evaluates costs and benefits from multiple perspectives and presents output metrics that are relevant to each.

The estimated scale, direct costs, and administrative costs of deployment of each policy are benchmarked against similar programs in Pennsylvania, California, and other states. For programs like rebates, costs are scaled to grow over time as EV market share grows. The policy scenarios modeled are intended to indicate the relative costs and benefits of different levels of effort of advancing EV adoption, but are not meant to suggest these policy combinations will result in the exact outcomes modeled given the uncertainty of policy impacts across contexts. The policy combinations in the benefit-cost analysis encompass the following key assumptions:

- Vehicle rebates: In both the low-policy scenarios, rebates remain at $1,750 per vehicle and remain at the same share of EVs rebated in Pennsylvania currently at 25 percent as market share grows. In the high-policy scenario, the size of the rebate grows to $2,500 per vehicle, and the overall number of rebates grows to rebate 50 percent of EVs sold per year as market share grows, similar to the share rebated in MA, CA, and CT according to those states' program data.
- Public and workplace EVSE investments (Table 17): In the low-policy scenario, a small number of incentives for public and workplace EVSE incentive programs are available, which maintain a similar ratio of EVSE to EVs that currently exists in Pennsylvania as the market grows. In the high-policy scenario, funds are included for both public/workplace incentive programs as well as public or utility-owned EVSE charging networks. The high-policy scenario ratios of workplace, public, and DCFC EVSE per 1,000 EVs are informed by projected requirements by NREL and EPRI.[67] One third of public EVSE installed is assumed to be utility-owned.
- Residential EVSE investments: A $500 residential EVSE incentive is assumed to be available for 50 percent of new EV owners in each year to install Level 2 chargers, based on EPRI's projection of home Level 2 chargers and estimated incentive costs for Maryland utilities in their recent proposals.[68]

Table 17: EVSE per 1,000 EV ratios used in BCA modeling analysis

	Low policy scenario	High policy scenario
Workplace EVSE per 1,000 EVs	**39**	**264**
Public EVSE per 1,000 EVs	**10**	**66**
- DCFC EVSE per 1,000 EVs	0.5	3
- Public EVSE funded by incentives per 1,000 EVs	6	44
- Public utility-owned EVSE per 1,000 EVs	-	22

[67] Cooper, A., Schefter, K. (2017, June). *Plug-in Electric Vehicle Sales Forecast Through 2025 and the Charging Infrastructure Required.* Retrieved from http://www.edisonfoundation.net/iei/publications/Documents/IEI_EEI%20PEV%20Sales%20and%20Infrastructure%20thru%202025_FINAL%20(2).pdf

[68] Cooper, A., Schefter, K. (2017, June). *Plug-in Electric Vehicle Sales Forecast Through 2025 and the Charging Infrastructure Required.* Retrieved from http://www.edisonfoundation.net/iei/publications/Documents/IEI_EEI%20PEV%20Sales%20and%20Infrastructure%20thru%202025_FINAL%20(2).pdf; Proposal to Implement a Statewide Electric Vehicle Portfolio.

Time-of-use rates were not modeled for the benefit-cost analysis, but are considered a critical element of an ambitious EV deployment policy scenario. While the impacts of a time-of-use rate are not modeled, time-of-use rates could in theory reduce the cost of potential utility transmission and distribution upgrades, capacity upgrades, and other incurred costs. A study for New York State found that if 50 percent of EV owners delayed most of their charging to off-peak hours, incentivized by a TOU rate or rebate program, the benefits to the grid would include up to $46 million annually in reduced generating costs and capacity costs, and $103 million in reduced infrastructure upgrade costs resulting from mitigation of PEV clustering by 2030.[69] Therefore, these rates would be expected to increase savings for participants and non-participants alike.

Additionally, supporting climate policies such as cap and trade and clean fuel standards in states like California were not modeled, though can be expected to have a substantial impact on EV adoption by increasing the cost of gasoline and other fossil fuels, as well as providing revenue to fund incentive programs.

In the benefit-cost analysis, administrative costs are also included for each policy measure, informed by similar programs implemented or proposed by other states and utilities. High policy scenarios assume that the federal tax credit for EVs gets extended through the last horizon year in 2033, while low policy scenarios assume the federal tax credit is phased out for all manufacturers by the first horizon year in 2023. Full details on assumed costs and sources are included in Appendix C.

4.1.1.3 Inputs and Methods

The EV market share and fleet penetration rates were modeled using a statewide vehicle fleet penetration model developed for this Roadmap. The energy and emissions impact were modeled based on the outputs of the vehicle fleet turnover model, utilizing open source emissions and energy models built by the EPA and Argonne National Laboratory.

The methodology for the cost-benefit analysis was based on the standard benefit-cost frameworks used to assess demand-side energy programs and energy efficiency programs. In Pennsylvania, this framework is used to evaluate the Act 129 energy efficiency and conservation plans administered by state utilities. As this cost-effectiveness framework is generally applied to energy conservation programs, several adjustments were necessary to reflect a vehicle electrification program. Primarily, gasoline savings are included in the analysis and valued in a similar manner as retail electricity savings. Further, because a vehicle electrification program leads to an increase in electricity consumption (rather than a decrease, as in energy conservation programs), the Utility Cost Test, frequently used in the evaluation of energy programs, was

[69] Jones, B. (2015, June). *Electricity Pricing Strategies to Reduce Grid Impacts from Plug-in Electric Vehicle Charging in New York State Final Report.* Retrieved from https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Transportation/EV-Pricing.pdf

not conducted in this case.[70] As such, this analysis assessed the costs and benefits of policy-driven EV deployment from four perspectives:

- Total Resource Cost Test (TRC). The TRC combines the participant and non-participant perspectives and considers whether EV investments are cost-effective investments without considering the distribution of costs and benefits among stakeholder parties. The TRC only includes financial factors. In this analysis, TRC compares the value of gasoline savings to the added costs of electricity supply, as well as the capital and operational cost implications of EV investment (including charging stations). The TRC does not include in-state incentive payments, which are considered a transfer payment from non-participants to participants.
- Societal Cost Test (SCT). The SCT is much the same as the TRC but takes a broader view towards program benefits, primarily by placing a value on environmental benefits rather than considering financial factors only. The SCT also calculates lifetime net benefits and costs using a societal discount rate, which places a greater value on future energy savings and environmental benefits than the discount rates used in other tests (which are based on financially attractive rates of return).
- Participant Cost Test (PCT): The PCT assesses the costs and benefits to program participants, in this case the owners of EVs. The test considers incremental upfront vehicle purchase costs, lifetime net fuel and operating cost savings, and any rebates, tax credits, or other incentives that are provided to participants.
- Ratepayer Impact Measure, or Non-Participant Cost Test (RIM). The RIM assesses whether non-participating utility customers and Pennsylvania residents are expected to benefit from a program. In an electrification program, increased electricity sales can put downward pressure on rates and benefit utility ratepayers because increased electricity sales allow utilities to spread revenue requirements across increased annual sales. However, ratepayers and taxpayers are burdened by policy costs, as any program expenditures are expected to be socialized.[71] The RIM test considers only electricity impacts, and does not value gasoline savings.

A more detailed description of methods for developing the fleet model, energy and emissions modeling, and benefit-cost analysis can be found in Appendix C.

[70] The UCT traditionally compares a utility's lifetime program costs to the monetary benefit of avoided energy and capacity costs. As a vehicle electrification intentionally leads to added rather than avoided electric utility energy and capacity costs, this comparison is not relevant in this case.

[71] In several of the policies evaluated in this study, program expenditures would likely be incurred by the state, rather than the utility. These were not dealt with separately in the RIM assessment, as it was assumed that these costs would ultimately be borne by non-participants in the long term either through in the form of utility rates or state taxes.

4.2 SCENARIO MODELING RESULTS

4.2.1 FLEET MODEL RESULTS

Figure 12 shows the sales shares for each of the four scenarios. The scenarios reference the total sales percentages of all plug-in vehicles whether they are PHEVs or BEVs. It is notable that in the early years, none of the scenarios deviate quickly from the Scenario 1 reference case. This can be explained by the fact that although Scenario 1 (low policy, low technology) plateaus around 10 percent sales, it approaches that 10 percent relatively quickly with rapid sales share growth in the early 2020s. The difference between Scenario 2 (Low policy, high technology) and Scenario 3 (High policy, low technology) was a subjective distinction and is based on the idea that the high policy scenario may involve significant early efforts such as expanded rebate values and program size, which would have a more significant impact on EV consumer economics in the short term than continued cost improvements. Furthermore, Scenario 3 (High policy, low technology) is defined as enabling Pennsylvania to reach a sales share that would put it in line with the ZEV states' goals for 2025, and therefore is predicated on rapid policy action. Scenario 3 plateaus in later years as it is expected that policy interventions reach a steady state.

