New York State Transportation Electrification Report

Final Report | Report Number 21-06 | February 2021

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NYSERDA provides resources, expertise, and objective information so New Yorkers can make confident, informed energy decisions.

Our Vision:

New York is a global climate leader building a healthier future with thriving communities; homes and businesses powered by clean energy; and economic opportunities accessible to all New Yorkers.

Our Mission:

Advance clean energy innovation and investments to combat climate change, improving the health, resiliency, and prosperity of New Yorkers and delivering benefits equitably to all.

New York State Transportation Electrification Report

Final Report

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NYSERDA Report 21-06 February 2021

Abstract

This report has been developed by the New York State Energy Research and Development Authority (NYSERDA) pursuant to Chapter 676 of the laws of 2019. The purpose is to evaluate the current status and future opportunities for transportation electrification in New York State and analyze the potential environmental and policy benefits.

Keywords

Electric vehicles, transportation, Climate Act, charging stations, infrastructure, greenhouse gas emissions, equity, environmental benefits, utilities, fleets

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Acronyms and Abbreviations

ACC2	Advanced Clean Cars 2. Also known as the “ZEV Mandate Extension,” ACC2 is a mandate requiring increasing numbers of zero emission light-duty vehicles be sold by automakers.
ACT	Advanced Clean Trucks. California regulation that requires increasing numbers of medium- and heavy-duty vehicle sales be zero emissions.
BEV	Battery electric vehicle. A vehicle powered exclusively by electricity (such as a Nissan LEAF).
CCS	Combined charging system. This is a DC fast charging standard supported by Volkswagen, General Motors, BMW, Daimler, Ford, FCA, Tesla, and Hyundai.
CHAdeMO	This is a DC fast charging standard developed in Japan that goes up to 62.5 kW, originally supported by Nissan, Mitsubishi, and Fuji Heavy Industries (which manufactures Subaru vehicles). Toyota later supported the standard as well, and Tesla sells an adapter allowing its vehicles to use CHAdeMO chargers.
Climate Act	Climate Leadership and Community Protection Act. Law in New York State that sets the State’s greenhouse gas (GHG) emissions limit to 85% below 1990 levels by 2050.
DCFC	Direct-current (DC) fast charging equipment. DCFCs are sometimes called DC Level 3 (typically 208/480V AC three-phase input) and enable rapid charging of an electric vehicle.
EV	Electric vehicle. A vehicle powered, at least in part, by electricity. Unless otherwise noted, the term “EV” in this report refers to all plug-in vehicles and includes BEVs and plug-in hybrid electric vehicles (PHEVs; defined below). The term “EV” is synonymous with “plug-in electric vehicle” (PEV).
EVSE	Electric vehicle supply equipment.
EVSP	Electric vehicle service provider. An EVSP provides the connectivity across a network of charging stations. Connecting to a central server, they manage the software, database, and communication interfaces that enable operation of the station.
GHG	Greenhouse gas. Gases that trap heat in the atmosphere, such as carbon dioxide, methane, and nitrous oxide.
ICEV	Internal combustion engine vehicle. A vehicle that combusts fuel, such as gasoline or diesel, for power.
kW	Kilowatt. A unit of power.
kWh	Kilowatt-hour. A unit of energy.
LDVs	Light-duty vehicles. Vehicles with a gross vehicle weight rating below 8,500 lbs, which aligns with Class 1 to Class 2a vehicles.
MHDVs	Medium- and heavy-duty vehicles. Vehicles with a gross vehicle weight rating above 8,500 lbs, which aligns with Class 2b to Class 8 vehicles.
$MMTCO_2e$	Million metric tonnes of carbon dioxide-equivalent.
MUD	Multiunit dwelling. Also called “multifamily dwellings,” these are apartments, condominiums, and group quarters. The other major housing category used in this report is single-family homes.

NYSERDA	New York State Energy Research and Development Authority.
PHEV	Plug-in hybrid electric vehicle. A vehicle powered by electricity or an internal combustion engine.
US DOE	United States Department of Energy.
VIUS	Vehicle Inventory and Use Survey.

Summary

In 2019, Governor Andrew M. Cuomo signed the Climate Leadership and Community Protection Act (Climate Act) into law, setting the State's greenhouse gas (GHG) emissions limit to 85% below 1990 levels by 2050. The Climate Act comes at a time of rapid change in the transportation sector, characterized by new electric vehicle powertrains, fuels, and mobility options, as well as growing recognition of the inequalities created by the transportation system. Amidst this change, as of 2019, transportation continues to be the largest source of emissions of any sector at 37% of the New York State total.

The New York State Assembly and Senate passed, and Governor Cuomo signed into law, Chapter 676 of the laws of 2019 which requires the New York State Energy Research and Development Authority (NYSERDA) to develop a report that:

- Analyzes the potential environmental and policy benefits derived from expanding the state's inventory of electric vehicles and electric vehicle infrastructure.
- Identifies current electric vehicle infrastructure, including public electric vehicle charging stations.
- Evaluates gaps in the current electric vehicle infrastructure, including geographic areas lacking access to public electric vehicle charging stations.
- Evaluates incentives to encourage purchasing, use, and ownership of electric vehicles in the State.
- Evaluates the feasibility of transitioning to a primarily electric State-owned vehicle fleet.
- Evaluates revenue allocation options to:
    - assist in an expansion of the State's electric vehicle infrastructure.
    - implement incentives to encourage purchasing use and ownership of electric vehicles.
    - expand the State-owned electric vehicle fleet.

In response, NYSERDA submits this report which summarizes the current status of and future prospects for transportation electrification in New York State including barriers, rates of technology adoption, GHG emissions, and policy impacts. The report covers a broad portion of the transportation sector, including light-duty vehicles (LDV) and medium- and heavy-duty vehicles (MHDV), but focuses heavily on electric LDVs given their relative market maturity and potential for catalyzing cost reductions in other transportation sub-sectors. Note the term electric vehicles, or EV, refers to all plug-in electric vehicles, including both plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV). The Executive Summary highlights key findings in this report.

S.1 Background, Current Status, and Barriers to EV Adoption

- **New York State is a leader in transportation electrification.** Since the introduction of the electric Interborough Rapid Transit in New York City in 1904, electrified passenger-miles have grown substantially in New York State, primarily due to New York City's electric-powered subway and the region's commuter rail system, and continued modernization of the infrastructure as outlined in the Governor Cuomo's 2021 State of the State address. Today, New York State has the highest share of electrified passenger-miles of any state in the country. Beyond electrified rail, the State serves in a leadership role with its transportation electrification programs and policies such as the Multi-State ZEV Task Force and Charge NY. The robust Charge NY portfolio has grown to include launch of the Drive Clean Rebate, Truck Voucher Incentive Program and Charge Ready NY. New York State is also examining many electric mobility and travel demand management strategies as ways to reduce greenhouse gas emissions, but those are beyond the scope of this report.
- **Electrification of LDVs and certain MHDVs remains at a relatively early stage of market development.** New York State has the 15th highest share of light-duty EVs in its vehicle stock of any state, at 1.4% of total registered vehicles. This fraction will continue to grow in coming years as the fraction of EVs among new registered vehicles is about 3% and growing. Certain MHDVs, such as delivery trucks and buses, are beginning to be electrified, for a variety of reasons including economic savings and increased public sector focus on environmental justice.
- **Several barriers impede EV growth in New York State, but the barriers vary by sub-sector.** The upfront purchase price of EVs is currently higher than that of conventional vehicles for most vehicle types. Upfront price parity for LDVs compared to traditional internal combustion vehicles is expected to occur between 2027 and 2028, and between 2021 and 2024 when using a total cost of ownership metric. Today's cost reductions in EVs are driven, in large part, by battery pack cost reductions which average 16% per year. For non-road sub-sectors, such as aviation and marine, widespread electrification appears to be farther off, due in large part to the relatively low-energy density of today's commercially available batteries.

S.2 Projections of EV Growth and Environmental Benefits

- **Assuming a continuation of current trends in technology costs, vehicle availability, consumer behavior, and existing policies (i.e., "reference scenario" assumptions), electric LDV adoption is expected to rise substantially through 2050**. Even without accelerating mandates on new car sales after 2025, electric LDV adoption is expected to increase to 24% of new vehicle sales by 2030 and 46% by 2050, driven by anticipated reductions in battery costs, among other factors. Electric MHDV adoption is expected to increase at a much lower sales rate (8% and 28%) in 2030 and 2050, respectively, as seen in figures relating to reference scenario projections.

- **Adopting aggressive policies to expand EV adoption in New York State could reduce transportation sector greenhouse gas emissions by more than 50% compared to 1990 levels by 2050.** Strong policies that promote EVs, could include regulations that require all new light-duty vehicles sold to have zero emissions by 2035 as well as regulations that require an increasing percentage of trucks and buses with zero emissions. These policies could result in total transportation sector emissions at 54% below 1990 levels in 2050.

S.3 EV Charging Stations

- **EV charging stations are available across New York State in growing numbers, but gaps exist, especially for direct current fast chargers (DCFCs) upstate.** As of January 2021, there are more than 6,000 charging stations in New York State, most of which are Level 2. These can be found in big cities and small towns across the State. DCFCs are less common, and many of the existing DCFCs are exclusively for the electric car, Tesla. Large portions of Upstate New York have few, if any, DCFCs, but there are plans to build more statewide.

S.4 New York State Fleet EV Conversion

- **New York State's government-owned fleet could realistically be converted to EVs by 2035 through normal turnover.** Most vehicle types that make up the State fleet have electric models available now, and electric models for other vehicle types will become available over the next three to five years. New York State could start converting its fleet to EVs, replacing vehicles along a typical replacement schedule over the next 15 years. This would require additional upfront capital, but operational savings are expected to more than offset the difference in upfront cost.

S.5 Policies and Funding to Increase EVs

- **Various policies can be considered to increase EV sales such as regulatory mandates to require the sale of more EVs, investing in EV charging stations, providing financial incentives for the purchase of EVs, and carbon pricing policies.**
  - Public EV charging station investment is an effective approach to spurring EV adoption, a strategy that New York State is pursuing aggressively in the Public Service Commission's Make-Ready Order (Narassimhan and Johnson 2018; NYSDPS July 2020), and other public infrastructure programs.
  - EV incentives, rebates, or feebates can reduce the upfront cost of vehicles and differentiate incentive levels based on vehicle cost or applicant income and allow sales in the secondary market.
  - Outreach and education programs can raise knowledge and understanding of electric vehicle technologies to spur adoption. Research has shown that in states where consumer awareness of EVs is high, there is a corresponding response seen in vehicle sales (Jenn et al. 2018).
  - Utility rate design remains an important element of building a supportive policy environment for EV adoption. The impact of utility rates on EV adoption is an ongoing area of research.

- **Creative solutions are needed to ensure equity in sharing the benefits of EV adoption.** A large portion of EVs are currently purchased by consumers with incomes greater than $100,000 per year. Ensuring that low- and moderate-income populations enjoy the benefits of EVs, including cleaner air and better health outcomes, may require a greater focus on incentive design, including targeting used EVs, and a greater emphasis on policies to electrify trucks and buses.
- **New York State's Climate Action Council and its Transportation Advisory Panel are considering various mechanisms used in other states to enable and increase EV adoption**. California has invested more than $3 billion in clean transportation in recent years, primarily with revenue generated from its cap-and-trade program. Other options for funding transportation electrification include a low-carbon fuel standard, registration fees, electric utility investments, and green banks.

1 Introduction

New York State enacted the Climate Leadership and Community Protection Act (Climate Act) in 2019, which set greenhouse gas (GHG) emission reduction targets of 40% of 1990 levels by 2030 and of 85% by 2050 (New York State Department of Environmental Conservation [DEC] 2019). To achieve these ambitious targets, New York State will need to reduce GHG emissions across the entire economy. The New York State Energy Research and Development Authority (NYSERDA) commissioned this report to examine the transportation sector in the State and identify feasible actions to achieve deep carbon reductions in accordance with the Climate Act.

The report summarizes the current state of transportation electrification, especially EVs, in New York State and examines some of the opportunities for increasing the sector's electrification.

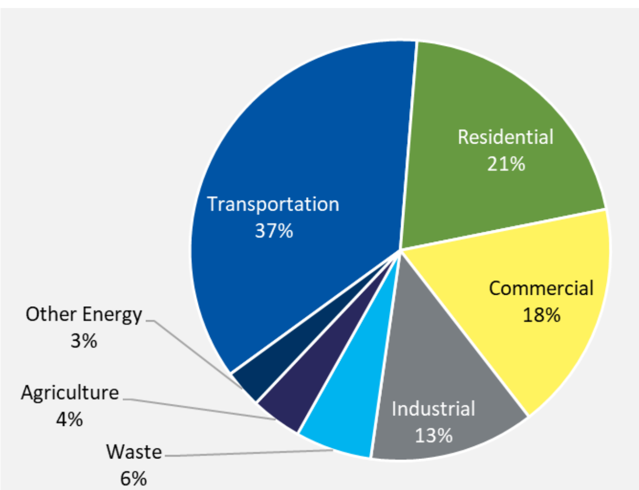
1.1 Transportation Emissions

At 37% of statewide GHG emissions, the transportation sector accounts for the largest portion of the State's total emissions of any sector (Figure 1). Emissions in transportation peaked in 2005. Even as emissions from fossil fuel combustion have decreased across all sectors, the rate of decline has been slower in the transportation sector. Aviation is the fastest growing sub-sector within transportation, as demand for air travel grew faster than improvements in aircraft design and operations.

Figure 1. New York State GHG Emissions: Economy (2016)

Note: Values use a 100-year Global Warming Potential (GWP) and only include direct emissions (no upstream).

Source: NYSERDA July 2019.



1.2 Organization of the Report

This report addresses the following topics:

- **Section 2. State of Transportation Electrification in New York State.** This section outlines the current state of electric vehicle (EV) adoption and barriers to further such adoption in all the major transportation sub-sectors, including personal light-duty vehicles (LDV), fleet LDVs, medium- and heavy-duty vehicles (MHDV), rail, landside marine ports, marine vessels, and aviation.
- **Section 3. Electric Vehicle Projections.** This section makes projections of electric LDVs and MHDVs under a reference scenario. All content in this chapter uses reference scenario assumptions, meaning a continuation of current trends in technology costs, vehicle availability, consumer behavior, and no new policies enacted beyond those that exist today.
- **Section 4. Electrification Policy Analysis.** This section provides a policy discussion and analysis about potential transportation electrification policies that could further reduce GHG emissions by 2050.
- **Section 5. Conclusion.** This section synthesizes the findings from this report.

Impacts of COVID-19 on Transportation Emissions

COVID-19 has lowered demand for travel across most modes of transportation during 2020. In the first four months of 2020, global estimates suggest surface transportation GHG emissions fell by 36% and aviation GHG emissions fell by 60% compared to 2019 levels (Le Quere et al. 2020). These estimates are likely upper bounds for the impact on GHG emissions in 2020 since many governments have had fewer restrictions on movement since April 2020. However, the extent to which observed changes will result in structural changes to travel remains unclear. Research suggests that 40–60% of U.S. workers are now telecommuting during the COVID-19 pandemic, compared to a pre-COVID-19 average rate of 5% (Mokhtarian 2020). A study by McKinsey for New York State's Metropolitan Transportation Authority estimates that, through the mid-2020s, increased telecommuting will result in 4–12% decline in MTA ridership compared to pre-pandemic levels (MTA November 2020). Other potential impacts of COVID-19 could include increased truck freight and last-mile delivery services, increased passenger car travel, and reduced reliance on transportation network companies (TRB 2020). Overall, the long-term consequences of COVID-19 on travel are uncertain and require further assessment.

2 State of Transportation Electrification in New York State

This section describes current electrification activities in New York State and the status of electrification in multiple vehicle sectors. The project team quantified the status of household electric LDV adoption in the State and compared the results to national adoption. The project team divided fleets in the State into LDV fleets and MHDV fleets and investigated the electrification in the non-road transportation sub-sectors of rail, marine, and aviation. The last section addresses key barriers to transportation electrification.

