WHITE PAPER

DECEMBER 2021

UNDERSTANDING AND SUPPORTING THE USED ZERO-EMISSION VEHICLE MARKET

Alexander Tankou, Nic Lutsey, Dale Hall

www.theicct.org

communications@theicct.org

twitter @theicct

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

BEIJING | BERLIN | SAN FRANCISCO | SÃO PAULO | WASHINGTON

ACKNOWLEDGMENTS

This work is conducted for the International Zero-Emission Vehicle Alliance and is supported by its members (Baden-Württemberg, British Columbia, California, Canada, Chile, Connecticut, Costa Rica, Germany, Maryland, Massachusetts, the Netherlands, New Jersey, New York, Norway, Oregon, Québec, Rhode Island, the United Kingdom, Vermont, and Washington). We thank Gordon Bauer for supporting the research on electric vehicle resale values and charging technology and Mike Nicholas, Nikita Pavlenko, and Peter Slowik for reviewing an earlier version of the report. We thank the members of the International Zero-Emission Vehicle Alliance who provided key input on policy activities and reviewed an earlier version of the report. Their review does not imply an endorsement, and any errors are the authors' own.

International Council on Clean Transportation
1500 K Street NW, Suite 650
Washington, DC 20005

communications@theicct.org | www.theicct.org | @TheICCT

EXECUTIVE SUMMARY

The transition to zero-emission vehicles (ZEVs) is a core element of governments' plans to achieve a stable climate and cleaner air. With policies to support new uptake and the declining cost of technologies, the global ZEV market is gaining momentum. However, most ZEV purchases are concentrated among early-adopting new vehicle buyers. Making ZEVs accessible to all drivers—including across the used vehicle market—is critical to ensuring used car buyers experience ZEV benefits and that broader environmental goals are met.

This report assesses market trends, technology changes, and policies to better understand and support the used ZEV market. The research summarizes used ZEV registration trends in major markets and the characteristics of new and used ZEV drivers. The report includes an analysis of upfront price parity of used ZEVs versus comparable used conventional vehicles, as well as an analysis of the growing stock of used ZEVs in major markets over time. The assessment also provides a synthesis of research on used ZEV prices, durability, incentives, and charging infrastructure needs to identify possible future policies for a successful used ZEV market. The research leads to the following findings:

The used market provides an opportunity for more affordable ZEVs. The faster technology advancements in ZEVs makes them depreciate faster than conventional vehicles. This dynamic results in used ZEVs reaching price parity with used conventional vehicles between the 2025-2028 timeframe. Furthermore, previous research found that used ZEVs could generate substantial maintenance and fuel cost savings for drivers compared to used conventional vehicles. In the United States, five-year-old plug-in electric vehicles could save 11% to 17% in annual ownership costs relative to a comparable conventional car, and the savings increase to 17% to 22% for seven-year-old vehicles. In the United Kingdom, the ownership costs of a five-year-old used ZEV are £2,600 to £3,200 ($3,600 to $4,600) less than comparable conventional vehicles.

Small-scale programs can fill information gaps and help to refine policies to encourage the development of the used ZEV market. While the volume of used ZEVs is still low, small-scale programs and pilot projects are critical for developing and tracking key data metrics to define success in the used ZEV market; these could include incentives, infrastructure deployments, and targeting programs in priority areas. The data gathered from these projects can be used to identify subsequent actions involving greater scale and cost. Based on tracking of the used ZEV market, jurisdictions can expand or modify regulations, purchasing support programs, charging infrastructure programs, and consumer awareness campaigns. The continuing collection and tracking of data trends will allow for refining or scaling down the various policies as used ZEVs become more mainstream over time.