On the other hand, the Scenario 2 (Low policy, high technology) sales share curve doesn't accelerate until the late 2020s, aligned with the third-party projections that were used. This is because these projections expect total cost of ownership parity to be achieved for more customers roughly in that time frame. There is continued growth through the end of our horizon due to the expectation that technology improvements could continue to have a positive impact on EV desirability.

An important note is that large gaps exist between the low policy scenarios and the levels needed for reaching the high policy scenarios. Regardless of whether technology rapidly improves and costs come down, EV sales shares will likely remain relatively low through the 2020s relative to an environment with more significant policy efforts.

Figure 12: Scenario modeling of projected EV sales shares, 2017-2035

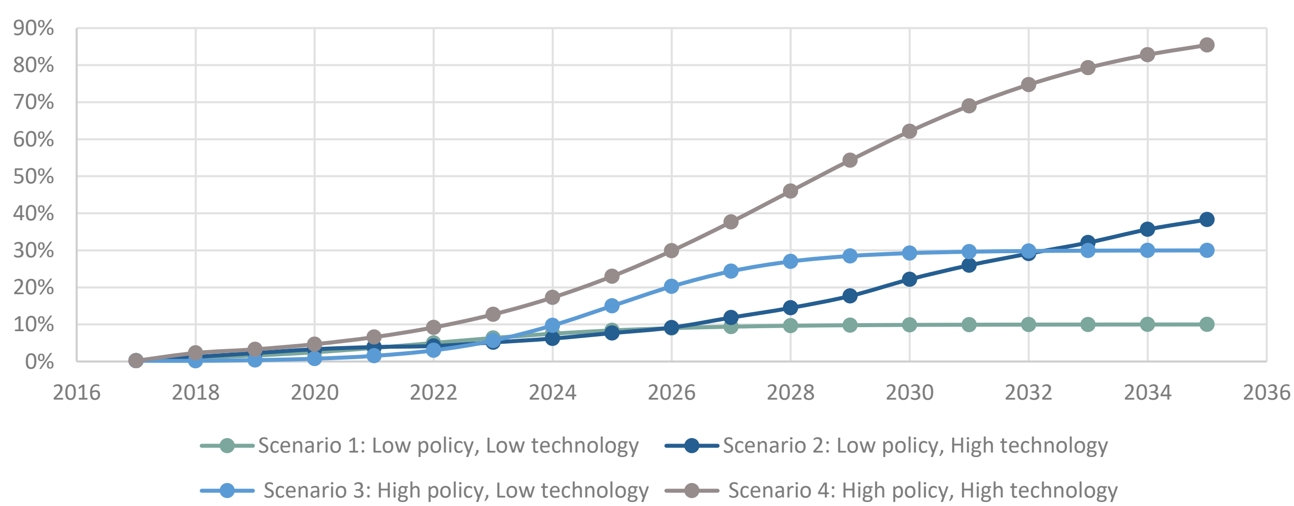

Table 18 presents snapshots of the above sales scenarios in our horizon years in tabular format.

Table 18: Percent EV of total light duty sales by scenario and horizon year

Scenario	2023	2028	2033
Scenario 1: Low policy, low technology	6%	10%	10%
Scenario 2: Low policy, high technology	5%	15%	32%
Scenario 3: High policy, low technology	6%	27%	30%
Scenario 4: High policy, high technology	13%	46%	79%

Figure 13 shows the lag between the acceleration of EV sales and their penetration within the fleet. It uses the sales and fleet penetration numbers from Scenario 4 (High policy, high technology). The figure is plotted through 2050, to show how fleet penetration catches up to sales after sales reach a steady state, although the modeling for the roadmap only extends through 2033. Note that because vehicles are typically driven for longer than a decade, it takes a significant number of years for the percent of EVs in the fleet to catch up to the new sales percentage of EVs.

Figure 13: Illustration of fleet penetration lagging sales – Scenario 4: High policy, high technology

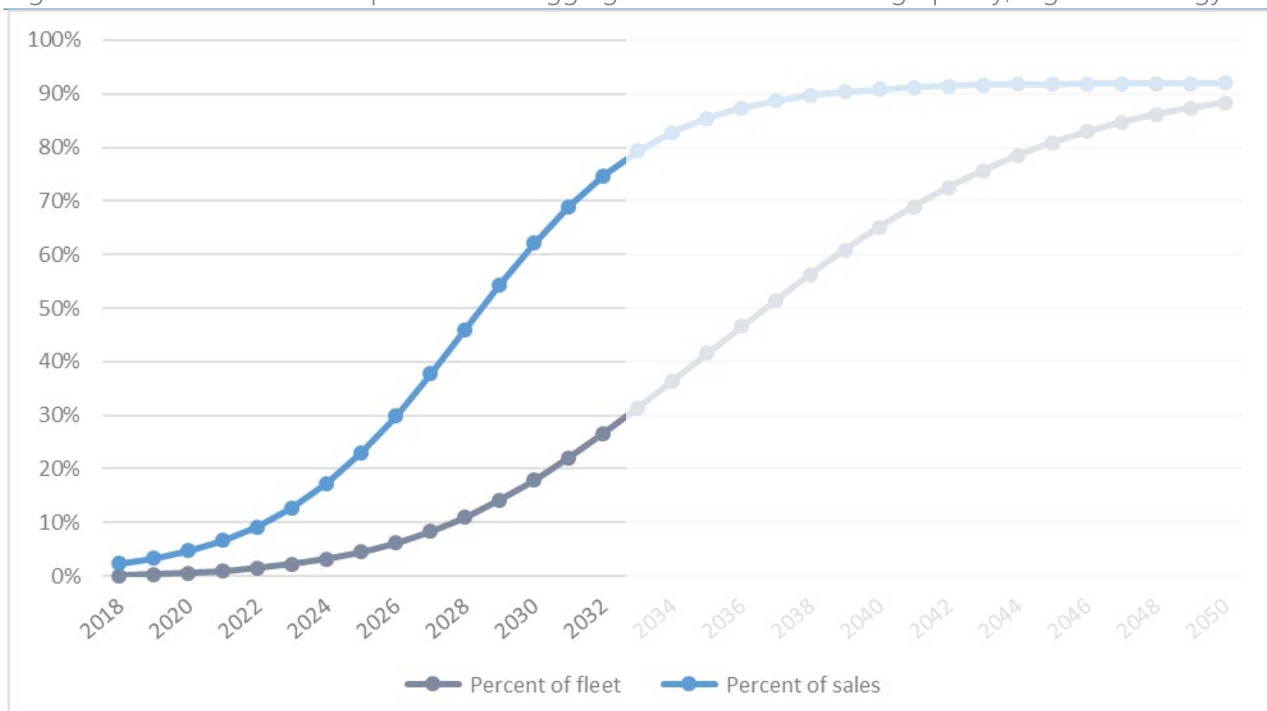

Table 19 shows how the sales scenarios demonstrated in Figure 12 manifest into fleet penetration in each horizon year, and Table 20 shows the estimated total number of EVs deployed for each scenario and horizon year. Finally, Table 21 shows the percentage of total vehicle miles traveled by electric vehicles for each scenario and horizon year. Since Pennsylvania's EV market share is less than the average EV market share across the U.S., it is expected that in the three more optimistic scenarios, the total light duty fleet penetration does not significantly exceed the EIA forecasts in any of the scenarios in our 2023 horizon year, and only by 2028 do the scenarios start to diverge more significantly.

Table 19: EV percent of total light duty fleet by scenario and horizon year

Scenario	2023	2028	2033
Scenario 1: Low policy, low technology	1%	4%	7%
Scenario 2: Low policy, high technology	1%	4%	11%
Scenario 3: High policy, low technology	1%	6%	16%
Scenario 4: High policy, high technology	2%	11%	31%

Table 20: Projected EVs on the road in Pennsylvania by scenario and horizon year

Scenario	2023	2028	2033
Scenario 1: Low policy, low technology	98,000	358,000	636,000
Scenario 2: Low policy, high technology	106,000	362,000	1,038,000
Scenario 3: High policy, low technology	45,000	540,000	1,445,000
Scenario 4: High policy, high technology	181,000	966,000	2,887,000

Table 21: Electric vehicle miles traveled as a share of total fleet vehicle miles traveled by scenario and horizon year

Scenario	2023	2028	2033
Scenario 1: Low policy, low technology	1%	4%	6%
Scenario 2: Low policy, high technology	1%	4%	11%
Scenario 3: High policy, low technology	1%	6%	15%
Scenario 4: High policy, high technology	2%	10%	30%

Together with the projections of fuel economy for each vehicle type, the results shown in Section 4.2.1 were used as inputs into the energy and emissions modeling of Section 4.2.2 and the benefit-cost modeling of Section 4.2.3.

4.2.2 ENERGY AND EMISSIONS RESULTS

The following sections detail the statewide energy and emissions impacts of each scenario across all horizon years, which were modeled using Argonne National Labs' Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) tool. Results for the six primary Pennsylvania metropolitan areas can be found in Appendix D.