2.1 Current Transportation Electrification Activities in New York State

New York State has a long history of innovative clean transportation and vehicle electrification programs, starting as far back as October 1904, when operations began on the electric New York City subway line (known as the Interborough Rapid Transit) from South Ferry to 155th Street. While the transportation sector has been dominated by petroleum fuel vehicles during the 20th and early 21st century, New York has relied more on electric transportation than any other state due to electrified rail such as the MTA subway and commuter rail system. In 1990, New York State adopted California's Low Emission Vehicle program, requiring all new vehicles sold in the State to meet California emission standards, which are more stringent than federal standards. In 2002 New York State released a comprehensive energy plan that set economy-wide GHG reduction goals of 5% below 1990 levels by 2010 and of 10% by 2020. While initially modest, these goals signaled the State's commitment to emission reductions which have increased exponentially under the Climate Act.

New York State continued its efforts to reduce emissions through transportation electrification in 2013 with two major actions by Governor Andrew M. Cuomo. First, the State signed on to the light-duty, zero-emission vehicle (ZEV) memorandum of understanding, which formed the Multi-State ZEV Task Force, a coalition of states working together to advance the deployment of EVs. This Task Force has served as a forum for collaboration between states and automakers to increase EV sales through policy research and joint marketing campaigns. Second, the State launched Charge NY, a series of initiatives that, over time, grew to include the Drive Clean Rebate program, offering up to $2,000 for EV purchases or leases, the New York State Truck Voucher Incentive Program, offering incentives of up to $385,000 for the purchase or lease of electric trucks and buses, the Charge Ready NY program, offering $4,000 per Level 2 charging port, and awareness and educational campaigns.

There are numerous additional statewide programs underway today:

- The State launched the **Clean Fleets NY program** in 2015, which supports deployments of EVs in State government fleets.
- In 2018, the New York Power Authority launched the **EVolve NY program**, which complements Charge NY 2.0 with an additional $250 million investment in EV charging infrastructure, services, and consumer awareness efforts.
- In 2020, New York State joined California and 21 other states in a joint effort to sue the U.S. government over their decision to revoke California's right to set more stringent **vehicle emission standards** and other states' rights to adopt those standards.
- Through the **New York Truck Voucher Incentive program,** New York State aims to accelerate the deployment of all-electric and alternative fuel trucks and buses in MHDV classes throughout New York State. NYSERDA administers the program, which currently offers $53.9 million and uses funds from the **Volkswagen settlement** (overseen by the New York State Department of Environmental Conservation) and the **Congestion Mitigation and Air Quality Improvement program** (overseen by the New York State Department of Transportation). New York State also directed Volkswagen funds ($9.9 million) to the New York City Department of Transportation for the New York City Clean Trucks program, which replaces diesel trucks in New York City Industrial Business Zones in defined Environmental Justice Areas.
- New York State actively participates in the Federal Highway Administration's **Alternative Fuel Corridor** designation program. As of July 2020, New York State has eight corridors designated as "corridor-ready" for EVs, which requires a minimum of one DC fast charging (DCFC) station every 50 miles and has four corridors designated as "corridor-pending."

In July 2020, Governor Cuomo announced two new sweeping programs. First, New York State was one of 15 states that signed a MHDV ZEV memorandum of understanding with the goal of having 30% of MHDV sales be ZEVs by 2030 and 100% be ZEVs by 2050. Second, the State announced a $701 million "Make-Ready" program by investor-owned utilities that pays up to 100% of the infrastructure costs necessary to make sites ready for charging electric LDVs.

Finally, in his 2020 and 2021e State of the State Addresses, Governor Cuomo announced a major commitment to transit bus electrification. The transit systems in Buffalo, Rochester, Albany, Westchester County and Suffolk County will convert their transit bus fleets to all-electric buses by 2035. In addition, the Metropolitan Transportation Authority (MTA), which has also committed to convert its bus fleet, the nation's largest, to all-electric, will purchase 45 electric buses for its fleet and partner with the U.S. Department of Energy to analyze the potential for utilizing traction power substations for bus charging.

In addition to state-level initiatives, many local jurisdictions and organizations—including counties, cities, utilities, ports, and others—are aggressively pursuing climate action and transportation electrification. New Yorkers also take advantage of available federal programs aimed at increasing vehicle electrification (such as the federal EV tax credit) and at lowering transportation emissions (such as the Diesel Emission Reduction Act and Voluntary Airport Low Emissions program).

2.1.1 Key Trends among New York State Transportation Policies and Programs

New York State and local governments invest more than $9.5 billion annually in clean transportation initiatives, with a large part supporting public transportation services.[1] Of the 87 unique initiatives (or programs) identified as supporting clean transportation, spanning technology types and transportation modes, 56 include or emphasize electrification measures. Many initiatives center around incentives or rebates and are administered as statewide programs. In addition, many local programs offer incentives or rebates through the local utility or State agency.

2.1.1.1 Role of Transit in New York State

A defining feature of the State's transportation sector emissions is the important contribution of transit. New York State has the highest number and share of transit commuters and users of any state in the country. Transit services help save 1.3 billion gallons of gasoline in the State annually, contributing to one of the lowest per capita use of gasoline in the region (NYPTA 2020). Since much of the State's transit services are electrified, resulting in deep GHG reductions. A Booz Allen study estimates that in the MTA operating region,[2] transportation-related GHG emissions would be approximately 30% greater without the MTA (MTA Blue Ribbon 2009). Public transportation reduces congestion, provides an alternative to single occupancy private vehicles, and allows high-density, transit-oriented development.

2.1.1.2 Private Sector Leadership

New York State is home to several EV-related companies that operate locally and have provided innovative products and solutions to the EV market. This includes a range of businesses from small technology start-ups to large multinational corporations. A notable example is BAE Systems' Electric

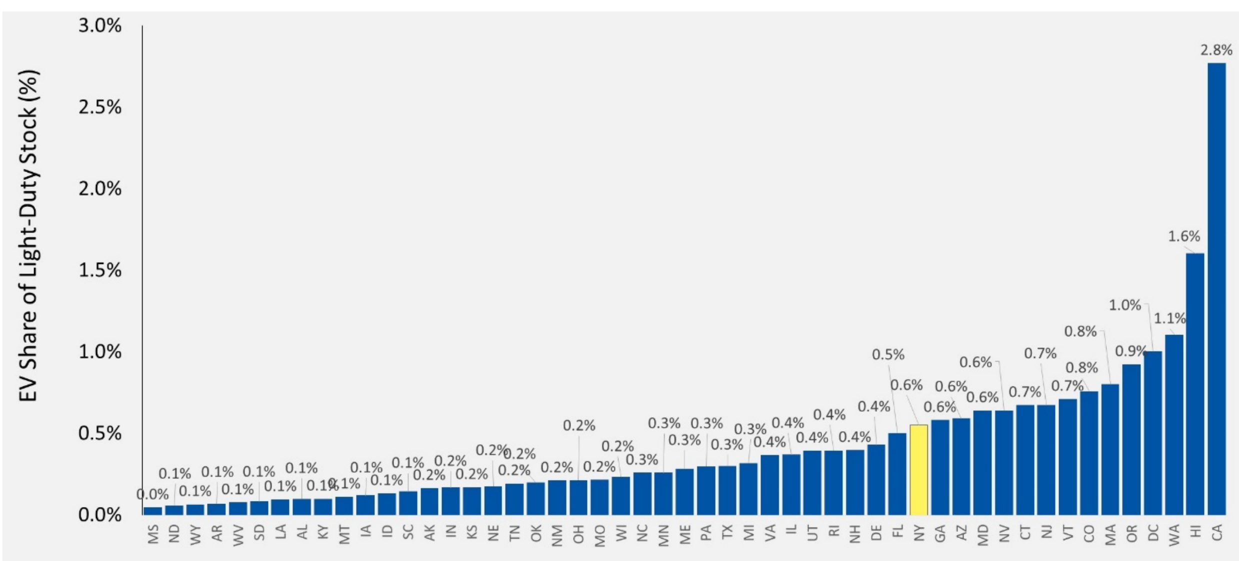
Systems plant in Endicott, NY. BAE Systems develops drive trains for electric buses that have been used throughout the world (BAE Systems n.d.). The State is also home to HEVO, a Brooklyn-based company launched in 2011 that is developing and deploying wireless EV charging technology (HEVO n.d.). One of the newest EV-related companies in New York State is Revel Transit, a dockless electric moped sharing start-up. Initially launched in 2018, the company now offers 1,000 scooters in Brooklyn and Queens and 400 scooters in Washington DC (Revel Transit 2020). Demonstrations in New York State are underway or under development from other innovative new companies, such as AMPLY Power, the Lion Electric Co., and Proterra.

2.2 Household Light-Duty EV Adoption

New York State vehicle registration data shows 9.6 million on-road Class 1 and 2a LDVs, with approximately 900,000 new vehicle registrations per year. Sedans make up approximately one-third of these, with sport utility vehicles, crossovers, pickup trucks, and vans making up the other two-thirds. Compared to other states, New York State has the 15th highest EV share of total vehicle stock and similar levels of EV public charging deployment (Figure 2). The blue bars in Figure 2 show the share of registered vehicle stock that is electric by state.

Figure 2. EVs per Registered Vehicle by State

Source: Atlas 2020b.



As of September 2020, New York State has about 60,000 unique EV registrations and over 5,000 public charging ports (Atlas 2020a). Figure 3 shows a general upward trend of battery electric vehicles (BEVs, shown in blue) and plug-in hybrid electric vehicles (PHEVs, shown in yellow) since 2011. The greatest EV density is on Long Island and in the New York City Metro area. Notably, sales peaked in 2018, coinciding with the introduction of the Tesla Model 3. Historically, PHEV sales have outnumbered BEV sales in New York State by a 70/30 split, but recent years have shown a trend toward BEV sales (closer to a 50/50 split).

Figure 3. EV Deployment in New York State: October 2011 through October 2020

Note: Numerical values are total cumulative sales at end of year.

Source: Atlas 2020a.

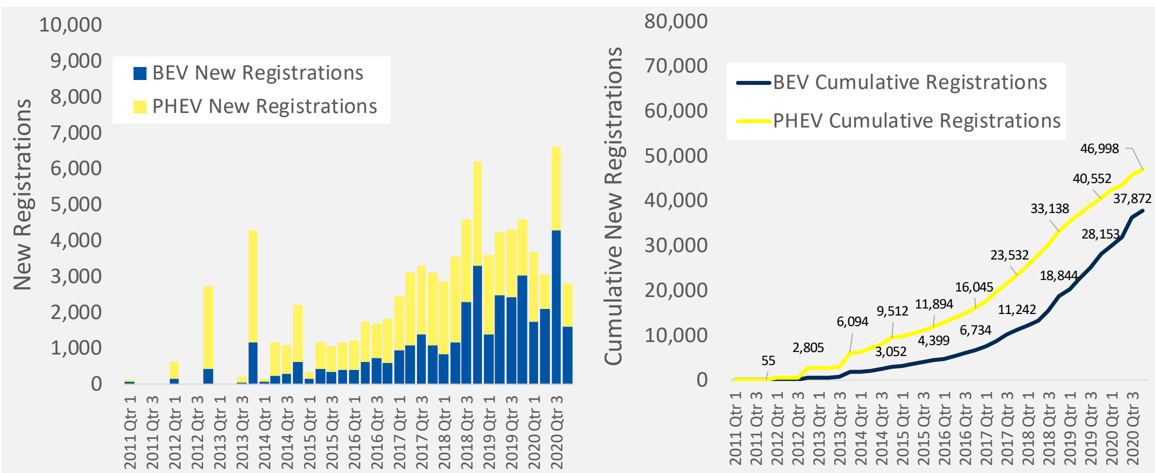
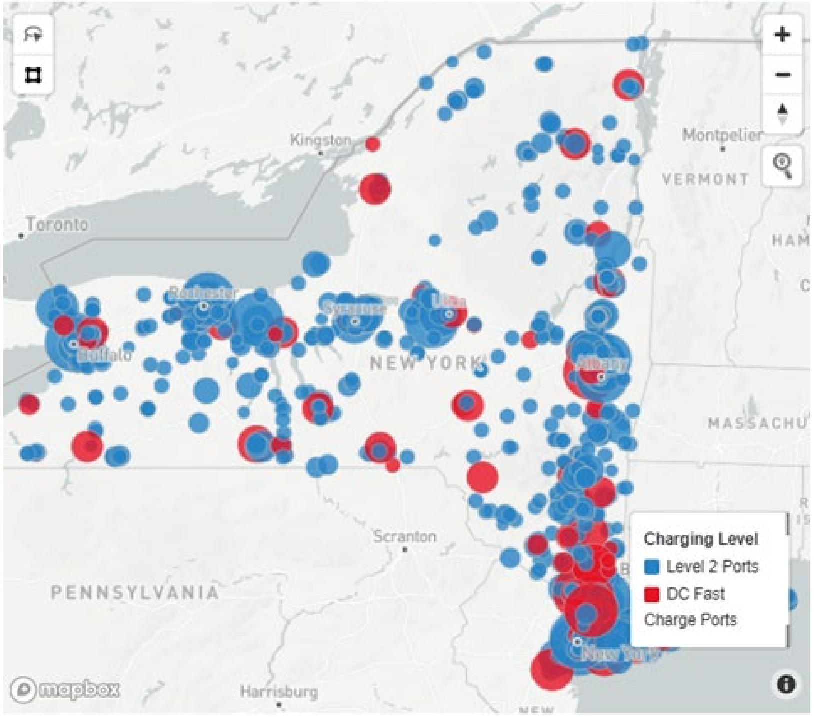


Figure 4 shows the density of charging ports across the State. An interactive map is available at EvaluateNY (Atlas 2020a). Currently, EV drivers meet most of their charging needs at home. NYSERDA's survey of 3,362 Drive Clean Rebate program participants reveals that 90% have access to charging at home with either a Level 1 or Level 2 charger (Drive Clean Rebate 2018–2019 Adoption Survey Report). Additionally, 83% of BEV owners and 79% of PHEV owners live in a detached house, which aligns with data from the National Household Travel Survey that clearly shows early adopters of EVs are much more likely than the general population to live in a detached home with a garage or carport (FAA 2017). On the other hand, a California survey of 2,831 EV owners indicates that 81% of apartment-dwellers with a low-range BEV and 52% of apartment-dwellers with a high-range BEV primarily use public charging. Because meeting the Climate Act's goals will likely entail nearly 100% electrification of LDVs, public and at-work charging will become more important in coming decades (as an increasing share of EV drivers will not have access to home charging).

Figure 4. Density of DC Fast Chargers and Level 2 Ports in New York State

Source: Atlas 2020a.



The left side of Figure 5 shows the total number of public EV charging ports and registered EVs for three regions of New York State. The right side of Figure 5 provides the same ratio per 1,000 people.

Figure 5. Total (Left) and per 1,000 People (Right) Public Plugs versus Registered EVs by Region

Note: In the figures, the project team classified New York City Metro as Bronx, Kings, New York, Queens, Richmond, and Westchester counties, considered Long Island as being in Nassau and Suffolk counties, and considered all other counties as upstate.

Source: Cadmus 2020.

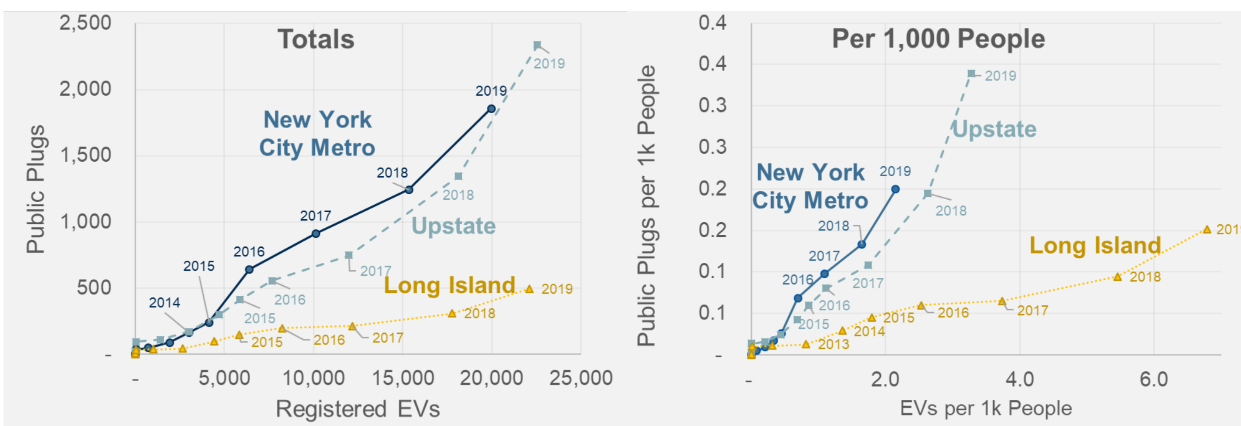


Figure 5 demonstrates the ratio of public plugs per EV varies by region. For example, Long Island has the lowest ratio of public plugs per EV compared to the two other regions—likely the result of several factors such as higher median household income, higher share of single-family homes, greater model availability of EVs, and the relative importance of high-occupancy vehicle (HOV) lane access. This reflects the factors observed to correlate with EV adoption throughout the State, detailed in Figure 6.