Reliability requirements and assurance provision measures could increase confidence and demand for used ZEVs. The number of older ZEVs in the market will inherently increase over time even as technology rapidly develops, raising concerns regarding different technological aspects such as battery degradation, fast charging access, or maintenance costs. Although early evidence indicates that batteries and other components of electric vehicles have better longevity compared to conventional vehicles, many consumers are uncertain given the novelty of the technology and well-publicized issues for select models in early years. Over time, policies and regulations that aim to strengthen ZEV durability, such as longer warranties and right to repair laws, could help older ZEVs to remain on the roads for an even longer period. Measures that guaranty access to charging, especially in multifamily homes, and that maintain fast charging compatibility with older ZEV models will also be important.

By the early 2040s, used ZEVs could surpass first-owner ZEVs. As shown in Figure ES-1 the stock of used ZEVs increases but remains far smaller than the stock of first-owner ZEVs until the late 2020s. Between 2028 and 2035, the population of used ZEVs increases more sharply, from 23 million to 168 million, with used ZEVs reaching upfront cost parity with comparable used conventional vehicle models around 2025-2028. As the number of used ZEVs surpass first owner ZEVs by the early 2040s, they become mainstream options. Considering successful advancements as of 2021, markets in Europe are likely to move through this progression faster, while emerging economies with few first-owner ZEVs in 2021 will be slower. Through the market stages shown, used ZEV policy support can phase down over time as the market matures.

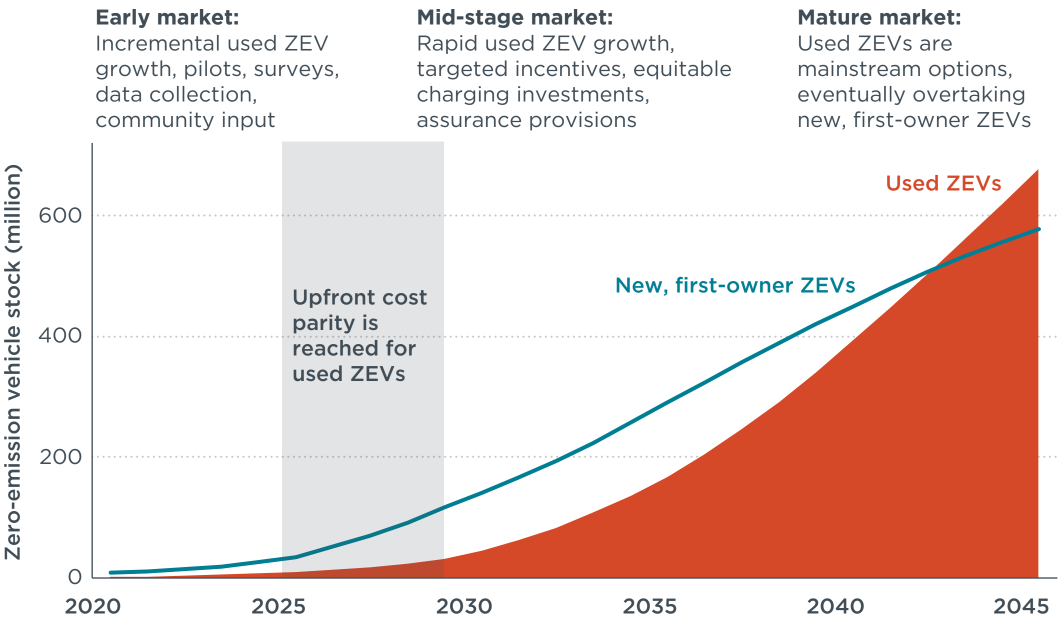

Figure ES-1. Stages in the global growth of the used zero-emission vehicle market.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

To address the need for clean air and a stable climate, governments around the world are enacting policies to transition their transportation sectors entirely to zero-emission vehicles (ZEVs). Beyond the environmental benefits, the direct long-term economic benefits of a ZEV transition from fuel savings, reduced maintenance costs, and lower vehicle purchase price are several times greater than the costs associated with infrastructure deployment, incentives, and awareness programs (National Research Council, 2013; Slowik, Hall, et al., 2019). Governments aim to capture these social and economic benefits of the ZEV transition by ensuring a successful transition to ZEVs for all drivers.