4.2.2.1 Energy Use Results

Table 22 highlights the changes in energy consumption for gasoline and electricity resulting from each scenario across the three horizon years. Even under the more conservative Scenario 1, gasoline consumption is anticipated to decrease substantially due to improving federal fuel efficiency standards and modest EV uptake. From this baseline, the other scenarios would result in even greater reductions in gasoline consumption, up to 25 percent for Scenario 4. Figures for Scenario 1 estimate total energy use for light duty vehicles for that year, and each additional scenario is reported as the raw difference from the baseline case in that year.

Table 22: Energy impacts by scenario and horizon year

Scenario and energy unit	Year		
Million gallons of gasoline for ICEVs	**2023**	**2028**	**2033**
Scenario 1: Low policy, low technology	**4,255.6**	**3,832.0**	**3,417.2**
Scenario 2: Low policy, high technology	*+0.1%*	*+0.1%*	*-4.5%*
Scenario 3: High policy, low technology	*+0.3%*	*-2.2%*	*-9.1%*
Scenario 4: High policy, high technology	*-0.7%*	*-5.8%*	*-24.6%*
Thousand MWh of electricity for EVs	**2023**	**2028**	**2033**
Scenario 1: Low policy, low technology	**315.2**	**1,129.4**	**1,948.6**
Scenario 2: Low policy, high technology	*+9.8%*	*+3.5%*	*+72.1%*
Scenario 3: High policy, low technology	*-53.5%*	*+53.3%*	*+132.3%*
Scenario 4: High policy, high technology	*+87.4%*	*+178.9%*	*+379.6%*

Electricity consumption from EVs increases substantially over the three horizon years in the baseline scenario (Scenario 1: low policy, low technology), starting from a very small share of EVs on the road. The increased penetration scenarios 2-4 represent even greater increases in electricity consumption, though the electricity consumption in each scenario and horizon year still represents a relatively small share of Pennsylvania's total electricity consumption. Table 23 highlights the total kWh consumption from EVs in each scenario as a share of Pennsylvania's total 2016 electricity consumption.

Table 23: Electricity consumption from EVs as share of 2016 Pennsylvania electricity consumption

Scenario	2023	2028	2033
Scenario 1: Low policy, low technology	0%	1%	1%
Scenario 2: Low policy, high technology	0%	1%	2%
Scenario 3: High policy, low technology	0%	1%	3%
Scenario 4: High policy, high technology	0%	2%	6%

4.2.2.2 Greenhouse Gas Emissions Results

Table 24 highlights the greenhouse gas emissions impact of each scenario in each horizon year relative to the baseline scenario (Scenario 1: low policy, low technology). In this baseline scenario, light duty passenger vehicles are anticipated to generate emissions of approximately 47 million metric tons in 2023, falling to 38.5 million metric tons by 2033 as fuel efficiency for the fleet improves and as moderate EV adoption takes place. Electric miles driven in Pennsylvania under the forecast electricity mix would emit approximately half that of a conventional vehicle, yielding greenhouse gas emissions savings as EV adoption increases. Greenhouse gas emissions from EVs are estimated to continue to decline as cleaner electricity sources are incorporated into the grid over time. Figures for Scenario 1 (low policy, low technology) are in metric tons, and each additional scenario is reported as a percent difference from that baseline case in that year.

Table 24: Light-duty vehicle greenhouse gas emissions by scenario and horizon year (well-to-wheels, million metric tons)

Scenario	2023	2028	2033
Scenario 1: Low policy, low technology	**47.0**	**42.7**	**38.5**
Scenario 2: Low policy, high technology	*+0.1%*	*+0.1%*	*-2.8%*
Scenario 3: High policy, low technology	*+0.1%*	*-1.5%*	*-6.0%*
Scenario 4: High policy, high technology	*-0.4%*	*-3.6%*	*-15.5%*

Substantial differences in greenhouse gas emissions between the scenarios do not become apparent until 2028 and 2033 due to slow fleet turnover. By 2033, Scenario 2 would yield a 3 percent reduction in greenhouse gas emissions from the baseline, while Scenario 3 would yield a 6 percent reduction, suggesting that the impact of more ambitious policy measures may be greater than technology improvements alone. Combined, a high policy and high technology future results in a 16 percent reduction in greenhouse gas emissions from the baseline by 2033.

The baseline (Scenario 1: low policy, low technology) figures of 47 million metric tons in 2023 are roughly in line with Pennsylvania's 2016 greenhouse gas inventory which estimated 40 million metric tons of greenhouse gases from motor gasoline, which is primarily used by passenger vehicles, in the state in 2013. The estimated well-to-wheels greenhouse gases for this analysis in 2023 are somewhat higher because 1) AFLEET estimates incorporate upstream emissions in addition to tailpipe greenhouse gas emissions, and 2) EIA Annual Energy Outlook projections for light duty vehicle fleet size forecasts Pennsylvania's light duty vehicle fleet to grow an average of 1.1 percent per year between 2018 and 2033.

4.2.2.3 Criteria Pollutant Results

Table 25 includes estimates of the total fleetwide criteria pollutant emissions in each horizon year and presents each scenario relative to the baseline scenario (Scenario 1: (low policy, low technology)), utilizing the outputs of the fleet model and the AFLEET model. Higher EV adoption rate scenarios than Scenario 1 (low policy, low technology) result in similar reductions in annual carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOC), and sulfur oxides (SOx) emissions. By 2033, annual vehicle emissions for CO, NOx, VOC, and SOx in Pennsylvania would be approximately 5-6 percent less than the baseline in Scenario 2 (low policy, high technology), approximately 9-10 percent less in Scenario 3 (high policy, low technology), and approximately 25-27 percent less in Scenario 4 (high policy, high technology). The anticipated emissions reductions for particulate matter are somewhat less. While EVs have zero tailpipe particulate matter emissions, they still emit large particulate matter (PM_{10}) and $PM_{2.5}$ from tire and brake wear, explaining the lower reductions for PM in the higher EV adoption scenarios than other pollutants. Researchers believe tire and brake wear from vehicles with regenerative braking (which includes EVs) to be less, though research has not yet been conducted to measure the difference in impacts. Figures for Scenario 1 (low policy, low technology) are in pounds, and each additional scenario is reported as a percent difference from that baseline case in that year.

Table 25: Criteria pollutant emissions by scenario and horizon year (vehicle operation only, million lbs.)

Scenario and pollutant	Year		
Carbon monoxide (CO)	2023	2028	2033
Scenario 1: Low policy, low technology	**468.7**	**490.1**	**389.0**
Scenario 2: Low policy, high technology	*-0.1%*	*0.0%*	*-4.9%*
Scenario 3: High policy, low technology	*+0.6%*	*-2.3%*	*-9.4%*
Scenario 4: High policy, high technology	*-1.0%*	*-7.2%*	*-25.8%*
Nitrogen oxides (NOx)	2023	2028	2033
Scenario 1: Low policy, low technology	**31.4**	**32.8**	**22.5**
Scenario 2: Low policy, high technology	*-0.1%*	*0.0%*	*-5.0%*
Scenario 3: High policy, low technology	*+0.7%*	*-2.4%*	*-9.7%*
Scenario 4: High policy, high technology	*-1.0%*	*-7.5%*	*-26.5%*
Large particulate matter (PM_{10})	2023	2028	2033
Scenario 1: Low policy, low technology	**8.6**	**9.2**	**8.8**
Scenario 2: Low policy, high technology	*0.0%*	*0.0%*	*-0.8%*
Scenario 3: High policy, low technology	*+0.2%*	*-0.5%*	*-1.6%*
Scenario 4: High policy, high technology	*-0.2%*	*-1.6%*	*-4.2%*
Fine particulate matter ($PM_{2.5}$)	2023	2028	2033
Scenario 1: Low policy, low technology	**2.5**	**2.6**	**2.3**
Scenario 2: Low policy, high technology	*0.0%*	*0.0%*	*-2.8%*
Scenario 3: High policy, low technology	*+0.4%*	*-1.5%*	*-5.5%*
Scenario 4: High policy, high technology	*-0.6%*	*-4.6%*	*-15.1%*
Volatile organic compounds (VOC)	2023	2028	2033
Scenario 1: Low policy, low technology	**30.2**	**31.5**	**29.5**
Scenario 2: Low policy, high technology	*-0.1%*	*0.0%*	*-5.1%*
Scenario 3: High policy, low technology	*+0.7%*	*-2.4%*	*-10.0%*
Scenario 4: High policy, high technology	*-1.0%*	*-7.5%*	*-27.4%*
Sulfur oxides (SOx)	2023	2028	2033
Scenario 1: Low policy, low technology	**1.2**	**1.1**	**1.0**
Scenario 2: Low policy, high technology	*0.0%*	*+0.1%*	*-4.6%*
Scenario 3: High policy, low technology	*+0.3%*	*-2.2%*	*-9.1%*
Scenario 4: High policy, high technology	*-0.7%*	*-5.8%*	*-24.6%*

NOx and VOC are important precursors to ozone, which can cause asthma and other respiratory problems, and Pennsylvania has areas that currently exceed national ozone standards. Pennsylvania also has areas that exceed national standards for fine particulate matter, $PM_{2.5}$, which is understood to have greater human respiratory and other health impacts than larger scale PM_{10}. Light-duty vehicles are the primary contributor to carbon monoxide, which can cause cardiovascular and heart problems.