2.3 Light-Duty Fleet EV Adoption

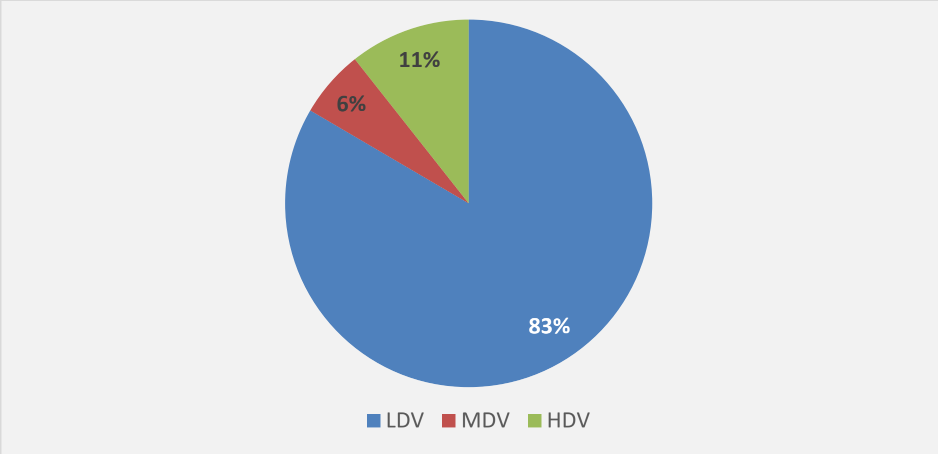
There are approximately 330,000 light-duty (Class 1 and Class 2) fleet vehicles in New York State. The total should be considered a lower bound, given that only partial data is available for county, utility, school, airport, port, and other government vehicles.[3] The project team made a separate estimate of 544,000 LDVs using New York State's vehicle registration data and removing vehicles coded as passenger, semi-trailers, motorcycles, and all-terrain vehicles. However, there is considerable ambiguity as to whether this estimate encompasses all fleet vehicles in the State. For more details on LDV fleets, data sources, and limitations see Figure 6.

The number of vehicles in light-duty fleets has stayed relatively constant over time, with the exception of personal vehicles used for ride-hailing services. The number of ride-hailing vehicles in New York City has grown quickly since 2015 compared to yellow taxis, green taxis, and livery cars. No public data exists on statewide ride-hailing fleet size (Schneider 2020). The current number of EVs in light-duty fleets is not publicly reported, except for certain fleets. Several fleets have made announcements regarding fleet electrification. For example, New York City has a goal for all municipal vehicles to be electrified by 2040, with a benchmark of 4,000 vehicles electrified by 2025 (including MHDVs) compared to today's count of 2,200 (NYC Mayor's Office February 2020, NYC Sustainability Office 2020). In addition, 130 of the Port Authority of New York-New Jersey's (PANYNJ) LDVs are already electric, and it is targeting for 600 by 2023, that is, 50% of its LDV fleet (PANYNJ October 2020).

2.3.1 New York State-Owned Fleet

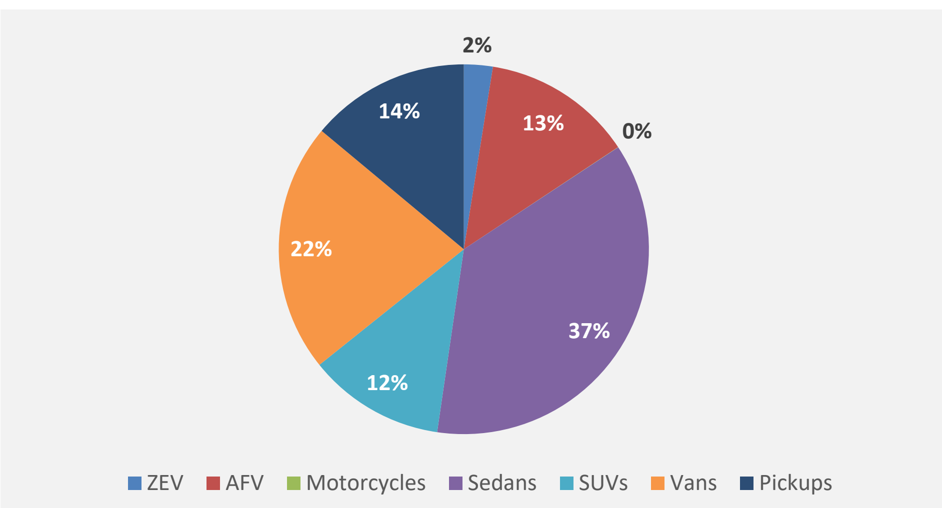
The New York State fleet—defined as vehicles that are owned or managed by New York State agencies and authorities—is comprised of approximately 26,000 vehicles (NYS OGS 2020) and serves diverse use cases that directly support the agencies' ability to fulfill their missions. Most of the fleet (83%) consists of light-duty vehicles (LDV), which for the purposes of reporting, includes sedans, vans, SUVs, and pickup trucks with a Gross Vehicle Weight Rating (GVWR) of 8,500 pounds or less.

Figure 6. New York State-Owned Fleet by Vehicle Category



Approximately 550 vehicles (2%) of the LDV fleet are categorized as ZEVs. Another 2,900 LDVs (13%) are categorized as alternative fueled vehicles (AFVs), which includes vehicles that run on biofuels (e.g., ethanol, biodiesel), natural gas, or propane. Combined, the lower-emitting ZEV and AFV vehicles make up 15% of the LDV fleet, with the rest of the fleet comprised of vehicles that run on traditional petroleum-based fuels (e.g., gasoline or diesel). To achieve the goals of the 2013 ZEV Memorandum of Understanding (MOU), the signatory states, including New York, created a ZEV Action Plan that includes a commitment that 25% of administrative LDV purchases be ZEVs by 2025. In addition, New York State Executive Order 188 directs all State agencies, departments, and authorities to develop plans to achieve its climate goals, providing the State with an opportunity to lead by example by transitioning fleet vehicles to EVs.

Figure 7. New York State-Owned LDV Fleet by Type



2.4 Medium- and Heavy-Duty EV Adoption

New York State vehicle registration data indicate that there are 1.01 million on-road Class 2b through Class 8 MHDVs.[4] Pickup trucks make up the highest share of these vehicles, followed by van trucks—large vans owned by businesses and used for moving cargo and passengers (NYSDMV 2020).

Electrification of MHDVs is at an early stage in New York State. Vehicle registration data show few electric MHDVs in the State, the majority of which are Class 8 buses. MHDV electrification is supported by public policies like the New York Truck Voucher Incentive Program and the New York City Clean Trucks Program, which both offer incentives of 80% to 100% of the incremental upfront cost of electric MHDVs. European fleets have been pursuing MHDV electrification for longer than U.S. fleets and offer some insights into user experience. In 2018, the PANYNJ became the first public transportation agency to embrace the Paris Climate Accords and pledged to take aggressive steps to reduce GHG emissions. As of October 2020, PANYNJ operates 36 electric buses and 130 light-duty EVs, primarily at airport locations (PANYNJ October 2020).

New York City's MTA operates the State's largest all-electric transit bus fleet, which currently comprises 10 leased electric buses and 15 purchased electric buses. The 2020-2024 MTA Capital Program, adopted before the COVID-19 pandemic, included a plan to purchase 295 electric buses by December 2024 and an additional 175 electric buses by December 2025 (MTA 2019). In total, 88% of the State's bus fleet is diesel or diesel hybrid, with the bulk of the remainder fueled by compressed natural gas: only 0.16% of the fleet is currently battery electric. In January 2020, the Capital District Transportation Authority rolled out the first electric bus in Upstate New York (CDTA 2020). In Governor Cuomo's 2020 State of the State address, he committed to electrify 25% of the fleets of five non-MTA upstate and suburban transit authorities by 2025 and 100% by 2035 (NYS Governor 2020). The MTA has committed to purchase only electric buses after 2029 and fully electrify its fleet by 2040[5]. In his 2021 State of the State, Governor Cuomo announced that in 2021 MTA will purchase 45 electric busses for its fleet and the State will assist transit systems in Buffalo, Rochester, Albany, Westchester, and Suffolk, to purchase at least 55 electric buses.

2.5 Barriers to Electrification

This section discusses barriers to expanding EV adoption in New York State. Primary barriers include purchase costs, vehicle model and charger availability, operational impacts, lack of familiarity, technology characteristics, and battery recycling.

The greatest challenges of owning a passenger EV, as identified by EV owners in New York State, relate to EV charging: access to public charging stations, range limitations, and the speed of vehicle charging.[6] Car performance, charging cost, and home charging access are also of concern to New York State EV owners. MHDV fleets face similar but unique barriers. Unlike households, fleet managers must navigate organizational barriers to successfully purchase an EV. For example, fleet managers, who may not be experts in EV technology, must develop a business case and transition plan for electrifying their fleet. The plan must be compelling enough to overcome internal organizational resistance from key decision makers. Even with the support of senior management, fleet cost accounting processes may lack the flexibility to enable a shift in procuring vehicles with higher upfront costs but lower operational costs. Similarly, the fleet may lack access to capital or financing that would allow it to pay for upfront costs that are higher than those for internal combustion engine (ICE) vehicles. Table 1 characterizes the relative importance and relevant sub-sector for key barriers identified in this report. A rating of High implies a significant barrier to electrification for that subsector and a Low rating implies the opposite.

Table 1. Sub-sector and Importance of Key Electrification Barriers

Barrier	LDV	MHDV	Non-Road
Initial Purchase Price	Medium	High	High
Electrical Infrastructure Impacts	Medium	High	High
Insufficient model availability	Medium	High	High
Vehicle range anxiety	High	Medium	High
Residential charging access and infrastructure	Medium	--	--
Awareness and education barriers	High	Medium	Medium
Cold weather	Low	Medium	Unknown

Source: Cadmus analysis

2.5.1 Cost Barriers

Cost barriers include challenges related to the upfront and ongoing costs of buying an EV and the decisions that influenced a customer's ability to purchase an EV. These include costs to the vehicle owner and vehicle cost depreciation.

2.5.1.1 Initial Purchase Price

The upfront price of new EVs without incentives continues to decline each year but is still higher than the price of comparable ICE vehicles. Table 2 shows the 16 most popular EV models in New York State and compares the prices of EVs with the average price of a comparable ICE vehicle. EV prices are the manufacturer's suggested retail price (MSRP) without federal or State incentives for the vehicle's base model. Average ICE vehicle prices in the far-right column are taken from Kelley Blue Book (2020) and reflect average transaction prices in January 2020 for all vehicles in a given EPA-size category across the entire United States.

Overall, the price of EVs before federal and State incentives is higher than the comparable ICE vehicle price for most vehicle models. However, the prices are difficult to compare with precision since each model varies in battery size, performance, add-ons, and aesthetic appeal. Furthermore, EV price is established by the automaker and does not reflect the actual production cost of the vehicle. Future EV costs are expected to decline with falling battery pack costs. For example, Figure 8 shows the production cost projections of an average sedan for both an ICE vehicle today and BEVs with a 250-mile range. Note these costs do not include the typical retail markup and therefore cannot be compared to the manufacturer's suggest retail price.

Figure 8. Before-Markup Production Cost for ICE Vehicle and 250-Mile Range BEV Sedan

Sources: Kapoor et al. 2020 and ICCT April 2019.

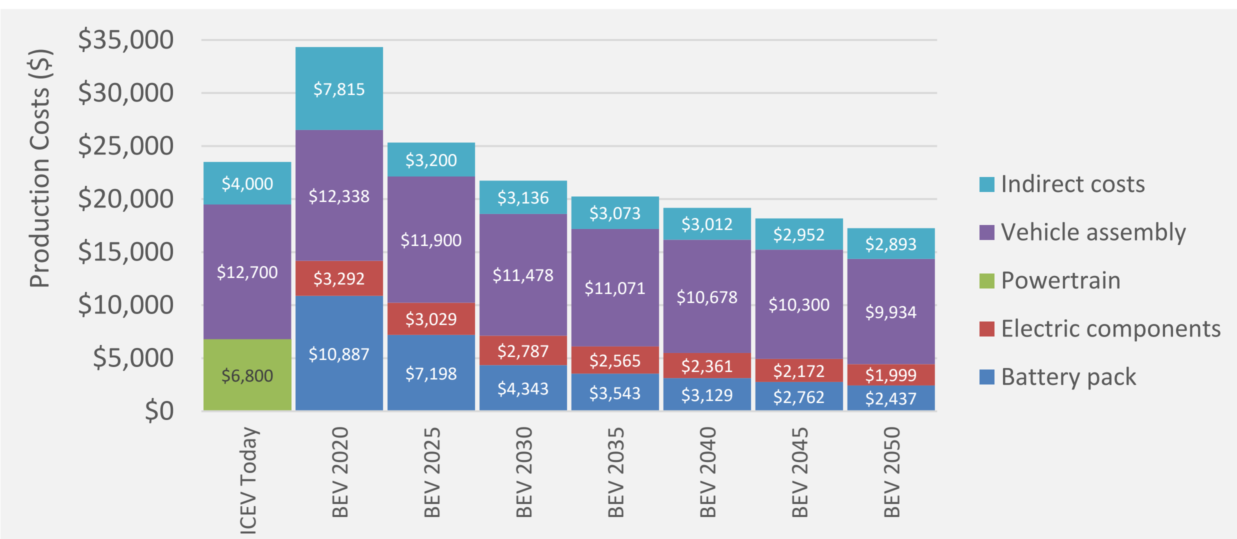
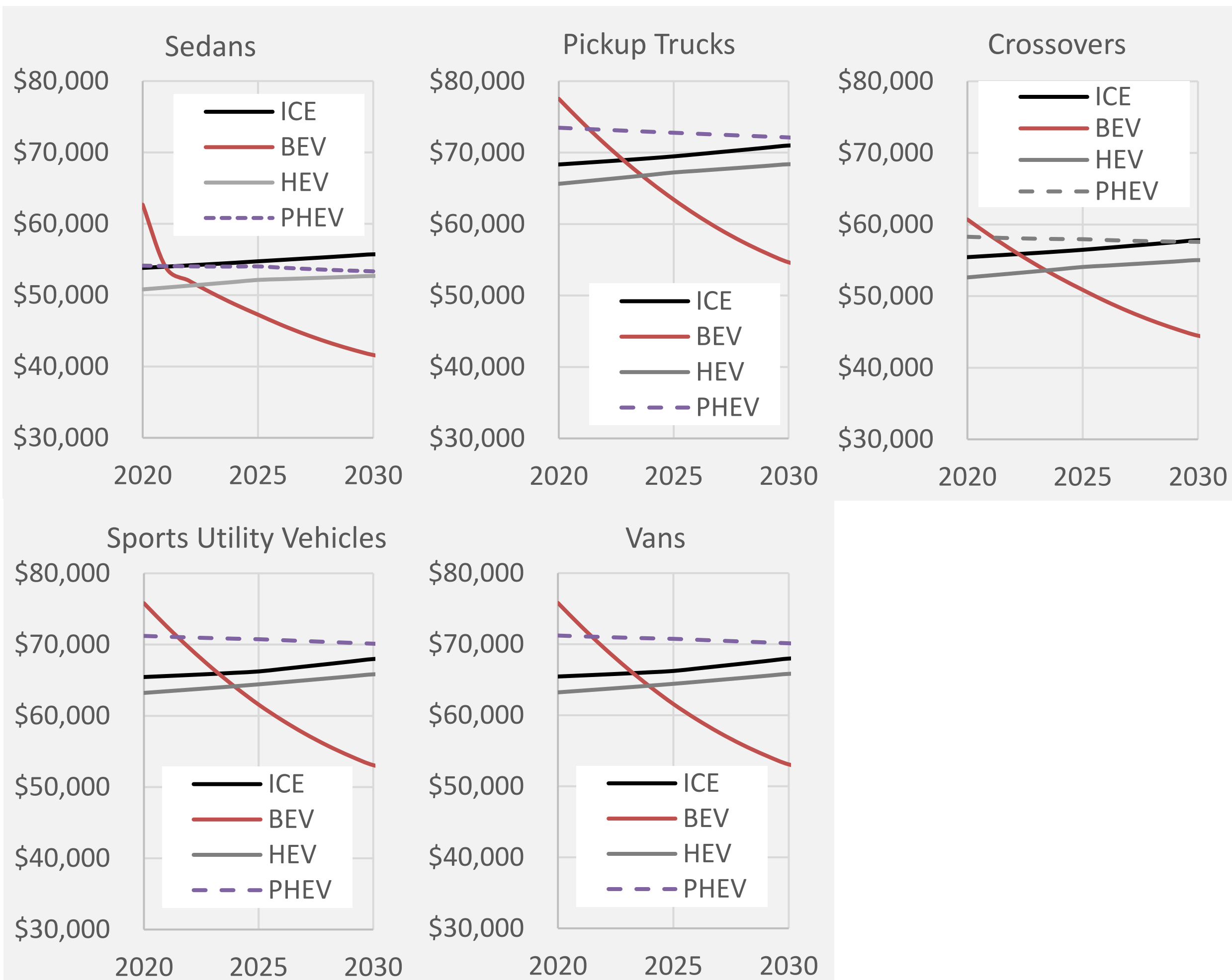


Figure 9 puts all costs together in terms of total cost of ownership (TCO), which includes retail cost, lifetime discounted fuel cost, lifetime discounted maintenance costs, battery disposal costs, and home charger costs for LDVs.[7] BEVs are expected to reach parity on a TCO basis between 2021 and 2024, while PHEVs reach parity towards 2030 or early 2030s. The decline in retail costs, along with the lower cost of operation, will make BEVs the cheapest type of vehicle to own in the near future.

Electric trucks typically cost more upfront than comparable diesel, gasoline, and natural gas trucks, due primarily to the cost of batteries. According to national data, the upfront and operating costs of electric MHDVs are higher than for comparable diesel vehicles but costs are declining. For example, one estimate shows a simple payback of electric MHDVs of three to seven years across Class 3 through Class 8 vehicles (Nadel and Junga 2020).

Figure 9. Projected Total Cost of Ownership of Light-Duty ICE Vehicles, BEVs, HEVs, and PHEVs

Source: Cadmus analysis 2020.



Another recent study projected that MHDV trucks will reach cost parity with comparable conventionally fueled vehicles on a total cost of ownership basis by 2030 (Tryggestad et al. 2017). Per MTA's reported data from 2020, it has not yet reached cost parity, signaling that the 2030 estimate may be optimistic for certain markets. MTA reported that in New York City, fuel costs for operating diesel buses are much lower than fuel costs for electric buses due to electricity demand charges. MTA estimated that it costs over $2.00 per mile on average to operate electric buses, much higher than diesel or CNG per mile costs (MTA April 2020). These are on top of the already higher upfront costs of electric buses relative to alternatives and reinforce the need to develop utility rate design strategies that encourage vehicle charging at times when the grid can most benefit.

Incremental costs for purchasing electric trucks and buses can vary dramatically. According to data collected by NYSERDA, recent transit bus procurements completed by CDTA, RGRTA, and Port Authority of New York and New Jersey found the incremental purchase cost between an electric and diesel bus to be in the range of $350,000 to $420,000. The incremental purchase costs of smaller electric MHDVs range from $60,000 to $150,000, while Class 7 and Class 8 electric trucks and school buses have incremental costs ranging from $100,000 to $250,000.

Electrical Infrastructure Impacts and Unmanaged Charging

Fleet EVs must be charged in a way that manages increases in electricity demand to minimize electricity demand charges that could otherwise make EV charging more expensive per mile than internal combustion engines. Fleets are subject to these demand charges as part of various commercial electric rates, and many EVs charging at once can make fleets particularly likely to experience significant increases in electricity demand. The simultaneous charging of MHDV will pose greater challenges than simultaneous charging of LDVs, as they typically have bigger batteries and require higher rated chargers. One offsetting factor is that, unlike households, fleets may have a greater ability to devise efficient charging schedules, which can be supported by managed charging software and hardware solutions that reduce peak electricity demand at a fleet depot and mitigate the impacts of demand charges.

In the near-term, electric MHDVs are expected to place greater stress on the electrical distribution system than light-duty EVs, particularly when several vehicles are charging at once. The Vehicle Inventory and Use Survey (VIUS) data suggests that 27% of non-bus MHDV fleet vehicles in New York State are part of a fleet with more than five vehicles (Census Bureau 2002). These larger fleets are geographically concentrated and pose a key challenge with respect to distribution system grid capacity. Overall, installing electric MHDV chargers is a substantial cost compared to installing light-duty EV chargers, operating costs are less predictable, and demand charges make a larger cost difference—all of which impose barriers compared to long-term diesel contracts.

Stresses on the electrical distribution system also arise from the coincidence of EV charging load with the utility's peak demand period for electricity. Especially during warm weather, the peak period for electric power demand in the late afternoon and early evening can coincide with the use of EV chargers by vehicle owners (both household and commercial fleets) who have returned from work or have parked their fleet at the close of the workday. Charge management measures, such as a time-of-use rate (TOU), can affect the baseline load shape. These measures incentivize users to charge their vehicles during off-peak periods, reducing the power draw during the peak load period.

Electric grid upgrade costs driven by transportation electrification in the State could require significant investment in the medium to long term. Even if managed charging is applied widely, large-scale EV adoption is likely to induce the need for upgrades to feeders that are already near capacity, causing additional costs to ratepayers. These costs may be offset by higher overall system utilization at a given level of grid investment, which tends to lower costs for ratepayers, but the net impact on ratepayers is not known at this time. As electric grid operators conduct system planning analyses and determine new investments that are required, increased electric demand resulting from electrified transportation will continue to be considered.

2.5.2 Insufficient Model Availability

The limited number of vehicle models currently available for purchase is a prominent barrier inhibiting both consumers and fleet managers from transitioning to electric options. There are 28 PHEV and 15 BEV models available in New York State markets in 2020 from 21 different auto manufacturers (Atlas 2020b). The only major new model in 2020 is the Tesla Model Y, which began deliveries in March 2020. Several additional new models are expected in 2021 and 2022, which will expand both the total number of EVs and the diversity of size classes (car and driver 2020). Additionally, several auto manufacturers have made announcements about new EV releases and commitments to EV deployment through 2025 (Buckland and Tajitsu 2019; Carey and White 2018; Lambert 2019; Winton 2019; and Volvo 2020).

Direct-to-Consumer Sales

EV adoption is hindered in New York State by restrictions on direct-to-consumer vehicle sales. As in approximately 30 other states, New York franchise laws require new cars be sold by independent, third-party dealers (Justia 2020). Tesla won a partial exception to this law in 2014. Other states have begun repealing these franchise laws to improve EV availability. For example, in 2020, Colorado passed Senate Bill 167, which allows an automaker to sell directly to consumers if they do not operate a franchise dealership in the state. This opens the door for emerging automakers like Rivian to have direct-to-consumer sales (which would not currently be permitted in New York State).

Even as automakers have made commitments toward electrification, the current availability of EVs at dealerships has been limited and inconsistent. In 2019, only 26% of auto dealerships in the United States had an EV for sale on their lot. In the Mid-Atlantic region, which includes New York State, less than 50% of dealerships that had at least one EV for sale on their lot had more than two EVs in inventory (Sierra Club 2019). Auto dealerships may lack the same incentive to sell EVs as they have to sell ICE vehicles, as the lower maintenance requirements on EVs compared to ICE vehicles imply lower revenue for dealership mechanic shops. Empirical evidence demonstrates that dealerships are much more likely to steer customers toward ICE vehicle models and that sales staff have low levels of knowledge about EV incentives (Zarazua de Rubens et al. 2018).

Model availability for electric MHDVs has grown substantially in the last five years yet remains a central barrier due to the diversity of vehicle types, sizes, and vocations in the segment. The Zero Emission Technology Inventory tool from CALSTART lists 11 medium-duty electric truck models available today and 67 expected by 2023, four heavy-duty electric truck models available today and 19 expected by 2023, two cargo electric van models available today and nine expected by 2023, and 290 electric transit bus models available today and more than 400 options expected by 2023. Most of these vehicles are being produced in low volumes, so availability may continue to be limited. By comparison, there are typically a dozen or more manufacturers for major conventional truck types, with each manufacturer offering multiple configurations of its basic model(s). New York State’s LDV stock is composed of 68% sports utility vehicles, crossovers, pickup trucks, and vans. Other than the Tesla Model X and Tesla Model Y, there are no BEV options in these vehicle categories and few PHEV options, although many models are expected in the next two years (from Tesla, Rivian, Ford, and General Motors). Additionally, many fleets are further restricted by Buy-America clauses in their procurement rules.

2.5.3 Charging Availability Barriers

Adequate access to charging is an important factor in EV adoption. Charging availability means having enough chargers available to serve EV travel needs and reduce EV drivers' vehicle range anxieties.

2.5.3.1 Vehicle Range Anxiety

As illustrated in the Drive Clean Rebate survey, vehicle range is the number one concern of light-duty EV owners in New York State.[8] Range anxiety refers to a driver's concern that they will not be able to reach their destination or a charging station before their vehicle runs out of power (Volvo 2019). The low density of charging availability today perpetuates this anxiety. DCFC stations are key to mitigating range anxiety for BEV drivers because of their fast charge time. Compared to other states, New York has a relatively low number of DCFC stations, ranking fifth nationally in total DCFC ports and 35th nationally in DCFC ports per 1,000 BEVs. This is due to several factors, including electric rate designs that may not be favorable to DCFC station economics and the historically high percentage of PHEVs in New York State (higher than in many other states) that are unable to use DCFC stations. Similarly, New York State ranks second nationally in total Level 2 ports but 28th nationally in Level 2 ports per EV (Atlas 2020b).

As noted in Figure 4, public charging is available in some form in most parts of the State. However, some gaps in public charging station availability remain. Level 2 charging stations have proliferated in and around most cities in New York State, but there is a continued need for greater availability at the types of locations that people frequently visit for an hour or more, such as workplaces, transit stations, public parking lots, parks, retail stores, restaurants, entertainment venues, and hotels. More rural parts of the State, especially in the Southern Tier and North Country, tend to have fewer Level 2 charging stations and could benefit from an increased deployment in these areas.

Complicating the question of charging station availability, some charging stations are equipped with distinct plug types that are compatible with different vehicles. Tesla uses its own proprietary plug types, which cannot be used by non-Tesla vehicles. According to the Alternative Fuels Data Center, there are 4,868 public Level 2 plugs available in New York State, 31% of which are Tesla plugs (U.S. DOE AFDC n.d.b). NYSERDA staff indicated that up to 20% of available charging stations in the State are not reported in the Alternative Fuel Data Center's database, so the numbers presented here are likely underreported. The non-reported chargers are primarily at workplaces and multiunit dwellings.

The DCFC market is characterized by three primary plug types—CCS, CHAdeMO, and Tesla. Of the 555 DCFC plugs in New York State, 76% are Tesla plugs (U.S. DOE AFDC n.d.b). Most PHEVs and some BEVs do not have a port compatible with DCFCs, but the proportion of EVs that can use DCFCs is expected to grow as more EVs on the road shift toward long-range BEVs. The diversity in connector equipment means that not all chargers and vehicles are interoperable, reducing the effective availability of charging infrastructure and creating a further barrier to EV adoption. Fortunately, most EV manufacturers other than Tesla are coalescing around the CCS standard for their U.S. operations, signaling a lessening of this barrier in the coming decades (Havlorson 2020). Non-Tesla DCFC availability is very limited throughout the State, but especially in Upstate New York. According to EValuateNY, 45 locations host non-Tesla DCFC stations outside of New York City, Long Island, and Westchester County, offering a total of 136 plugs, and most of those stations are in the Hudson Valley. There are 220 Tesla DCFC plugs in the same area, at 25 separate locations. New York City, Long Island, and Westchester County have 47 locations with non-Tesla DCFC stations, offering 113 plugs, and 27 locations with Tesla DCFCs offering 232 plugs. Even Tesla chargers are likely to need to increase in number to support an increasing number of Tesla vehicles on the road. The availability of DCFC stations that are non-proprietary to a specific vehicle manufacturer will be essential to greater EV adoption. New York State funding for DCFC is focused on expanding the installation of these non-proprietary stations.

2.5.3.2 Residential Charging Access and Infrastructure

According to the 2017 American Housing Survey, 51% of homes in New York State are in multiunit dwellings and 56% of homes lack an attached garage or carport, compared to the national averages of 29% and 34%, respectively (U.S. Census Bureau 2017). These realities present a major barrier to greater EV penetration in New York State, since most charging by early EV owners occurs at home (U.S. DOE EERE n.d.). Additionally, older buildings sometimes lack sufficient electric capacity to accommodate charging, limiting the viability of owning one or more EVs without upgrading the building's electrical infrastructure (U.S. DOE AFDC n.d.a). In New York State, the median home age is 66 years, compared to 43 years nationally (U.S. Census Bureau 2017).

Installing charging infrastructure at multiunit dwellings has the additional challenge of determining who should install, maintain, and pay for the charger (CEC March 2019). Multiunit dwellings are often inhabited by renters, who may be reluctant to invest in a charging station. Similarly, a building owner might be reluctant to invest in a charging station for tenants, assuming there would not be tangible benefit to the owner. However, the installation of home charging in multiunit dwellings can help retain existing tenants who drive EVs and can attract future tenants who value home charging access. Enabling EV adoption among multiunit dwelling residents is important to reach New York State's greenhouse gas emission goals, but it is important to recognize that these New Yorkers have, on average, lower greenhouse gas emissions from transportation than typical residents of single-family homes.

2.5.4 Awareness and Education Barriers

There is a general lack of understanding and awareness about EVs among consumers. Even in California, the state with the largest share of EVs (Auto Alliance n.d.), fewer people were able to name a single PHEV model in 2017 than in 2014, despite a significant increase in the number of available models (Kurani and Hardman 2018). The lack of awareness spans all aspects of EV ownership including vehicle options, incentive availability, and the benefits of driving electric.
This lack of information is further exacerbated by a lack of EV knowledge at many auto dealerships (Sierra Club 2019). Given the pivotal role of auto dealerships in consumer car-buying experiences, a lack of knowledge about EVs at these dealerships further limits the opportunity for consumers to choose electric. Lastly, consumers often make purchase decisions based on upfront cost rather than the lifetime cost of the vehicle (Goodwin et al. 2020). Therefore, even if EVs have a lower total cost of ownership, the upfront cost will still deter consumers who are more focused on the cost over the short term rather than on the lifetime cost.

2.5.5 Technology Barriers

Technology barriers include challenges brought on by a lack of standardization among product manufacturers and limitations of the EV technology relative to alternatives. Typical of new technology markets, there is a lack of standardization among vehicle and charging technologies, which translates to limitations on the interoperability of EV equipment. Likewise, certain technology characteristics, such as how charging impacts fleet operational schedules, cold weather vehicle performance, and marine vessel stock turnover, present additional barriers to electrification.

2.5.5.1 Cold Weather

New York State has many regions where the temperature during winter drops under 0°C for stretches of days or weeks. Cold weather requires increased energy for heating the cabin of the vehicle, which is energy that isn't used for propulsion, and impacts battery performance, especially when the vehicle is parked outside and not plugged into a charger (Jaguemont et al. 2016). A recent test by the Norwegian Automobile Federation estimated that EVs lose approximately 20% of their range in winter conditions in Norway compared to test-cycle ranges (Veihjelp 2020).

Cold weather also prolongs fast charging events because the onboard battery management system limits the charging rate to avoid detrimental effects on the battery cells (Motoaki and Shirk 2017). Charging might also be slower when the state of charge is low in cold climates, due to an increase in the battery's internal resistance under such conditions (Neubauer and Wood 2014).