4.2.2.4 Social and Environmental Impacts

Table 26 summarizes the social and environmental impacts for each scenario, meaning the estimated cost of impacts to human health, property damage due to increased natural disasters, natural ecosystems, agricultural systems, and other damages from greenhouse gas and air pollution. The AFLEET model uses estimates from the Interagency Working Group on Social Cost of Carbon[72] to estimate the future impacts of greenhouse gas emissions, and utilizes values from the Air Pollution Emission Experiments and Policy Analysis (AP2) model,[73] which calculates the marginal damages from additional emissions of each criteria pollutant regionally. Figures for Scenario 1 (Low policy, low technology) are reported as the total estimated social and environmental costs, and each additional scenario is reported as the difference from that baseline case in that year. Negative figures indicate a reduction in social and environmental costs.

Table 26: Social and environmental impacts costs by scenario and horizon year

Scenario and Emissions Impact	Year		
Greenhouse gas social and environmental impacts	**2023**	**2028**	**2033**
Scenario 1: Low policy, low technology	**$1,959M**	**$1,780M**	**$1,605M**
Scenario 2: Low policy, high technology	*+$1M*	*+$2M*	*-$45M*
Scenario 3: High policy, low technology	*+$3M*	*-$27M*	*-$96M*
Scenario 4: High policy, high technology	*-$8M*	*-$64M*	*-$249M*
Criteria pollutant social and environmental impacts	**2023**	**2028**	**2033**
Scenario 1: Low policy, low technology	**$1,117M**	**$1,157M**	**$1,059M**
Scenario 2: Low policy, high technology	*-$0.7M*	*-$0.2M*	*-$47M*
Scenario 3: High policy, low technology	*+$6M*	*-$24M*	*-$92M*
Scenario 4: High policy, high technology	*-$10M*	*-$75M*	*-$251M*

By 2033, it is estimated that Scenario 2 would save an estimated $45 million annually in damages from greenhouse gases and $47 million annually from criteria pollutants. Scenario 3 would save an estimated $96 million from greenhouse gases and $92 million from criteria pollutants annually, and Scenario 4 would save about half a billion dollars in combined damages from greenhouse gases and criteria pollutants annually.

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[72] Interagency Working Group on Social Cost of Carbon, United States Government. (2010, February). *Technical Support Document: - Social Cost of Carbon for Regulatory Impact Analysis - Under Executive Order 12866*. Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf

[73] National Research Council. (2010). Appendix C: Description of the Air Pollution Emission Experiments and Policy (APEEP) Model and Its Application. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. Washington, DC: The National Academies Press. Retrieved from https://www.nap.edu/read/12794/chapter/16

4.2.3 BENEFIT-COST ANALYSIS RESULTS

Table 27 and Table 29 present the results of the benefit-cost analysis for each scenario. Results are reported in the form of a benefit-cost ratio (with ratios over 1.0 indicating a cost-effective program), net benefits, and in snapshots for program investments made in the years 2023, 2028, and 2033. Note that these scenarios provide a range of possible impacts to the state of Pennsylvania rather than a prediction of future impacts, given that these estimates are highly sensitive to several variables in the model, such as the future level of policy support, EV technology advancement, and EV market uptake.

Across all tests, results are more cost-effective in scenarios that assume higher technology improvement than scenarios that assume lower levels of technology improvement. Similarly, results are more cost-effective in scenarios that assume lower rather than higher policy costs. In most scenarios, the program is expected to be cost-effective from both the TRC and SCT perspectives, with the SCT providing greater net benefits due to the inclusion of environmental benefits and the use of a lower discount rate. In Scenario 3, the TRC benefit-cost ratio falls below one, though the societal cost test still passes, representing a case in which EV technology advances minimally while the state makes significant investments in incentive programs and policies.

All scenarios are expected to be cost-effective from the participant perspective by 2033 (Table 27: Benefit-cost analysis ratio results for each scenario in each horizon year*Table 27), with the greatest participant benefits experienced in Scenario 2, in which rapid technology advancement reduces upfront costs and maintenance costs for EV drivers. Ratepayer impacts are closely connected to policy costs. In scenarios with low policy costs, ratepayer benefits of electrification programs are expected to yield a net benefit to non-participants as increased utility revenues provide downward pressure on rates. In scenarios with higher policy costs, however, the socialized costs of additional state and utility policies and incentive programs override the benefits of increased electric loads, and lead to a net cost for non-participants.

Table 28 expands upon the benefit cost analysis results, showing the absolute benefits, absolute costs, and net benefits of each scenario in the year 2033 (in millions of U.S. dollars). For example, under the TRC test, Scenario 1 may reach $381 million in net benefits by 2033, whereas Scenario 4 may reach closer to $2.8 billion in net benefits by 2033. Similarly, both absolute benefits and absolute costs are also higher in Scenario 4, compared to Scenario 1.

Table 27: Benefit-cost analysis ratio results for each scenario in each horizon year*

Scenario and Cost Test	Year		
Scenario 1: Low policy, low technology	**2023**	**2028**	**2033**
Total Resource Cost	1.1	1.2	1.4
Societal Cost	1.4	1.6	1.8
Participant Cost	0.9	1.0	1.1
Non-Participant Cost	2.1	2.2	2.2
Scenario 2: Low policy, high technology	**2023**	**2028**	**2033**
Total Resource Cost	1.5	1.9	2.5
Societal Cost	1.9	2.4	3.1
Participant Cost	1.2	1.5	1.9
Non-Participant Cost	2.2	2.2	2.2
Scenario 3: High policy, low technology	**2023**	**2028**	**2033**
Total Resource Cost	0.8	0.8	0.9
Societal Cost	1.0	1.1	1.2
Participant Cost	1.0	1.0	1.1
Non-Participant Cost	0.9	0.9	0.9
Scenario 4: High policy, high technology	**2023**	**2028**	**2033**
Total Resource Cost	1.0	1.1	1.3
Societal Cost	1.2	1.4	1.6
Participant Cost	1.3	1.6	1.9
Non-Participant Cost	0.9	0.9	1.0

**Note:* *Ratios over 1.0 indicate cost-effectiveness. A ratio of 1.1 indicates the lifetime benefits are 10 percent greater than the lifetime costs for program investments made in that year, whereas a ratio of 2.0 indicates the lifetime benefits are 200 percent of the costs for program investments made in that year.*

Table 28: Benefit-cost analysis results: absolute costs, absolute benefits, and net benefits for each scenario in 2033 (listed in Million $)

Scenario and Cost Test	2033		
Scenario 1: Low policy, low technology	**Benefits**	**Costs**	**Net benefits**
Total Resource Cost	$1,407	-$1,026	$381
Societal Cost	$1,977	-$1,103	$875
Participant Cost	$1,316	-$1,233	$84
Non-Participant Cost	$552	-$255	$298
Scenario 2: Low policy, high technology	**Benefits**	**Costs**	**Net benefits**
Total Resource Cost	$4,700	-$1,905	$2,795
Societal Cost	$6,628	-$2,161	$4,468
Participant Cost	$4,843	-$2,615	$2,228
Non-Participant Cost	$1,864	-$849	$1,014
Scenario 3: High policy, low technology	**Benefits**	**Costs**	**Net benefits**
Total Resource Cost	$4,220	-$4,634	-$415
Societal Cost	$5,929	-$5,086	$843
Participant Cost	$4,162	-$3,696	$466
Non-Participant Cost	$1,655	-$1,784	-$128
Scenario 4: High policy, high technology	**Benefits**	**Costs**	**Net benefits**
Total Resource Cost	$11,614	-$8,833	$2,781
Societal Cost	$16,377	-$10,055	$6,322
Participant Cost	$12,535	-$6,462	$6,073
Non-Participant Cost	$4,605	-$4,802	-$197

SECTION 5 CONCLUSIONS AND NEXT STEPS

This section summarizes the benefits of increasing policy action in Pennsylvania to strengthen and expand the EV market in the state and reviews the priority strategies recommended to achieve the state's EV deployment goals.

5.1 SUMMARY OF THE BENEFITS OF PROACTIVE EV POLICY ACTION FOR PENNSYLVANIA

As mentioned previously, an electrified transportation system can provide significant benefits for the environment, economy, and society in Pennsylvania. The potential benefits include greenhouse gas reductions, air pollutant reductions, consumer cost savings, benefits to the electricity grid, and economic development benefits.