A 2018 study used fast charge event data from 2012 Nissan LEAFs in New York City to examine temperature impacts on charge rates. The authors found that the state of battery charge after a 30-minute session could be up to 36% lower at 0°C compared to at 25°C (Motoaki et al. 2018). Another study conducted in Norway estimated that winter fast charging lowers the average charging power by 24% relative to summer charging (Figenbaum 2017).

2.5.6 Barriers to State Fleet Electrification

In surveys conducted with more than 60 state agencies and authorities, several barriers to electrification were identified. In general, these barriers are related to feasibility, access to charging infrastructure, and economics.

Feasibility—The NYS fleet serves diverse use cases that directly support agencies' abilities to fulfill their missions. In some cases, this includes functions such as highway maintenance and law enforcement, which require vehicles to be equipped with specialized capabilities not readily available in EV models presently on the market. Many agencies serve large geographic regions and require the frequent ability to travel long ranges or to remote areas to effectively perform responsibilities. Agencies have expressed that the market availability of EVs that are both cost-competitive and meet these specialized needs is not a strong enough incentive for them to electrify not only medium- and heavy-duty vehicles, but in some cases light-duty vehicles as well.

Access to Charging Infrastructure—Agencies often cited the lack of charging capabilities at their facilities and in areas where they frequently travel as a factor that prevents them from purchasing EVs. Many agencies occupy shared facilities that they do not own or directly manage and installing charging stations may not be allowed by the owner. Some agencies have expressed concern about the logistics of charging EVs at their facilities. Some agencies have indicated a need for cost-sharing models in order to make charging station investments viable, such as in cases where upfront costs are high and funding is not available. Even among agencies that express willingness to contribute funding, the uncertainty of how to effectively share charging assets among overlapping needs has been noted as a barrier to progress.

Economics—While EVs may present agencies with a lower total cost of ownership (TCO) than ICE vehicles, the annual state budget model emphasizes the upfront cost of acquiring EVs in agency decision-making which could make EV purchases more difficult. Furthermore, the savings on operations and maintenance costs over the years may be difficult to track and do not necessarily accrue back to the agency. The cost of installing charging stations for fleet vehicles is an additional cost that would need to be funded through the State budget or other means. Familiarity with EV technology may not yet be widespread among fleet managers. Without sufficient data on TCO, cost-benefit analyses and viable case studies, it is difficult for an agency with limited financial flexibility to justify an EV purchase from both a capital and operating-cost perspective.

To increase fleet electrification in the State fleet, New York could help agencies conduct fleet analyses and share best practices, including procurement guidelines.

Many State agencies have fleets that serve a dedicated function in a specific unit or department. Often, fleet management consist of capital and operating processes that may not be fully aligned. For example, a capital decision to purchase a certain number of vehicles may be based on useful life metrics of existing assets but including TCO as a factor in decision-making could help accelerate the transition to EVs. A comprehensive approach to fleet management would consist of a detailed inventory and analysis of factors including fleet right-sizing, matching vehicle types to functions or duty cycles, identifying high-vehicle miles traveled (VMT) vehicles, and other feasibility factors by fleet category (e.g., school bus versus transit bus fleets) or other vehicle characteristics. These analyses can help fleets identify which vehicles to convert to EVs first, and which vehicles may be appropriate for other technologies. Fleet analyses are an additional expense, but the data they provide can help fleet managers and procurement departments make more informed decisions.

By taking a proactive approach to gathering data and sharing between agencies, State agencies can evaluate options to install electric vehicle supply equipment (EVSE) at facilities where feasible. OGS and New York Power Authority (NYPA) have worked with many State agencies already and are well positioned to compile data on EV purchases and EV charging stations that can help inform State agencies. This helps build awareness of EV options, especially among fleet managers and decision-makers. For example, NYPA holds ride-and-drive events for its staff and has installed EV chargers at several facilities. Through Executive Order 4 and other lead-by-example sustainability initiatives, New York State has encouraged the purchase of clean products, including vehicles. Enhancing the vehicle procurement guidance could accelerate EV adoption.

3 Electric Vehicle Projections

To understand the expected growth in EVs and EV charging stations, a reference scenario was created that assumes a continuation of current trends in technology costs, vehicle availability, consumer behavior, and no new policies enacted beyond those that exist today. This scenario helps to address how many light-, medium-, and heavy-duty electric vehicles would be expected in coming decades absent additional policies (section 3.1); what EV infrastructure needs are associated with this level of EV adoption (section 3.2); and what the resulting greenhouse gas emissions are with this level of EV adoption (section 3.3).

3.1 EV Penetration Levels

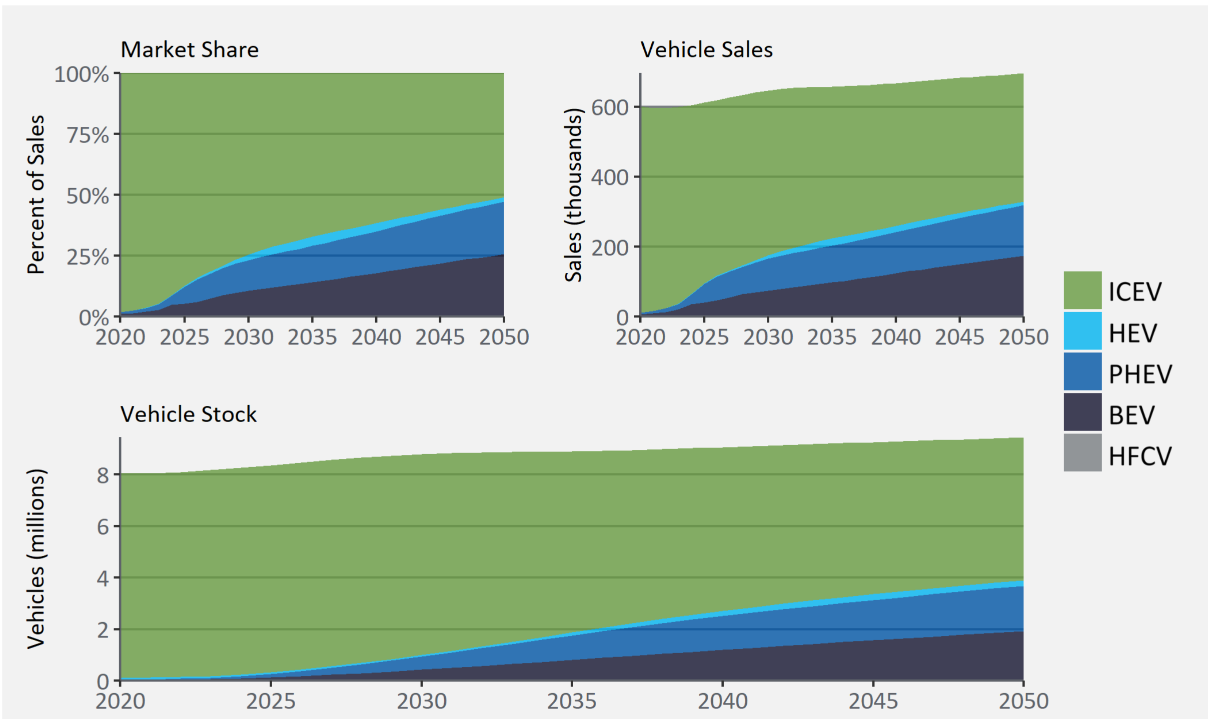
The pace and magnitude at which EVs grow in the future depend on a host of factors, including policy changes, relative ownership costs between EVs and ICE vehicles, EV model availability, charging availability, peer influence, awareness of the technology and incentives, and consumer preferences. This report captures the impact of these factors on the State's EV growth using customized modeling tools developed specifically for New York State. Light-duty vehicle choices are projected using a model that has been set up to capture the diverse vehicle preferences of New Yorkers, both now and in the future. MHDV EV projections are conducted with an accounting tool that includes a stock-turnover model.

3.1.1 Light-Duty Vehicles

Figure 10 depicts the reference scenario projections for light-duty market share (upper left), sales (upper right), and vehicle stock (bottom) by vehicle type. EV market share is projected to be 12% of new vehicles purchased in 2025, rising to 29% in 2035, 42% in 2045, and 46% in 2050. EVs are projected to represent 39% of the LDV stock in 2050. EV market share is projected to remain relatively evenly divided between BEV and PHEV over time with BEV share of EV sales ranging from 42% to 54%. Hybrid Electric Vehicle (HEV) market share is projected to fall to near 0% in the near-term (2020–2025) as buyers who might choose an HEV are pushed toward BEV and PHEV. EV sales grow rapidly between 2020 and 2025 under the influence of the current California Advanced Clean Cars rules (also known as the California ZEV regulations), which requires increasing EV sales through 2025 in states that have adopted the rules (this includes New York). EV sales in this reference scenario grow more slowly thereafter as the Advanced Clean Cars rules expire and several other factors—such as decreasing battery costs, increasing EV model availability, and increasing charging availability—increase EV adoption but not as rapidly as the regulations. It is important to note that California is currently considering an Advanced Clean Cars 2 program, which would continue the rapid growth of EV sales. This is discussed in Section 4.1, under ZEV Mandates.

Figure 10. Reference Scenario Projections for Light-Duty Vehicles in New York by Vehicle Type

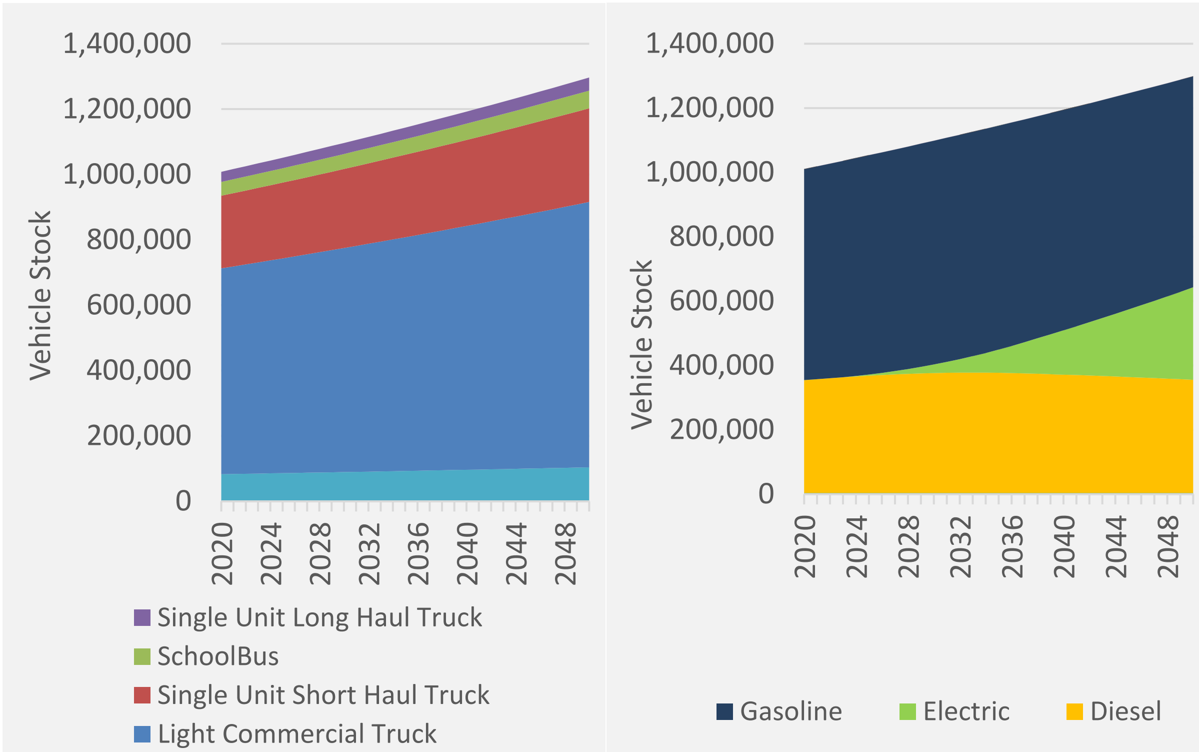
Source: Cadmus analysis using CMAT 2020.



3.1.2 Medium- and Heavy-Duty Vehicles

In the reference scenario MHDV EV, sales account for 1% of sales in 2024 and increase to 28% of vehicles sales in 2050. Additionally, a year-over-year vehicle population growth of 0.85% is projected for most vehicle classes except for long-haul combination trucks that have a growth rate of 0.61%. The resulting vehicle stock is expected to increase as shown in Figure 11. Light commercial trucks account for 62% of all vehicles in the medium- and heavy-duty categories.

Figure 11. Vehicle Stock

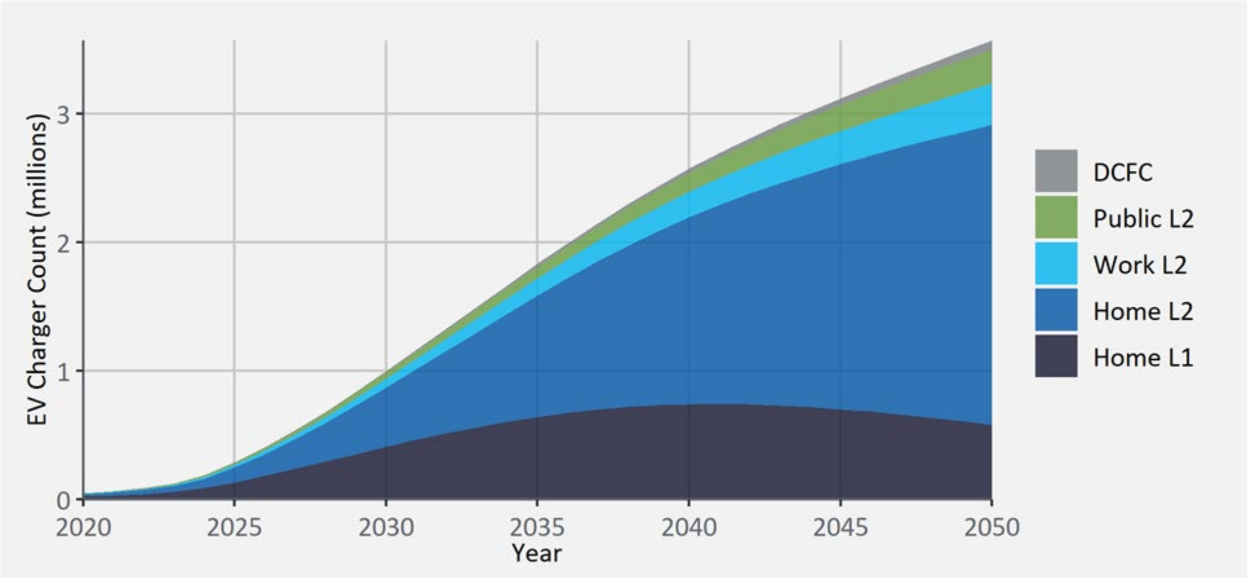


3.2 EV Charging Infrastructure Projections

The number of charging plugs needed to support New York State's EV population is an important consideration for development of public policy incentives and goals. The project team projected charging infrastructure for the reference scenario vehicle population using assumptions about the number and utilization of chargers of six typologies: home Level 1 (L1), home Level 2 (L2), workplace L2, public L2, public DC fast chargers (DCFC), and fleet chargers (Figure 12). MHDV chargers are not shown in this figure.

Figure 12. Reference Scenario EV Charger Counts

Source: Cadmus 2020.



Overall, home L1 and L2 chargers comprise approximately 80% of all plugs in 2050, with approximately 700,000 as Workplace L2, Public L2, and DCFC plugs. Note that Figure 12 only captures the number of chargers, not the number of vehicles served per day, the electricity load, or the installation cost, which differs substantially from the relative size of the wedges in Figure 12. Table 2, below, contains the projected charger counts in selected years.

Projections in Figure 12 use a simple spreadsheet projection tool, custom-built for New York State. The tool uses detailed data on the State's housing stock, VMT, and existing charging infrastructure, along with assumptions about charger utilization, power levels, and session times. The tool performs a similar function as other tools like EVI-Pro Lite (U.S. DOE AFDC n.d.c).

A key challenge to estimating future charging need is the uncertainty about whether observed charging behavior of early EV adopters persists into the future. For example, DCFC and vehicle technology are evolving quickly towards higher power levels and faster charging times. The extent to which extreme high-powered charging will compete with lower-powered residential, workplace, and public charging in the future remains an open question, but it is clear that public charging is critical to long-term EV adoption. Future EV adopters are expected to be less likely to have access to home charging than early EV adopters. The Drive Clean Rebate Survey found that 83% of BEV owners and 79% of PHEV owners lived in detached homes in 2018.

Table 2 contains the projected charger counts by type. DCFC projections vary according to the low- and high-DCFC scenarios.

Table 2. Projected Charger Counts

(Numbers displayed in thousands).

Year	Home L1	Home L2	Public L2	Workplace L2	DCFC	
					Low Scenario	High Scenario
2020	26	17	2	3	0	0
2025	133	115	15	22	3	4
2030	410	460	48	71	10	18
2035	643	944	93	133	21	43
2040	742	1,454	145	197	35	77
2045	703	1,905	203	257	52	118
2050	583	2,333	267	317	71	164

3.3 Greenhouse Gas Reductions

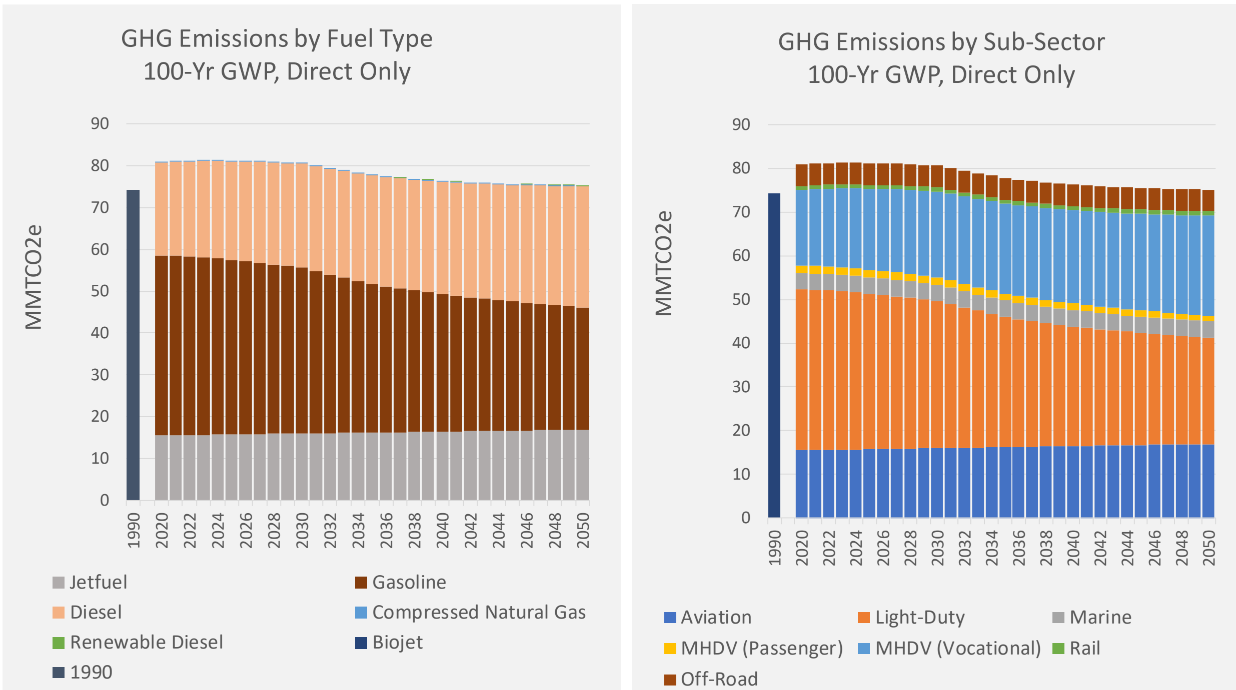
EV adoption is expected to grow steadily—particularly among LDVs—to 2050, even in the absence of additional State policy. As shown in Figure 13, under the reference scenario assumptions, the transportation sector has relatively flat GHG emissions through 2030, which then decline to total sector-level emissions of 75.2 MMTCO2e in 2050. Emissions modeled in the reference scenarios for 2050 are 7% lower than current emission levels but approximately the same as 1990 levels.

GHG reductions are largely due to the adoption of BEVs and efficiency gains in the LDV sector. The most notable emission reductions are projected for LDVs, where emissions are projected to decline by 34% between 2020 and 2050. Additionally, MHDV GHG emissions increase between 2020 and 2050 due to projected increases in VMT.

Figure 13. Reference Scenario GHG Emissions by Fuels for the New York State Transportation Sector

Type (Left) and Sub-sector (Right) Using 100-year GWP Lifecycle Emission Factors.

Source: Cadmus 2020.



4 Electrification Policy Analysis

Electrification is expected to play an important role in GHG emission reductions in the transportation sector. However, EV adoption projected in the reference scenario does not, in and of itself, achieve the GHG reductions necessary for meeting Climate Act goals. Other GHG emission reduction actions, such as use of low-carbon fuels (e.g., renewable diesel and waste-derived biofuels), travel shifts to low-carbon modes (such as public transportation, walking, or biking), and other activities to manage VMT, will also be needed to meet New York State's GHG emission reduction goals.

This section presents a range of policies that could be considered to increase transportation electrification in the State.

4.1 Policies for Transportation Electrification in New York State

This section provides an overview of policies that could be considered and is presented for informational purposes. The section draws upon academic research, economic theory, and GHG modeling conducted by the Cadmus Group. The policies are assessed along three dimensions: (1) demonstrated effectiveness of the policy to increase EV sales, (2) financial and economic implications of the policy, and (3) projected social equity and public health effects. A mix of qualitative and quantitative findings were used for each dimension.

Table 3 summarizes each policy considered. A rating of high in the first and third categories implies that the policy would increase EV sales (EV Sales Impact), does not pose a financial burden to the State (Fiscal Impact), and promotes equity and public health (Equity/Health Impact). A low rating implies the opposite. For the second category, a rating of low implies that the policy does not pose a significant financial cost to the State (Fiscal Impact), whereas a rating of high implies the opposite.

Table 3. High-Priority Policy Suitability Matrix

(High is more desirable, except for the Fiscal Impact column)

Policy	EV Sales Impact	Fiscal Impact	Equity/Health Impact
CA ACC2 Revised ZEV Mandate Extension	High	Low	Medium
CA Advanced Clean Trucks Rule	High	Low	High
Vehicle Purchase Incentives	Medium	High	Medium
Feebates	Medium	Low	Low
Carbon Pricing	Medium	Low	Low
Low Carbon Fuel Standard	Medium	Medium	Medium
Outreach and Education	Medium	Medium	Low
Charging Infrastructure Investment	Medium	High	Low
Utility Rate Designs	Low	Medium	Low

4.1.1 Policy Overviews

This section provides a high-level overview of each of the nine policy categories. Subsequent sections describe the effectiveness, financial and economic implications, and social equity and public health effects.

Table 4. ZEV Mandates

CA ACC2 Revised ZEV Mandate Extension	
The proposed California ZEV mandate (ACC2) would likely increase ZEV sale percentages beginning in 2026 to require that 100% of applicable passenger car and light-truck sales are reduced to zero-emission by 2035.	
Scope	LDVs from Classes 1-2a, All Fuels
Jurisdiction	State, Local
Timing	Mid-to-long-term (6-11+ years)
Barriers Addressed	Up-Front Cost, Insufficient Model Availability, Awareness and Education
EV Sales Impact	High
Fiscal Impact	Low
Equity/Health Impact	Medium
Advanced Clean Trucks Rule	
This California ZEV mandate would require that zero-emission truck sales to be 55% of Class 2b–3 truck sales, 75% of Class 4–8 straight truck sales, and 40% of truck tractor sales by 2035. If adopted in NYS, the MHDV ZEV sale requirements could begin with the 2025 model year.	
Scope	MHDVs from Class 2b to Class 8, All Fuels
Jurisdiction	State, Local
Timing	Mid-to-long-term (5-11+ years)
Barriers Addressed	Up-Front Cost, Insufficient Model Availability, Awareness and Education
EV Sales Impact	High
Fiscal Impact	Low
Equity/Health Impact	High

ZEV mandates are part of a broader policy category that includes binding and non-binding vehicle sales requirements. These policies are useful in providing policy certainty and setting expectations on vehicle sales for all stakeholders involved in vehicle markets and transportation infrastructure (Melton et al. 2017). There is a long history of the use of mandates to regulate transportation emissions at both the federal and state levels, such as the mandated phaseout of leaded gasoline that began in the 1970s (U.S. EPA 1996). The United States Environmental Protection Agency (U.S. EPA) has authority over air quality and vehicle efficiency standards, but Section 177 of the Clean Air Act permits California to set its own standards that other states may adopt.

Through the Section 177 provision, New York State adopted the California ZEV Program in 1993 (CARB 2017). Since 2018, the State has implemented the multistate ZEV Implementation Plan, which requires automakers of a given size to sell increasingly larger shares of light-duty EVs (and fuel cell electric vehicles) beginning with the 2018 MY, with increasing required sales percentages through 2025. California is now in the early stages of the regulatory process of considering a post-2025 Advanced Clean Cars (ACC2) ZEV Mandate Extension that would target 100% ZEV sales for passenger cars and light trucks by 2035. Additionally, in July 2020, New York State signed a joint memorandum of understanding with 14 other states and Washington, DC committing to 30% ZEV sales in the MHDV subsector by 2030, and 100% by 2050 (NESCAUM 2020). The signatories have agreed to consider the adoption of the Advanced Clean Trucks Rule promulgated by the California Air Resources Board, which requires 55% of Class 2b–3 truck sales, 75% of Class 4–8 straight truck sales, and 40% of truck tractor sales be ZEVs by 2035 (CARB June 2020).

Table 5. Vehicle Purchase Incentives

Vehicle Purchase Incentives	
EV purchase incentive programs, generally in the form of a purchase rebate, provide financial support that covers a portion of the purchase price of an EV.	
Scope	All Sizes, Electric
Jurisdiction	State, Local
Timing	Near-term (1-3 years)
Barriers Addressed	Up-Front Cost
EV Sales Impact	Medium
Fiscal Impact	High
Equity/Health Impact	Medium

Policies that send price signals to the consumer align private and societal costs and address cost barriers associated with EVs relative to ICE vehicles. New York State implements such policies on a statewide basis under the Charge NY initiative, which includes NYSERDA's existing Drive Clean Rebate program, which offers a vehicle purchase incentive of up to $2,000 per vehicle, and the New York Truck Voucher Incentive Program, which offers a vehicle purchase incentive for electric trucks and buses that varies by weight class and vehicle type. There are at least 300 pricing-based programs offered across the U.S., including grants and rebates, registration and licensing fees or exemptions, and tax incentives (U.S. DOE AFDC 2020). Typologies include incentives and disincentives affecting both up-front and on-going vehicle costs. The highest EV purchase incentive programs in the United States are currently in Colorado, which offers up to $5,000 per EV and California, which offers a mix of rebates worth up to $5,850 for certain household types and regions.

Table 6. Feebates

Feebates	
Feebates institute a penalty for vehicles with high CO_2 emissions and provide a rebate for vehicles with low or no CO_2 emissions.	
Scope	All Sizes and Fuel-Types
Jurisdiction	Regional, State
Timing	Near- to Long-Term (can phase in/out over a decade)
Barriers Addressed	Up-Front Cost
EV Sales Impact	Medium
Fiscal Impact	Low
Equity/Health Impact	Low

Feebates are another price-based policy that helps align private and social costs. The format of a feebate policy can change over time to accommodate changing market dynamics. In early years, a small fee on the many higher-emission vehicles in the market can fund a relatively substantial benefit for the few lower/no-emission vehicles in the market; later, as the market evolves, the policy might levy heavier penalties on higher-emission vehicles, which can fund a small benefit to the larger population of lower/no-emission vehicles. Jurisdictions at the state and local levels have the authority and administrative capacity to establish a feebate program. Feebates have been discussed widely for nearly two decades in the Unites States. Currently, no state implements a feebate program.

Table 7. Carbon Pricing

Carbon Pricing	
Carbon pricing encourages switching to less carbon-intensive fuels, modes, and vehicles. Over the long-term, it can spur innovation.	
Scope	All Sizes and Fuel-Types
Jurisdiction	Regional, State
Timing	Near- to Long-Term (can phase in/out over a decade)
Barriers Addressed	Total Cost of Ownership
EV Sales Impact	Medium
Fiscal Impact	Low
Equity/Health Impact	Low

A carbon price places a cost on GHG emissions, either in the form of a tax, a cap-and-trade, cap-and-invest, or another similar system. This price can serve as a long-term signal to consumers and investors to shift away from fossil fuels by pricing the externalities of carbon emissions. Carbon pricing can be applied in a variety of ways including technologies, economic sectors, or geographies.

New York State already participates in the Regional Greenhouse Gas Initiative (RGGI) along with Northeast and Mid-Atlantic states. RGGI is a cap-and-trade program covering the electric power sector that establishes an auction through which electric power generators must purchase pollution allowances. California's cap-and-trade program has included a declining cap on transportation sector emissions since 2015, which are regulated at the point of fuel distributors. California's program provides certainty about emission reductions year over year and uses the revenues to fund programs that further EV deployment and other sustainable transportation initiatives. Since 2015, California has invested more than $3.5 billion of its cap-and-trade revenue in sustainable transportation programs (CCI 2020). In December 2020, Massachusetts, Connecticut, Rhode Island, and the District of Columbia agreed to move forward with a cap-and-invest program covering GHG emissions from the transportation sector and the Transportation and Climate Initiative Program (TCI-P). New York State continues to monitor the TCI-P and collaborate with these states and other Northeast and Mid-Atlantic states on the development of the framework behind the TCI-P.

Table 8. Low-Carbon Fuel Standard

Low-Carbon Fuel Standard (LCFS)	
A NY LCFS could, for example, require a 20% reduction in average carbon intensity for fuels by 2030. Compliance would occur through the sale of low-carbon fuels or exchange of credits.	
Scope	All Sizes and Fuel-Types
Jurisdiction	Regional, State
Timing	Near- to Long-Term (can phase in/out over a decade)
Barriers Addressed	Total Cost of Ownership
EV Sales Impact	Low
Fiscal Impact	Medium
Equity/Health Impact	Low

An LCFS would regulate the carbon emission intensity of transportation fuels, setting a target that declines over time compared to current trends. Compliance would occur through the sale of lower carbon intensity fuels such as electricity, biodiesel, and natural gas, or through the purchase of credits from other manufacturers that have generated credits through their own sales of low-carbon fuels.

The New York State Senate has been considering establishing an LCFS since the 2019–2020 Legislative Session. S2962A, which is in Committee as of January 2021, would reduce carbon intensities from the on-road transportation sector by 20% by 2030 (NY Senate 2019). If adopted, the State would join

Oregon and California as one of the few U.S. states with an LCFS. California's LCFS has been in place since 2011 and targets the same reductions as proposed in New York State, while since 2016 Oregon's Clean Fuels Program has targeted reductions of 25% by 2035 (CARB 2020a, Oregon 2020).

Table 9. Outreach and Education

Outreach and Education	
Aimed at increasing EV awareness and familiarity, activities can include partnerships with dealerships, social media campaigns, ride-and-drive events, major employer partnerships, and online cost calculators.	
Scope	All Sizes and Fuel-Types
Jurisdiction	Regional, State
Timing	Near- to Long-Term (can phase in/out over a decade)
Barriers Addressed	Awareness
EV Sales Impact	Medium
Fiscal Impact	Medium
Equity/Health Impact	Low

Research indicates that the car-buying public lacks awareness and understanding of EV technologies. Insufficient familiarity with EVs can inhibit adoption as unfamiliar buyers are intimidated by unfamiliar technology or view only sticker prices without considering potential available incentives, TCO savings, and other benefits of EV ownership (Jenn et al. 2018). Outreach and education can address these challenges. State agencies, cities, and utilities have used different types of advertising campaigns to increase EV awareness, such as partnerships with dealerships, social media campaigns, major employer partnerships, and online cost calculators. The "Drive Change. Drive Electric." EV marketing campaign, which NYSERDA supports, is one such program.