The modeling component of this roadmap illustrates that a growing EV market in Pennsylvania provides numerous health and environmental benefits, while also maintaining economic benefits to society and potential EV consumers. All scenarios analyzed are projected to be cost-effective to society and to the future EV consumers in 2033. By 2033, the most ambitious EV adoption scenario (Scenario 4: 80x50) is likely to reduce greenhouse gas emissions in the state by about 16 percent by 2033 from 38.5 million metric tons of greenhouse gases and reduce nitrogen oxides by about 27 percent from 22.5 million pounds. As Pennsylvania's electric grid adopts more low-carbon sources of energy, environmental benefits to the commonwealth will continue to increase.

5.2 PRIORITY ACTIONS FOR PENNSYLVANIA'S EV MARKET

This roadmap is the result of 10 months of policy research, data and policy analysis, and facilitated discussions with DEP and stakeholders in the Drive Electric Pennsylvania Coalition. The facilitated discussions centered on goals for the EV market in Pennsylvania, key barriers to EV adoption in the commonwealth, existing EV-supportive policies across the U.S., and high-priority market interventions (e.g., policies, initiatives, actions) for Pennsylvania.

Research about the impact of EV adoption policies have found individual policies to be less effective in isolation than in combinations that are complementary to one another. The strategies identified in this roadmap are intended to collectively represent a feasible yet high impact pathway to overcome key barriers and accelerate EV market development in Pennsylvania. Priority actions for the near term include setting a statewide EV sales target, legislating a utility transportation electrification directive, consumer and dealer marketing campaigns, and a fleet education and purchasing program. This set of strategies, combined with potential EV technology advancement, is likely to jumpstart Pennsylvania's EV market far beyond its current deployment level.

Table 29: Timeline of recommended strategies to support EV adoption in Pennsylvania.

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 multi-family EVSE education and outreach program		■	
Adopt EV-Ready building code amendments			■
Explore development of financing for EVs/EVSE			■

As the commonwealth works to implement the strategies laid out in this roadmap, it will be important to do so in an iterative manner, i.e., implementing pilot programs and evaluating impacts to refine policies and programs to ensure that they have the desired impact of increasing EV adoption. Accordingly, it is recommended that these strategies be revisited periodically to adjust to changes in the EV marketplace in Pennsylvania.

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APPENDIX A - ROADMAP PROCESS AND REVIEW

Through three quarterly facilitations and monthly subcommittee conference calls, stakeholders from different sectors around the state contributed their perspective to this roadmap. To inform the roadmap process, the Consulting Team reviewed several EV deployment plans and roadmaps from other states, including the highlighted plans in Table 30.

Table 30: Highlights from other state EV roadmaps

State	Year	Title (Author)	Description
MD	2012	Final report to the Governor and Maryland General Assembly (Maryland Electric Vehicle Infrastructure Council)	This plan outlines actions designed to help Maryland reach its goal of having 60,000 PEVs on the road by 2020, or 2.3% of the state passenger fleet. The plan includes a detailed set of recommendations with specific goals, set out in different phases of implementation, with primary recommendations focused on the state fleet, working with counties and municipalities on local programs, exploring bulk purchase strategies, extending current incentive programs, providing grants for EVSE installation, and exploring low cost financing strategies to reduce incremental costs.
OH	2013	Electric Vehicle Readiness Plan for Ohio (Drive Electric Ohio)	This plan includes analysis of EV adoption projections, EVSE needs, economic impacts, grid impacts, and a wide range of policy and program recommendations to accelerate adoption. This plan emphasizes the potential economic impact of EV investment for Ohio's 3rd in the nation automotive industry and suppliers, estimating that every 1,000 EVs in Ohio supports 20 additional jobs and over $1.3 million in economic impact.
CO	2015	Electric Vehicle Market Implementation Study (Colorado Energy Office)	This study for the state of Colorado assesses the progress in EV deployment thus far, assesses the barriers to further deployment through a survey of Colorado consumers, forecasts potential levels of penetration, analyzes and recommends charging station locations, and makes policy and program recommendations to drive further adoption.
WA	2015	Washington State Electric Vehicle Action Plan (WSDOT)	This report outlines a five-year plan to achieve Washington state's goal to put 50,000 EVs on the road between 2015 and 2020, outlining 13 strategies/actions to reach that goal. The study engaged over 50 partners in the preparation of the report, which was conducted by staff of the state Department of Transportation.
IA	2016	Advancing Iowa's Electric Vehicle Market (Iowa Clean Cities Coalition)	This study includes an analysis of the current state of the EV market in Iowa, a geographic analysis of locations with anticipated charging station demand, recommended locations for charging station investments, an analysis of current EV utility rates, an analysis of behavioral as well as policy barriers in Iowa, a menu of policy and program recommendations, resources for employers and other stakeholders who might wish to market EVs to their constituents, and other marketing strategies.

State	Year	Title (Author)	Description
CA	2016	2016 ZEV Action Plan (Governor's Interagency Working Group on Zero-Emission Vehicles)	This action plan outlines California's progress to date with reaching its goal of 1.5 million ZEVs by 2025. California as of 2016 had 47% of the estimated 500,000 EVs on the road in the US, driven by strong climate targets, revenues from cap and trade being invested into vouchers and incentives for electric and other alternative fuel vehicles, and legislation such as Senate Bill 350 driving utility investment in transportation electrification. The plan documents existing legislation and programs, as well as recommended areas of focus moving forward, including raising consumer awareness, increasing equity and accessibility to EVs, and increasing commercial viability for select applications with an emphasis on California's large freight sector.
NJ	2017	A Roadmap for Vehicle Electrification in New Jersey (The Electric Vehicle Coalition of New Jersey)	This roadmap was created by a coalition of industry, community, labor, local government, and environmental advocates, and focuses on setting clear EV deployment and market share targets based on the ZEV state targets and their climate change targets, clear EVSE installation goals, ensuring equity and accessibility in their approach to electrification, and increasing educational and awareness initiatives.

APPENDIX B – NATIONAL EV DEPLOYMENT STRATEGY EXAMPLES

GOALS AND TARGETS

Public fleet electrification targets

Public fleet electrification targets set goals that must be achieved for state-owned fleet vehicles by a certain time. Targets can be based upon a certain proportion of new vehicle purchases, a proportion of the entire vehicle fleet, or a greenhouse gas or fossil fuel use reduction target specifically for state fleets. One example is Massachusetts' Chapter 169, Section 1 of "An Act Relative to Green Communities", which set a goal of 50 percent of vehicles owned and operated by the commonwealth to be alternative fuel vehicles or hybrids by 2018 [https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169].

PRICING-BASED POLICIES

HOV lane access for EV drivers

Some states have granted EV drivers access to high occupancy vehicle lanes. California's Green Clean Air Vehicle decal program provides special identifying decals to a certain number of applicants that are capped each year. According to one analysis, the ability to access HOV lanes was responsible for up to 40 percent of EV purchases in some California metro areas in 2013. Some challenges with this approach include that consumers may grow to expect this benefit, but at higher deployment levels, it could prove problematic for the functioning of HOV lanes to continue to provide this benefit. [http://innovation.luskin.ucla.edu/content/how-does-presence-hov-lanes-affect-plug-electric-vehicle-adoption-california-generalized-pro]

ENABLING REGULATIONS

Atlanta "EV Ready" Ordinance

Atlanta passed a new ordinance in 2017 requiring all new residences and parking facilities to accommodate EVs. Specifically, the ordinance requires 20 percent of commercial and multi-family parking spaces to be EV-ready, and for residences to be equipped with the needed infrastructure to install EVSE, such as conduit, wiring, and electrical capacity. https://www.atlantaga.gov/Home/Components/News/News/10258/1338?backlist=/

FINANCING AND BUSINESS MODELS

BlueIndy electric shared-use mobility partnership

Electrifying shared-use mobility can provide electric options for those who don't own their own cars, can help reduce single occupant vehicle use, and can help expose more consumers to EV technology. Multiple cities have experimented with creating partnerships for electric car share options, including Indianapolis' BlueIndy. BlueIndy was formed through *a contract between the City of Indianapolis and Bollere to provide one-way electric car-sharing service in the city. Funding for the charging infrastructure network comes from the city, the car-sharing company, and from ratepayer funds from Indianapolis Power and Light to provide distribution system level upgrades. [*http://www.indy.gov/eGov/Mayor/initiatives/Pages/Electric-Vehicles0124-4069.aspx*, http://atlaspolicy.com/wp-content/uploads/2017/04/2017-04-06_Lessons_Learned_from_BlueIndy.pdf;]*

PUBLIC PLANNING AND INVESTMENT

Kansas City Power and Light

Kansas City's utility, Kansas City Power and Light invested $20 million of investor funds to build 1,000 public EV charging stations in 2015 and in one year, saw 130 percent growth in EV registrations. https://www.theicct.org/sites/default/files/publications/US-Cities-EVs_ICCT-White-Paper_25072017_vF.pdf