Improved signage for EV-ready corridors can also raise awareness of EVs and EV charging availability among potential EV drivers. There are eight corridors in New York State that have been designated EV Ready through the Federal Highway Administration’s Alternative Fuel Corridor program (FHWA 2020). Ride-and-drive events, where consumers and fleet managers have the opportunity to test drive the vehicles, can give New Yorkers hands-on experience with the technology and function of EVs.

Table 10. Charging Infrastructure Investment

EVSE Investment	
Investment in EV charging infrastructure can support the viability of EVs. These can be public funds or utility-funded upgrades aimed at increasing transportation electrification and growing the utility rate base.	
Scope	All Sizes and Fuel-Types
Jurisdiction	Regional, State
Timing	Near- to Long-Term (can phase in/out over a decade)
Barriers Addressed	Charging Access
EV Sales Impact	High
Fiscal Impact	Medium
Equity/Health Impact	Medium

Charging infrastructure investments provide financial support for residential, workplace, public, or commercial EVSE installations. This support most often comes in the form of incentives, rebates, and financing, but could also entail direct installation by governments or utilities. Investment can support any number of EVSE-related costs, including a variation to cover the cost of the electrical infrastructure required, up to but excluding the charger itself, called make-ready infrastructure. Investment in EVSE supports EV adoption by reducing range anxiety, increasing charger availability, and enabling infrastructure in locations and for market segments not covered by the private EVSE industry.

Several charging infrastructure investment programs are available in New York State, spanning the LDV and MHDV sectors and backed by both government and utilities. NYSERDA's Charge Ready NY Program currently offers $4,000 per new charging port installed and $1,500 per charging port replaced in parking lots at eligible public sites, workplaces, and multiunit dwellings. New York State's Department of Public Service recently approved a $700 million Make-Ready program, which mandates New York State's six IOUs invest $200 million into environmental justice communities and install over 53,000 level 2 chargers and 1,500 DCFC by 2025 (NYSDPS July 2020). NYPA's Evolve NY program will invest up to $250 million statewide, primarily by building a network of DCFCs across the State. Additionally, $19.2 million from New York State's portion of the Volkswagen Settlement will fund light-duty EVSE (DEC 2019b).

Table 11. Utility Rate Designs

Utility Rate Designs	
Changes to utility rates to better reflect system costs and encourage transportation load is managed cost-effectively. Interventions include TOU rates, subscription-style demand charges, or demand charge holidays.	
Scope	All Sizes and Fuel-Types
Jurisdiction	Regional, State
Timing	Near- to Long-term (can phase in/out over a decade)
Barriers Addressed	Total cost of ownership
EV Sales Impact	Low
Fiscal Impact	Low
Equity/Health Impact	Low

EVSE investment can be supplemented by utility rate designs that encourage vehicle charging during periods when there are lower wholesale energy prices and less demand on the grid. To the degree that grid carbon intensity is correlated with the time-differentiated factors underlying these utility rates, bill cost management should be correlated with carbon reductions. Designs might entail introduction of TOU rates, variable or critical peak pricing, or peak day pricing, all of which aim to better align retail prices with real-time grid prices.[9] New York State utilities already offer TOU rates across their customer classes; however, uptake of these rates instead of the default flat rate is low, as shown in Table 12 (Synapse 2018).

Table 12. Uptake of Opt-In Residential TOU Rates in New York State

Utility	Residential TOU Customers	Total Residential Customers	% TOU
National Grid	5,624	1,475,271	0.4%
Con Edison	1,720	2,896,029	0.1%
Central Hudson	1,000	266,061	0.4%
RG&E	1,273	334,750	0.4%
NYSEG	4,016	766,954	0.5%
O&R	3,399	198,331	1.7%

Additionally, utility rate designs—like the demand subscription embedded in Pacific Gas and Electric Company's Business EV rate or subsidies such as the demand charge deferral Southern California Edison offers to Commercial and Industrial customers—can improve the economics for high-power EVSE installations that would otherwise incur high-demand charges, such as those at fast-charging stations or serving MHDV fleets (PG&E 2020, SCE 2020). Such designs are aimed at mitigating the potential imbalance between demand and energy charges when charging station utilization is low. When utilization increases and stations deliver more energy, fixed costs can then be spread over a larger utilization making the capital investment more viable.

It should be noted that demand charges support critical policy objectives of reducing utility system costs and protecting utility customers, including low-income customers, from cost shifts and bill increases, and these objectives should be considered alongside benefits of potential utility rate designs. One example of a utility rate design currently underway in New York State is the re-examination of the Standby Rate through a series of Department of Public Service Staff whitepaper proposals which will allow customers, including those with commercial and residential EV charging loads, an increased ability to manage their bills to more accurately reflect the impacts of their usage on the system.

4.1.2 Effectiveness of Policies on Electric Vehicle Sales and Emissions

A literature review suggests that many of the policies described above present cost-effective ways to increase EV adoption. In a paper by Narassimhan and Johnson (2018), the authors find that adding one additional public charger per 100,000 people results in 7.2% increase in BEV sales and 2.55% increase in PHEV sales. Additionally, increasing a vehicle rebate value by 1% results in 2.1% higher BEV sales. According to this analysis, of the policy types examined, the most cost-effective policy to achieve emission reductions through induced EV adoption is investment in public EVSE. The measured effect may be because investments address several key barriers to electrification, including vehicle range anxiety and charging access for renters, residents of multiunit dwellings, and others that are unable to install a home charger. Vehicle purchase incentives are also found to be reasonably cost effective. Some policies, including carbon pricing, LCFS, and utility rate design policies, were not found to have as large a direct impact on EV adoption, but provide other benefits to the EV market. A carbon price or LCFS is more likely to influence EV adoption through the investment of revenue generated from the policy. EV outreach and education efforts are likely to have the greatest impact in the short term, while EV market share remains relatively low.

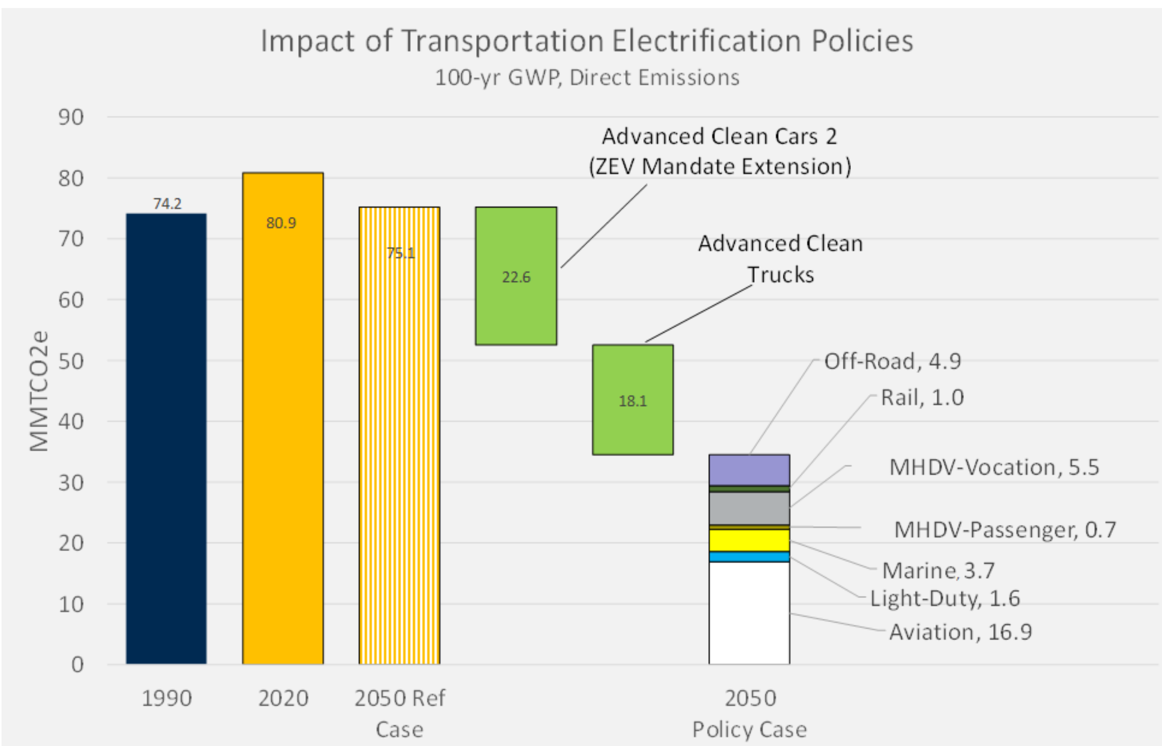
Policy effectiveness varies based upon size and delivery-mechanism of the signal. The impact of pricing signals on market transformation depends partly on when the signal is provided to the vehicle buyer. Notably, incentives offered to vehicle buyers at the time of purchase ("on-the-hood" rebates) have a greater impact on EV adoption than the same amount offered later (such as three months later), or than income tax credits, which tend to be realized at tax filing (Gallagher and Muehlegger 2011; Sierzchula et al. 2014). To this end, vehicle purchase incentives or feebates that can be realized by consumers at or near the time of purchase decisions are likely more effective at increasing EV adoption than an LCFS or carbon price, where cost impacts are ongoing. Analysis of state vehicle purchase incentives offered in the U.S. between 2010–2015 found that a $1,000 increase in incentive is correlated with increases in registrations within the state of 11% for BEVs and 5% for PHEVs (Wee et al. 2018).

Regulatory mandates can be more broadly impactful than other policy actions. A ZEV mandate's long-term market signal—and threat of penalty for noncompliance—work in concert to encourage increased EV adoption. EV market share is roughly twice as high in states that have adopted the ZEV Program compared to states without the mandate (CAP 2018). Likewise, cities in ZEV Program states have higher EV deployment than those in non-ZEV Program states (ICCT 2015). Compliance with the existing ZEV Mandate is expected to drive EVs to comprise 12% of new vehicle sales by 2025 in New York State. However, a ZEV Mandate alone may not create the appropriate conditions for broad EV adoption. Compliance is not guaranteed (manufacturers can opt to pay a fine instead of earning program credits), and additional investments in incentives, charging infrastructure, education and awareness, and other activities may be needed to help ensure the success of the mandate. This can underestimate the cost and overestimate the effectiveness of simply instituting a mandate.

If New York State were to adopt both the California Advanced Clean Cars ZEV Mandate Extension and the California Advanced Clean Truck rule and do what is necessary to make them effective, this could lead to an increase in EV adoption that results in a more than 50% reduction in GHG emissions compared to the reference scenario. An extended and expanded light-duty ZEV Mandate Extension that requires 100% of new vehicles sold be zero emissions by 2035 would lower total LDV emissions by an estimated 22.6 $MMTCO_2e$ per year by 2050, beyond the reference scenario.[10] Adoption of California's Advanced Clean Truck regulation would further lower MHDV emissions by an estimated 18.1 $MMTCO_2e$ per year by 2050, beyond the reference Scenario. Together, the combined impact of the ZEV Mandate Extension and Advanced Clean Truck regulation would lower transportation sector emissions by 40.7 $MMTCO_2e$ per year by 2050 beyond the reference scenario. This level of reduction results in a 54% reduction relative to 1990 levels.

Figure 14. Emission Reductions Projected from ZEV Mandate Extension and Advanced Clean Trucks ZEV Mandates

Source: Cadmus 2020.



4.1.3 Fiscal and Economic Implications

Transportation electrification policies can have a wide range of effects on government budgets. Policies like a carbon price and gasoline tax can be revenue-generating for the administrator, while vehicle purchase incentives, rebates, and refunds are costs, and tax credits equate to forgone income. Policies can be implemented or adjusted to be revenue-neutral, either by facilitating transfers between groups or by providing refunds from the income generated by the policy. Furthermore, the financial burden of activities that enable EV transition can be expected to shift as the market matures and approaches adjust, as illustrated in Figure 14.

Adoption of sale mandates like the ZEV Mandate Extension and the Advanced Clean Trucks Rule may be relatively low cost to administer but should be considered in conjunction with other supporting policies required to ensure that they are successful. Under the current LDV ZEV Mandate, automakers can either sell enough ZEVs to meet the requirement or buy ZEV credits from other manufactures if they do not produce enough of their own. This mechanism rewards vehicle manufacturers that can produce ZEVs more cost-effectively, enabling a more efficient ZEV transition.

Pricing-based signals can be enacted in the near-term to accelerate adoption of EVs while the market is still maturing. As EV uptake increases, the total cost of vehicle purchase incentive programs likewise increases. Incentive design can account for these dynamics by building in a phase-out of the incentive when the market reaches a specified threshold of mainstream EV adoption or by limiting incentives to specific target buyers or vehicles. Feebates are an alternative to vehicle purchase incentives that can be implemented in a revenue-neutral manner by using funds collected from the penalty on high-emission vehicles to finance the rebate.

While charging infrastructure investments can be financed by government, New York State regulators have assigned electric utilities a leading role in these initial efforts (NYSDPS July 2020). Utility investment of ratepayer funds to advance transportation electrification can be prudent for ratepayers and society. With more charging infrastructure and associated EV adoption, utilities can increase utilization of their existing assets through EV charging at off-peak times, which can potentially bring down rates for all ratepayers. Utility charging infrastructure investments can also be deployed in tandem with ongoing utility efforts to upgrade and modernize the grid. Current approved utility charging investments in the State are approved through 2025.

Utility rate designs that better align price signals with system costs have the potential to further enable efficient load growth and downward pressure on electricity prices. From a government and societal perspective, this should not introduce any new costs or cross-subsidization. As upfront price and total cost of ownership for EVs are expected to continue to decline, an important future consideration will be the policy implications of the cost decline trend.

4.1.3.1 Cost of Electrifying the New York State Fleet

Converting the entire New York State fleet to electric vehicles is likely to require a higher level of investment, at least upfront, compared to replacing-in-kind gasoline and diesel vehicles, *but* it is very likely the State can realize significant total lifetime savings that will offset these upfront costs. Fleets turn over on a prolonged schedule, typically over approximately 15 years, depending on the vehicle type. This means that the cost to the State will be lower to replace EVs as needed rather than convert the entire fleet immediately, as the cost of the vehicles and the TCO is expected to continue to fall. Over this period, model availability is expected to improve and EV models should be available in nearly all vehicle segments.

The current incremental cost of a light-duty EV is estimated to be about $11,500, falling to zero around 2028. If the entire fleet of nearly 22,000 LDVs is replaced steadily over 15 years and prices fall accordingly, it would cost $76 million in additional purchase costs compared to what it would have cost to buy gasoline vehicles over that time. The excess upfront costs would start at nearly $17 million per year, falling to $0 by 2028.

The economics of owning MHDVs are expected to improve until the TCO is equivalent to diesel vehicles around 2030, although some vehicle segments are expected to reach TCO equivalence with diesel vehicles much sooner. Incremental costs of MHDVs range from $60,000 to $400,000, with average incremental costs in the range of $100,000 to $200,000. If the entire fleet of approximately 4,000 State-owned MHDVs is replaced over 20 years and incremental costs fall by 75% over that period, it would cost $375 million in additional purchase costs compared to what it would have cost to buy diesel vehicles over that time. The excess upfront costs would start at $30 million per year, falling to $7.5 million per year by 2040.

Additionally, charging stations would be needed to support these electric vehicles. Assuming that each LDV would require its own Level 2 charging station, which would cost an average of $7,000 per vehicle, this amounts to an additional $154 million over 15 years, or approximately $10 million per year. MHDVs may be able to share charging stations but each charging station would be higher powered and more expensive. If the 4,000 MHDVs require 2,000 charging stations at an average of $50,000 per station, this amounts to an additional $100 million over 20 years, or $5 million per year.

In total, converting the State fleet to EVs could cost $705 million more in upfront expenses over 20 years than it would cost to continue purchasing gasoline and diesel vehicles, but cost savings from reduced operating expenses can be expected to significantly, if not totally, offset these upfront costs.

4.1.3.2 Revenue Options

This report does not recommend one particular path in raising revenue to pay for incentives, or which type of incentive New York State should consider. The Climate Action Council is currently considering a range of options for these types of policies, which are expected to be part of the council's scoping plan of recommendations for achieving the GHG reduction targets specified in the Climate Act.

Options to generate revenue to support EV programs can be found by looking to other states that have instituted similar measures to fund EV incentives and other programs.