MARKETING, OUTREACH, AND EDUCATION

Cooperative purchasing programs

Solar Benefits Colorado was a regional EV cooperative purchasing initiative of Boulder County, Adams County, and the City and County of Denver that worked with solar providers and dealerships to negotiate bulk purchase prices resulting in a 26 percent discount on 2015 Nissan LEAFs. The program increased sales three-fold from 2014-2015 in Boulder County, with just 28 percent of participants reporting they had been considering an EV previously. http://www.swenergy.org/data/sites/1/media/documents/publications/documents/Colorado_EV_Group_Purchase_Programs_Mar-2016.pdf

APPENDIX C – SCENARIO MODELING METHODS AND ASSUMPTIONS

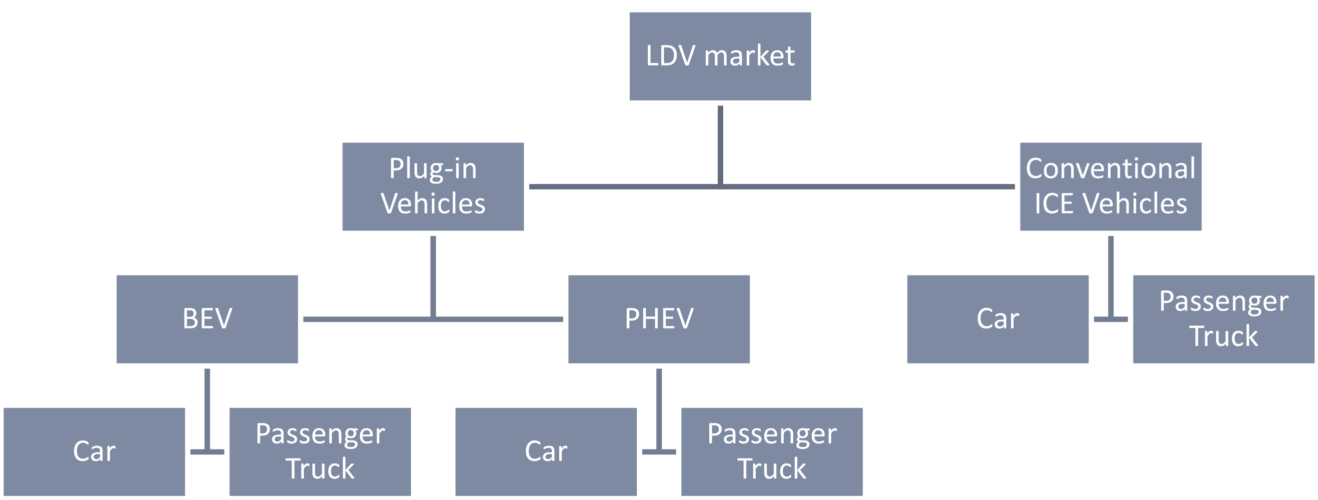
METHODS FOR FLEET, ENERGY, AND ENVIRONMENTAL MODELS

As noted previously, the market share inputs for each scenario were reported as percentage of plug-in vehicle sales in each vehicle model year. To track overall fleet penetration of EVs, vehicle utilization, fuel consumption, and emissions resulting from each sales scenario, a range of tools and inputs were utilized:

- A custom fleet penetration model based on sales and scrappage
- A wide range of federally available data
- Argonne National Laboratories' AFLEET tool

Within the AFLEET tool, the Pennsylvania light duty vehicle market was divided into six broad segments as demonstrated in Figure 14:. This hierarchy was chosen to align with 1) input from the Drive Electric Pennsylvania Coalition on the sales ratio of plug-in vehicles versus internal combustion vehicles in the four scenarios, 2) data available from the U.S. DOE Alternative Fuels Data Center on the historical breakdown of BEV versus PHEV sales[74], and 3) the assumptions used in MJ Bradley's recent analysis of Pennsylvania plug-in EV futures[75], which provided insights regarding the percentage of BEVs and PHEVs respectively that were likely to be cars and passenger trucks. Numerous additional assumptions were made in the fleet modeling. A summary of the most important of these parameters and inputs is provided below.

Figure 14: Groupings of vehicles in the fleet model



[74] U.S. Office of Energy Efficiency & Renewable Energy. (2017, May). Alternative Fuels Data Center. *U.S. Plug-in Electric Vehicle Sales by Model.* Retrieved from https://www.afdc.energy.gov/data/10567
[75] Lowell, D., Jones, B., Seamonds, D. (2016, December). *Electric Vehicle Cost-Benefit Analysis: Pennsylvania.* https://mjbradley.com/sites/default/files/PA_PEV_CB_Analysis_FINAL.pdf

METHODS FOR ECONOMIC MODELING

For each test, lifetime costs and benefits were determined by discounting a series of annual cashflows relevant for each test and are reported as ratio of lifetime benefits to lifetime costs. The components of each benefit-cost test used in this analysis are summarized in Table 31.

Table 31: Summary of Utility Cost Tests for EV Benefit-Cost Analysis

	Total Resource Cost (TRC)	Societal Cost Test (SCT)	Participant Cost Test (PCT)	Ratepayer Impact Measure (RIM)
Benefits				
Avoided Gasoline Purchases	X	X	X	
Avoided ICE Vehicle O&M	X	X	X	
Increased Ratepayer Revenue				X
State/Utility Incentives to Participants			X	
Federal EV Tax Credit	X	X	X	
Environmental Benefits		X		
Costs				
Added Utility Energy Costs	X	X		X
Added Utility Capacity Costs	X	X		X
Added Retail Electricity Costs			X	
Upfront EV & Home EVSE Costs & O&M	X	X	X	
EVSE Costs Incurred by State of Utility	X	X		X
EVSE Costs Incurred by Private Entities	X	X		
State/Utility Incentive Expenditures				X
State/Utility Administrative Expenditures	X	X		X

This analysis relied on the results of the policy, adoption, and technology scenarios above to source inputs related to policy and program costs, vehicle and infrastructure costs, and participation rates. Utility inputs (utility energy and capacity costs, and line losses) were collected from utility reporting related to Act 129 program evaluations; where available data from PPL, PECO, and Duquesne were averaged to yield representative statewide numbers. Retail electricity and gas prices were sourced from utility and U.S. EIA data, and escalated using EIA forecasts. Peak impacts were calculated using peak hourly data from the PJM market, and hourly EV charging patterns from the U.S. DOE EV Project were utilized.[76] Following the evaluation of energy efficiency programs under Act 129, cashflows in TRC and

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[76] The degree to which added EV charging increases the need for additional electricity generation facilities at the times at which the electricity grid is at its highest utilization is considered the "peak impact" and requires the utility to secure additional generation capacity to serve this new level of peak load. Therefore, assumptions around when EVs will be charged are essential for determining the costs in several of the cost tests.

RIM tests were discounted using utility-weighted average costs of capital (values from the three utilities noted above were averaged to yield an input of 8.33 percent). A participant discount rate of 10 percent was used. A societal discount rate of 3 percent was used, based on the current 20-year U.S. treasury yield. Environmental benefits related to avoided GHG and criteria pollutant emissions were calculated from the AFLEET model. A more detailed description of inputs can be found below.

FLEET MODEL ASSUMPTIONS

1) Initial age distribution (model year distribution) of conventional internal combustion engine vehicles (ICEVs)
    a. National vehicle age distribution data was obtained from U.S. DOT Volpe Center calculations and applied to Pennsylvania.
    b. Based upon U.S. Bureau of Transportation Statistics (BTS) data (https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_11.html)
2) Initial age distribution (model year distribution) of EVs
    a. From AFDC: https://www.afdc.energy.gov/data/10567
3) Growth in annual light duty vehicle (LDV) market sales
    a. Sales growth rate was set to a number that would make Pennsylvania's total LDV fleet grow by the same percentage as the AEO national projections by 2033.
    b. Based upon data from AEO 2018 Table 40 (https://www.eia.gov/outlooks/aeo/tables_ref.php)
4) Rates of scrappage of LDVs of different ages
    a. The model applied nationwide historical scrappage data from the U.S. National Highway Traffic Safety Administration (NHTSA), and assumed it remains unchanged through 2033.
    b. Obtained from Table 3, Column 2 of DOT HS 809 952 Technical Report: Vehicle Survivability and Travel Mileage Schedules (https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/809952)
5) Fraction of LDVs that are cars versus light trucks
    a. Data was sourced from Volpe calculations for its Volpe Model and the assumption was made that the percentage of light trucks versus cars in the LDV fleet in Pennsylvania approximates the national percentage.
6) Fuel economy
    a. MPG of conventional cars and light trucks
        i. Projections are based on the Volpe Model adjusted CAFE standards, which are based upon 40 CFR 86.1818-12(h).[77]
        ii. Volpe performed calculations to adjust MPG assumptions to account for the varying amount of EV credits in each of the Pennsylvania EV Roadmap scenarios.

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[77] Though there is a pending NHTSA rulemaking in the spring of 2018, the current regulations on the books were used.