As noted above, a carbon price can raise revenue that could be used to invest in EVs and EV charging infrastructure, either through a cap-and-trade or cap-and-invest system, or through a carbon tax. For example, California instituted its economy-wide cap-and-trade system in 2013 and expanded it to the transportation sector in 2015 (CARB 2015), and since then has used revenue generated through the sale of carbon credits to invest nearly $700 million in its LDV EV rebate program, the California Clean Vehicle Rebate Project (CVRP), and approximately $350 million in its MHDV EV rebate program, the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program (HVIP). These two programs have been the beneficiary of nearly 20% of all revenue generated through the cap-and-trade program (CARB 2020).

In California, electric utilities generate credits through the sale of electricity for use in transportation. Utilities are required to reinvest any revenue generated from the sale of those credits for the benefit of current of future EV owners (CARB 2021). California's utilities currently offer rebates to consumers that cover the purchase of new EVs, home charging stations, and/or the electricity to charge an EV.

Incentives range from $800 to $1,500 per customer. Public EV charging station owners generate LCFS credits, which can help improve the business case for installing these stations. EV fleets can capture the credits associated with their EVs, so trucks and buses can earn credits worth up to $10,000 per year from the LCFS.

States have used other mechanisms to encourage or require investment in EV incentives and EV charging infrastructure as well. Many states, including New York, have authorized utilities to invest in EV charging infrastructure, often using ratepayer funds. Public utility commissions have recognized that greater EV adoption can be beneficial to ratepayers because of the potential to flatten load curves and increase overall system utilization, which can put downward pressure on all electric rates. According to Atlas Public Policy, since 2012, 28 states have approved utility filings to invest in the EV ecosystem, totaling more than $2.6 billion (Atlas 2019). Of these filings, the large majority have been in California ($1.5 billion) and New York State ($700 million). Most of the funding in these filings is expected to go toward installing EV charging infrastructure for both LDVs and MHDVs.

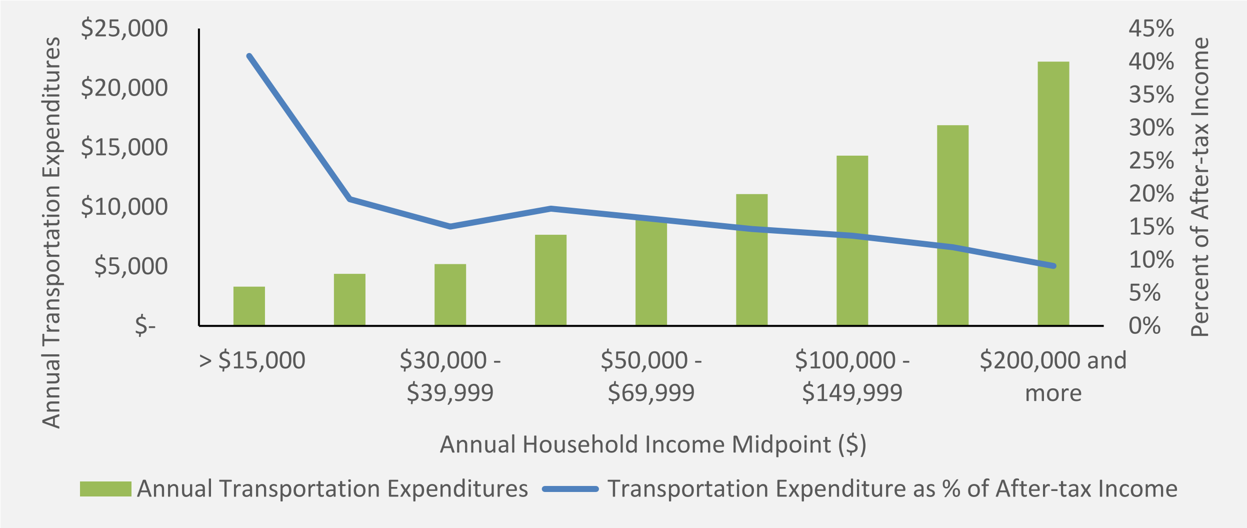
Green banks like the NY Green Bank can also encourage increased private investment in the EV market. By providing lower cost capital through agreements with private entities in the EV ecosystem, including vehicle manufacturers, charging station providers, and fleets, they can help de-risk investments in EVs to help them move forward.

4.1.4 Social Equity and Public Health Effects

Transportation-related costs are a significant portion of household spending across all income brackets. On a relative basis, low- to moderate-income households spend more income on transportation; transportation-related expenditures exceed 40% of total expenses for the lowest-income households in the Northeast (Figure 15, BLS 2020).

Figure 15. Transportation Expenditures versus After Tax-Household Income in the Northeast

Source: BLS 2020.

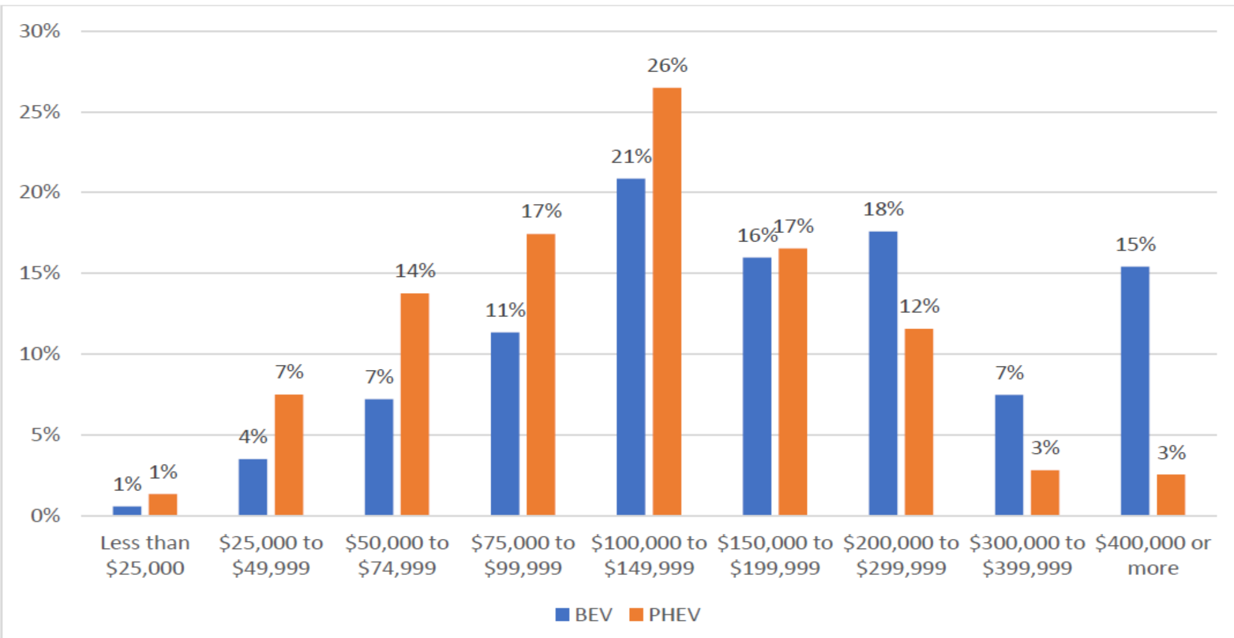


Policies that apply a uniform cost signal to all consumers may have a disproportionate impact on low- and moderate-income households, perpetuating existing inequities. For example, tax credits can only be redeemed by households with tax liability, which means wealthier households benefit from these incentives. Another consideration is how policies affect the secondary vehicle market, especially because consumers that buy used cars tend to have lower incomes than buyers of new or leased vehicles (BLS 2003). Creative solutions may be needed to design policies that are well-tailored to address distributional issues around transportation electrification. The Climate Action Council, specifically through the Climate Justice Working Group, is currently working in close collaboration with the Transportation Advisory Panel to address these issues and identify ways to expand EV adoption to disadvantaged communities in the State.

Because EV sales in the current market are concentrated among higher-income families (as are all new car sales), without intentional program design, vehicle purchase incentives can be expected to accrue to higher-income consumers. The Drive Clean rebate survey indicates that 77% of BEV owning participants and 61% of PHEV owning participants have an annual household income greater than $100,000, as seen in Figure 16. Rebates from CVRP were also heavily concentrated among households with incomes greater than $100,000 during the program's early years. The California CVRP has since changed its rules to eliminate rebates for higher income EV buyers and increase rebates for low- and moderate-income (LMI) consumers (CSE 2020a). Intentional policy design choices can enhance positive impacts on social equity by differentiating vehicle purchase incentive levels based on applicant income, or by making tax credits refundable so they can be redeemed as a benefit by people without tax liability. Equity-related incentives have been shown to spur adoption of EVs at a lower total cost to taxpayers (DeShazo et al. 2017; Jenn 2020), although rebates for new EV sales for low-income buyers still make up a small portion of total rebates in states that offer bonuses for low-income EV buyers. Still, increasing rebates for LMI customers and reducing rebates for higher income customers would significantly shift the distributional impacts of a vehicle purchase incentive program.

Figure 16. Distribution of Drive Clean Rebate Survey Respondents by Household Income

Source: Drive Clean Rebate Survey Report 2018-2019.



Currently, only sales or leases of new EVs are eligible for New York's Drive Clean Rebate, while vehicle purchase incentives available to LMI consumers in Oregon and California are also made available for purchase of used EVs (CARB 2020c). Considering that most car sales are used car sales, and most car purchases among LMI consumers are used cars, focusing funding on incentives to buy used EVs could dramatically increase EV adoption among LMI car buyers.

Another approach to address the potential distributional impacts of electrification policy is to prioritize investment aimed at electrified public transportation, as public transportation services are used more heavily by lower income households and often have congested, diesel-polluting bus depots located in or adjacent to low-income neighborhoods (APTA 2017). In addition to making improvements to the overall public transportation system, the State continued its focus on investing in electrified public transportation in early 2020 when Governor Cuomo announced that five large upstate and suburban transit operators would convert to 25% electric buses by 2025 and 100% electric buses by 2035, representing a combined total of more than 1,300 transit buses. In addition, as part of the New York Truck Voucher Incentive Program (NYTVIP), purchasers of new, zero-emissions all-electric transit buses are eligible to have 100% of the incremental vehicle cost covered if the buses are housed at bus depots or operate on routes located within a half-mile of a disadvantaged community. DEC and NYSERDA also announced they would provide $40 million in vehicle purchase incentives for electric transit buses, and additional funding for electric transit buses was included in the New York State budget (NYSERDA March 2020 and December 2020).

While GHGs are a global pollutant and their environmental impacts manifest at a global scale, their associated co-pollutants can have very localized impacts with social, health, and economic implications. Therefore, efforts to reduce emissions should consider the local impacts especially within historically disadvantaged communities. Policymakers in California attempted to mitigate this risk in 2017 through passage of AB 617, which aims to improve localized air quality monitoring, especially in disadvantaged communities and near point-sources (CARB 2020b). Another approach is to focus investment of program revenues and associated benefits in these areas, as is the case under New York State's Climate Act law, which directs at least 35% of spending to benefit disadvantaged communities.

As part of the Climate Act, the Climate Justice Working Group is working closely with the Transportation Advisory Panel to help identify clean transportation strategies that will bring the greatest benefit to disadvantaged communities. The work will build upon existing New York State initiatives underway that will improve clean transportation access in disadvantaged communities, including the $701 million Make Ready order, which allocates $206 million toward electric transportation projects in disadvantaged communities.

While the primary goal of transportation electrification investigated in this report is GHG reduction, electrification is expected to generate a parallel reduction in associated co-pollutants. Co-pollutants that are monitored by DEC include gaseous criteria pollutants such as ozone, sulfur dioxide, oxides of nitrogen, carbon monoxide, as well as particulate matter. Although they comprise a small portion of total vehicles in the State, diesel MHDVs are responsible for 30% of total PM and NO_x emissions from mobile sources (United States Department of Transportation [U.S. DOT] OSTI 2018). Diesel pollution is particularly problematic in disadvantaged communities, which often are the location of facilities with high truck and bus traffic. This leads to an increased burden of health impacts in these communities, such as higher rates of asthma. Policies that target MHDVs, such as MHDV EV incentives, fleet EVSE investments, or a MHDV ZEV mandate, can be expected to generate significant public health and resiliency benefits. These benefits will accrue across the State but will be especially noticeable along major highways and thoroughfares and in areas adjacent to heavy industrial traffic, such as warehouse districts and ports, which tend to be lower income areas and communities with larger populations of color. Making progress toward environmental justice will require enhanced approaches to transportation electrification, but especially MHDV electrification.

Distributional impacts of ZEV mandates, utility rate designs related to transportation electrification, and EV outreach and education are other ongoing areas of additional research.

5 Conclusion

5.1 Synthesis of Results

The preceding chapters describe the transportation electrification landscape in New York State.

The report presents the following key insights, among others:

- Transportation electrification is a key enabling strategy for reducing New York State's transportation sector emissions.
- Transportation-related emissions from fossil fuel combustion have decreased since 2005, but the rate of decline has been slower than in other sectors.
- State and local jurisdictions have instituted numerous policies and programs to further clean transportation, many of which include or emphasize electrification.
- New York State currently has approximately 60,000 EVs and more than 5,000 public charging stations. While EV charging stations are available across the State, DC fast chargers are less commonly found, especially in Upstate New York.
- The greatest challenges for electric LDV ownership in New York State relate to perceived range limitations and range anxiety, upfront purchase price, consumer awareness of EVs, and access to public charging stations. Car performance, charging cost, and home charging access are also of concern to these EV owners.
- Insufficient model availability, costly electrical infrastructure upgrades, demand charges, and EV performance characteristics are the principal obstacles for electrification of MHDVs.
- New York State's government-owned fleet faces challenges to electrification regarding upfront purchase prices, access to charging, and vehicle availability, but many of these barriers are addressable and the total cost of ownership savings should offset some or all of the upfront costs over the lifetimes of the vehicles.
- Without introduction of new policies, as illustrated by the reference scenario, EV market share is projected to be 12% of new vehicles purchased in 2025, rising to 29% in 2035, 42% in 2045, and 46% in 2050. By 2050, EVs will comprise an estimated 39% of the State's LDV stock.
- EVs are also expected to increase in the MHDV sub-sector under the reference scenario, with the sales share growing from 1% today to 28% in 2050. No meaningful electrification beyond current levels is expected in the aviation, marine, or rail sub-sectors without significant policy interventions. Because these sectors are regulated federally and involve primarily interstate transportation, improvements in these sectors will require leadership at the federal level.
- Policies such as investing in charging stations, educating the public about EVs, and setting utility rates that are favorable for EVs, can help increase EV adoption.
- The cost of policies to advance EV adoption could vary dramatically depending on policy design and market conditions.

- Supporting the electrification of other modes of travel, such as public transportation, and investing in incentives for used EVs can help LMI populations access clean transportation options especially within cities. Policies that focus on electrifying medium- and heavy-duty trucks and buses can also have a major impact on air quality in environmental justice communities, which have historically been located near many truck and bus depots and highways and suffered from negative health impacts as a result.
- Reaching Climate Act goals will require additional reductions beyond the reference scenarios for both 2030 and 2050. The Climate Action Council will propose recommendations for how to achieve these goals.

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Endnotes

[1] Cadmus analysis of current programs and activities in the State.

[2] This area consists of New York City, Long Island, and Westchester, Putnam, and Rockland Counties.

[3] Note that for several segments, data is limited to New York City. Additionally, in some segments, discrepancies exist between data sources. For example, New York's vehicle registration dataset reports 7,877 taxis statewide, whereas New York City's Taxi & Limousine Commission reports 13,587 yellow taxis just in New York City. The project team used the best available data for each row of the table.

[4] This value includes all Class 2b through Class 8 vehicles except all-terrain vehicles, boats, trailers, locomotives, and snowmobiles.

[5] MTA Deploys First All-Electric Articulated Bus Fleet to 14th Street Busway https://www.mta.info/press-release/nyc-transit/mta-deploys-first-all-electric-articulated-bus-fleet-14th-street-busway

[6] This is based on the results of an EV owner survey administered by NYSERDA to participants in the Drive Clean Rebate program.

[7] Operational costs are discounted at an annual 5%.

[8] This is based on the results of an EV owner survey administered by NYSERDA to participants in the Drive Clean Rebate program.

[9] More information can be found at https://www.smartgrid.gov/recovery_act/time_based_rate_programs.html

[10] ZEV emissions reductions are dependent on the deep-decarbonization of the electricity grid.

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and support to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

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