The amount of EV credits generated in the scenarios impacts the fuel economy of the rest of the fleet. The source for this adjustment is the U.S. EPA "Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards," p. 4-133.

b. MPGe of BEV cars and light trucks
    i. Current fuel economy of pure battery EVs, in miles per gallon equivalent (MPGe), was estimated by taking the midpoint of the range of fuel economy statistics reported for BEVs on www.fueleconomy.gov. The model assumes a 1 percent increase in efficiency per year through 2033.

c. Overall MPG of PHEV cars and light trucks
    i. Fuel economy for plug-in hybrids (PHEVs) was estimated for both charge sustaining mode and charge depleting mode. A simplifying assumption was made that no gasoline is consumed during charge depleting mode (i.e., that most PHEVs in the fleet will operate more like an extended range EV (EREV) than a vehicle that spends a lot of time in a blended mode.
    ii. Charge sustaining (CS) mode and charge depleting (CD) mode efficiencies for 2017 were sourced from AFLEET default assumptions and www.fueleconomy.gov. For forecast years, the model assumes a 1 percent increase in efficiency per year through 2033, for both CS and CD modes.
    iii. Assumptions on the percentage of mileage driven on charge sustaining versus charge depleting modes were sourced from AFLEET and increased linearly over time to account for a larger fraction of PHEVs having larger batteries in future model years.
    iv. We selected the midpoint of the range of MPGe figures listed on www.fueleconomy.gov to estimate the 2017 MPGe of PHEVs in charge depleting mode.

7) Vehicle utilization (in annual vehicle miles traveled, VMT) as a function of age
    a. The model applied nationwide historical VMT data as a function of vehicle age from the U.S. National Highway Traffic Safety Administration (NHTSA), and assumed it remains unchanged through 2033.
    b. Obtained from DOT HS 809 952 Technical Report: Vehicle Survivability and Travel Mileage Schedules (https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/809952)

8) Fraction of BEVs and PHEVs that are cars versus light trucks out to 2033
    a. The model adopted the assumptions found in the 2016 report *Plug-in Electric Vehicle Cost-Benefit Analysis: Pennsylvania* by MJ Bradley. https://mjbradley.com/sites/default/files/PA_PEV_CB_Analysis_FINAL.pdf

ENVIRONMENTAL, ENERGY, AND ECONOMIC MODELING ASSUMPTIONS

1) Regional electricity mix
   a. Electricity mix uses EIA AEO 2018 for the Reliability First Corporation East (RFCE) region, which largely coincides with Pennsylvania (note: AEO 2018 does not include the Clean Power Plan assumption). Analysis then uses AFLEET emissions factors for each electricity fuel type.
2) Vehicle prices
   a. For the low technology scenarios, figures from EIA AEO 2018 are utilized, using weighted average by sales (EIA) for vehicle size. For light trucks, prices for small SUVs only are included due to lack of prices for other models. Prices are also weighted for PHEV, BEV prices between PHEV 10/40 mile and EV 100/200 mile based on EIA sales forecasts.
   b. For the high technology scenarios, the modeling uses NREL Electrification Future Studies' ratio of their BEV and PHEV prices in their Rapid Advancement to Slow Advancement cases (https://www.nrel.gov/docs/fy18osti/70485.pdf)
3) Utility costs
   a. Retail rates: First year rates averaged from PECO, PPL, and Duquesne values reported in Pennsylvania Act 129 programs. Escalators from EIA forecasts. The model assumes retail rates for public and home charging, since some public charging is free, and others are very expensive. The model does not currently assume any time-of-use rates are available.
   b. Utility Energy and Capacity costs: Averaged from PECO, PPL, and Duquesne values reported in Pennsylvania Act 129 programs.
   c. Discount rate: Averaged from PECO, PPL, and Duquesne values reported in Pennsylvania Act 129 programs for TRC/RIM (8.33%) and PCT (10%). Societal discount rate based on U.S. Treasury 20-year yield (3%).
   d. Peak hour: Peak hour sourced from PJM hourly load data.
4) EVSE investment costs, availability, and behavior
   a. Costs for charging infrastructure and installation from AFLEET, except for Level 1 chargers, which are assumed to be $0, since chargers usually come with vehicle purchase.
   b. Costs for EVSE are not assumed to differ between the high and low technology scenarios, and do not change over time, based on assumptions in NREL Electrification Futures Study. https://www.nrel.gov/docs/fy18osti/70485.pdf
   c. The model assumes 80% home charging, and assumes home and public charging profiles based on U.S. DOE's EV Project data. https://energy.gov/sites/prod/files/2014/02/f8/evproj_infrastructure_q22013_0.pdf, https://avt.inl.gov/project-type/downloads
   d. For residential charging, the model assumes half of EV owners will just have Level 1 at home, and half will have Level 2. http://www.edisonfoundation.net/iei/publications/Documents/IEI_EEI%20PEV%20Sales%20and%20Infrastructure%20thru%202025_FINAL%20(2).pdf

e. EV to EVSE ratios assumed are based on Pennsylvania's current ratios for the low policy scenarios, and based on EPRI/NREL projections for the high policy scenarios. Workplace EVSE, or "quasi-public" EVSE are assumed to be eligible for rebates, while in the high policy scenarios, some direct utility ownership that would cover the whole cost of public EVSE is envisioned. The share of direct utility ownership to private ownership is based on recent filings by utilities in Maryland to the PSC. [Proposal to Implement a Statewide Electric Vehicle Portfolio](http://www.edisonfoundation.net/iei/publications/Documents/IEI_EEI%20PEV%20Sales%20and%20Infrastructure%20thru%202025_FINAL%20(2).pdf). http://www.edisonfoundation.net/iei/publications/Documents/IEI_EEI%20PEV%20Sales%20and%20Infrastructure%20thru%202025_FINAL%20(2).pdf.

Table 32: EVSE plugs per 1,000 EV ratios used in BCA modeling analysis

	Low policy scenario	High policy scenario
Workplace EVSE per 1,000 EVs	**39**	**264**
Public EVSE per 1,000 EVs	**10**	**66**
DCFC EVSE per 1,000 EVs	0.5	3
Public EVSE funded by incentives per 1,000 EVs	6	44
Public utility-owned EVSE per 1,000 EVs	-	22

5) Individual/per vehicle costs (participant cost)
   a. Modeling assumes same VMT per year as in fleet model.
   b. Modeling assumes 15-year vehicle lifetime (same as AFLEET).
   c. Model only includes fuel, maintenance, vehicle purchase, and EVSE costs – and doesn't include insurance, etc. which AFLEET assumes is the same between vehicle technologies.
6) Fuel costs
   a. Gasoline prices from EIA for the PADD 1B: Central Atlantic are utilized for 2018.
   b. Fuel cost escalators for the EIA Annual Energy Outlook 2018 Reference Case are utilized for gasoline and electricity prices.
7) Maintenance costs
   a. The BCA modeling utilizes LDV scheduled maintenance cost assumptions from NREL's Electrification Futures Study Slow and Rapid Technology Advancement scenarios, which are matched to the Roadmap's low and high technology scenarios.[78] In the low technology case, NREL assumes EVs would have the same scheduled maintenance costs as conventional vehicles, while in the high technology case, NREL assumes scheduled maintenance costs for BEVs would be half that of conventional vehicles per mile, and costs for PHEVs would be 75 percent of conventional vehicles per mile.
   b. EVSE operations and maintenance costs from AFLEET are utilized in the model.

[78] Cooper, A., Schefter, K. (2017, June). *Plug-in Electric Vehicle Sales Forecast Through 2025 and the Charging Infrastructure Required.* Retrieved from https://www.nrel.gov/docs/fy18osti/70485.pdf

8) Policy packages

a. Federal tax credits: The scenario modeling for consistency assumes the federal tax credit remains available for BEVs and PHEVs through 2033 in the high policy scenarios, while in the low policy scenarios, it is assumed that the federal tax credit has been phased out for all vehicle manufacturers.

b. Utility transportation electrification directive: This policy is not assumed to have any program administrative costs, as it is meant simply to enable other programs listed below to be enacted.

c. ZEV sales mandate: In the high policy scenarios, costs for having a sales mandate program like the ZEV program are based on reported costs by New Jersey for complying with the CALEV program (http://dlslibrary.state.md.us/publications/OPA/I/OCLEVP_2006.pdf)

d. EV rebates: In the low policy scenarios, the share of new EVs rebated is assumed to remain constant at 25 percent (approximate share of EVs sold rebated in Pennsylvania in recent years) at a rebate level $1,750 per vehicle). In the high policy scenarios, the share of new EVs rebated is assumed to increase to 50 percent of EVs sold (closer to other leading ZEV states like CA, CT, and MA), with rebates also rising to $2,500 per vehicle. Sources: CA: https://www.arb.ca.gov/msprog/aqip/cvrp/cvrp_fy1112_qa_080911.pdf and https://cleanvehiclerebate.org/sites/default/files/docs/nav/transportation/cvrp/documents/CVRP-Implementation-Manual.pdf. CT: http://www.ct.gov/deep/cwp/view.asp?a=2684&q=565018&deepNav_GID=2183. MA: https://mor-ev.org/funding

e. Public, workplace, and fleet EVSE funding: In the low policy scenarios, $5,000 rebates for public/workplace/fleet EVSE are available for the ratio of EVSE to EVs highlighted in the table above. In the high policy scenarios, $5,000 rebates for public/workplace/fleet EVSE are available for the ratio of EVSE to EVs for the high policy scenarios in the table above, and 1/3 of the publicly available EVSE are fully funded by the utility at $17,000/charger on average. Rebate levels and EVSE costs are based on recent utility filings with the Maryland PSC. Proposal to Implement a Statewide Electric Vehicle Portfolio.

f. Residential EVSE incentives: In the high policy scenarios, $500 rebates are available for 50 percent of new EVs each year, based on rebate programs proposed in recent utility filings with the Maryland PSC. Proposal to Implement a Statewide Electric Vehicle Portfolio.

g. Education and awareness campaign: In the high policy scenarios, a statewide education campaign is funded at a level of 5 percent of the total program costs of all other programs, which is a benchmark from recent utility filings with the Maryland PSC. Proposal to Implement a Statewide Electric Vehicle Portfolio

APPENDIX D - MODELING RESULTS FOR MAJOR METROPOLITAN STATISTICAL AREAS IN PENNSYLVANIA

Table 33 through Table 36 highlight the EV adoption, energy impacts, and emissions impacts of each scenario in each of the major Pennsylvania metropolitan areas (MSAs), as well as in the rest of the state outside those MSAs. Figures are based on the number of vehicles registered in the Pennsylvania counties within each MSA, according to PennDOT data.

Table 33: Projected EVs deployed in Pennsylvania major MSAs by scenario in 2033

Scenario	Allentown-Bethlehem-Easton	Harrisburg-Carlisle	Lancaster	Philadelphia-Camden-Wilmington	Pittsburgh	Scranton-Wilkes-Barre	Rest of state
Scenario 1: Low policy, low technology	23,000	31,000	26,000	139,000	111,000	26,000	281,000
Scenario 2: Low policy, high technology	37,000	51,000	43,000	226,000	180,000	42,000	459,000
Scenario 3: High policy, low technology	52,000	70,000	60,000	315,000	251,000	59,000	638,000
Scenario 4: High policy, high technology	103,000	141,000	119,000	629,000	502,000	118,000	1,276,000

Table 34: Energy impacts for Pennsylvania major MSAs by scenario in 2033

Scenario and energy unit							
Million gallons of gasoline	Allentown-Bethlehem-Easton	Harrisburg-Carlisle	Lancaster	Philadelphia-Camden-Wilmington	Pittsburgh	Scranton-Wilkes-Barre	Rest of state
Scenario 1: Low policy, low technology	122.2	166.3	141.3	744.3	593.9	139.2	1,509.9
Scenario 2: Low policy, high technology	116.7	158.8	135.0	710.7	567.1	132.9	1,441.8
Scenario 3: High policy, low technology	111.1	151.1	128.4	676.2	539.5	126.4	1,371.8
Scenario 4: High policy, high technology	92.2	125.4	106.6	561.3	447.9	105.0	1,138.7
Thousand MWh of electricity	Allentown-Bethlehem-Easton	Harrisburg-Carlisle	Lancaster	Philadelphia-Camden-Wilmington	Pittsburgh	Scranton-Wilkes-Barre	Rest of state
Scenario 1: Low policy, low technology	69.7	94.9	80.6	424.4	338.6	79.4	861.0
Scenario 2: Low policy, high technology	120.0	163.3	138.7	730.6	582.9	136.6	1,482.0
Scenario 3: High policy, low technology	161.9	220.3	187.2	985.8	786.5	184.3	1,999.7
Scenario 4: High policy, high technology	334.3	454.9	386.5	2,035.5	1,624.1	380.6	4,129.1

Table 35: Light duty vehicle greenhouse gas emissions in Pennsylvania major MSAs by scenario in 2033 (well-to-wheels, million metric tons)

Scenario	Allentown-Bethlehem-Easton	Harrisburg-Carlisle	Lancaster	Philadelphia-Camden-Wilmington	Pittsburgh	Scranton-Wilkes-Barre	Rest of state
Scenario 1: Low policy, low technology	1.38	1.87	1.59	8.39	6.69	1.57	17.01
Scenario 2: Low policy, high technology	1.34	1.82	1.55	8.15	6.50	1.52	16.53
Scenario 3: High policy, low technology	1.29	1.76	1.50	7.88	6.29	1.47	15.99
Scenario 4: High policy, high technology	1.16	1.58	1.34	7.08	5.65	1.32	14.37

Table 36: Light duty vehicle criteria pollutant emissions in Pennsylvania major MSAs by scenario in 2033 (vehicle operation, million lbs.)

Scenario and pollutant							
Carbon monoxide (CO)	Allentown-Bethlehem-Easton	Harrisburg-Carlisle	Lancaster	Philadelphia-Camden-Wilmington	Pittsburgh	Scranton-Wilkes-Barre	Rest of state
Scenario 1: Low policy, low technology	13.92	18.93	16.09	84.73	67.60	15.84	171.87
Scenario 2: Low policy, high technology	13.24	18.01	15.30	80.59	64.30	15.07	163.48
Scenario 3: High policy, low technology	12.60	17.15	14.57	76.75	61.23	14.35	155.68
Scenario 4: High policy, high technology	10.32	14.05	11.94	62.86	50.15	11.75	127.51
Nitrogen oxides (NOx)	Allentown-Bethlehem-Easton	Harrisburg-Carlisle	Lancaster	Philadelphia-Camden-Wilmington	Pittsburgh	Scranton-Wilkes-Barre	Rest of state
Scenario 1: Low policy, low technology	0.81	1.10	0.93	4.91	3.92	0.92	9.96
Scenario 2: Low policy, high technology	0.77	1.04	0.89	4.67	3.72	0.87	9.47
Scenario 3: High policy, low technology	0.73	0.99	0.84	4.44	3.54	0.83	9.00
Scenario 4: High policy, high technology	0.59	0.81	0.69	3.61	2.88	0.68	7.32
Large particulate matter (PM_{10})	Allentown-Bethlehem-Easton	Harrisburg-Carlisle	Lancaster	Philadelphia-Camden-Wilmington	Pittsburgh	Scranton-Wilkes-Barre	Rest of state
Scenario 1: Low policy, low technology	0.32	0.43	0.37	1.93	1.54	0.36	3.91
Scenario 2: Low policy, high technology	0.31	0.43	0.36	1.91	1.52	0.36	3.88
Scenario 3: High policy, low technology	0.31	0.42	0.36	1.89	1.51	0.35	3.84
Scenario 4: High policy, high technology	0.30	0.41	0.35	1.85	1.47	0.34	3.74

Fine particulate matter ($PM_{2.5}$)	Allentown-Bethlehem-Easton	Harrisburg-Carlisle	Lancaster	Philadelphia-Camden-Wilmington	Pittsburgh	Scranton-Wilkes-Barre	Rest of state
Scenario 1: Low policy, low technology	0.08	0.11	0.09	0.50	0.40	0.09	1.01
Scenario 2: Low policy, high technology	0.08	0.11	0.09	0.49	0.39	0.09	0.99
Scenario 3: High policy, low technology	0.08	0.11	0.09	0.47	0.38	0.09	0.96
Scenario 4: High policy, high technology	0.07	0.09	0.08	0.42	0.34	0.08	0.86
Volatile organic compounds (VOC)	**Allentown-Bethlehem-Easton**	**Harrisburg-Carlisle**	**Lancaster**	**Philadelphia-Camden-Wilmington**	**Pittsburgh**	**Scranton-Wilkes-Barre**	**Rest of state**
Scenario 1: Low policy, low technology	1.06	1.44	1.22	6.42	5.13	1.20	13.03
Scenario 2: Low policy, high technology	1.00	1.36	1.16	6.09	4.86	1.14	12.36
Scenario 3: High policy, low technology	0.95	1.29	1.10	5.78	4.61	1.08	11.73
Scenario 4: High policy, high technology	0.77	1.04	0.89	4.66	3.72	0.87	9.46
Sulfur oxides (SOx)	**Allentown-Bethlehem-Easton**	**Harrisburg-Carlisle**	**Lancaster**	**Philadelphia-Camden-Wilmington**	**Pittsburgh**	**Scranton-Wilkes-Barre**	**Rest of state**
Scenario 1: Low policy, low technology	0.04	0.05	0.04	0.21	0.17	0.04	0.43
Scenario 2: Low policy, high technology	0.03	0.05	0.04	0.20	0.16	0.04	0.41
Scenario 3: High policy, low technology	0.03	0.04	0.04	0.19	0.15	0.04	0.39
Scenario 4: High policy, high technology	0.03	0.04	0.03	0.16	0.13	0.03	0.33