Although the benefits of ZEV technologies are vast and the ZEV market has grown rapidly, the limited volume and higher upfront costs have meant that uptake has been disproportionately driven by higher-income buyers and in areas where adoption barriers have been sufficiently overcome through policy interventions. For a successful transition to zero-emission mobility, ZEV technologies will need to penetrate the used vehicle market. However, there are still many unknowns regarding when used ZEVs might reach price parity with comparable used gasoline or diesel fueled vehicles, whether operating costs will be lower than combustion vehicles, and the durability of ZEV technology. Another factor to consider is how the charging experience will differ for used ZEV owners, particularly for households with limited access to at-home charging. As with the new ZEV market, governments are considering targeted policies to overcome barriers that impact the used ZEV markets.

This report, focused on light-duty vehicles, describes differences between the new and used ZEV markets and identifies best practices to foster success in the used ZEV market. The report analyzes some of the major trends for used ZEVs, including market volumes, vehicle price, reliability, and warranty information that could impact the widespread success of ZEVs in the used market over time. Government programs under consideration are summarized to glean insights related to policy actions that could further support the used ZEV market in the future.

ASSESSING THE USED ZEV MARKET

This section assesses demographic data, the market growth of used ZEVs relative to the new market, and global used ZEV price trends. Building from those data, we analyze expected shifts in new and used ZEVs, including their annual travel patterns, fleet average age, and other characteristics. The research literature and available data included in this assessment are primarily based on battery electric vehicles, although to a lesser extent plug-in hybrid and fuel cell electric vehicles are included in the underlying references. We also note that while data referenced and included on vehicle transactions are often referred to as sales, they include vehicles that were purchased, financed, or leased. Finally, this report focuses on the light-duty vehicle market; the second-hand market for medium- and heavy-duty vehicles is a rich area for further research. All dollar references are in U.S. dollars.

BACKGROUND

A review of new ZEV sales through 2020 provides important background for this assessment on supporting the used ZEV market, including how early ZEV adopters are likely to differ from used ZEV buyers. Figure 1 illustrates the global growth in new passenger ZEV sales through 2020, with China, Europe, and North America accounting for 94% of the cumulative sales (based on EV-Volumes, 2021). There have been over 10 million new zero-emission capable vehicles that have been purchased, financed, or leased, of which 67% are battery electric vehicles (BEVs), 33% are plug-in hybrids (PHEVs), and 0.3% are fuel cell vehicles (FCVs). With 80% of new ZEV sales since 2010 taking place from 2017 to 2020, relatively few ZEVs have yet entered the used vehicle market.

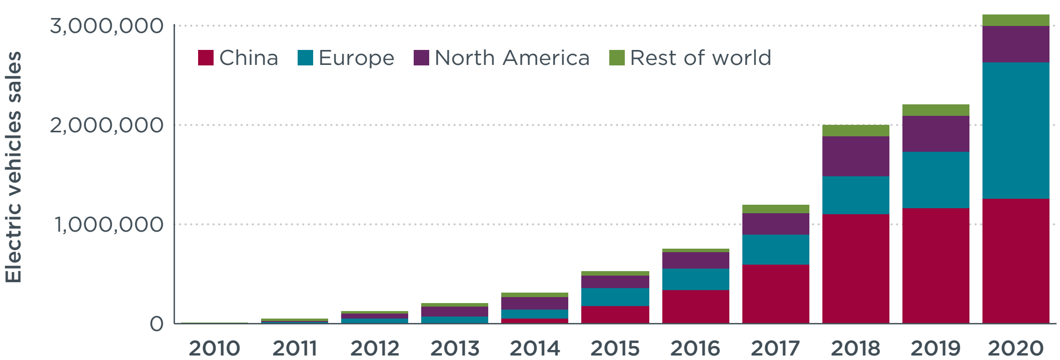

Figure 1. Global new passenger electric vehicle sales, 2010 through 2020.

Although the exact number of the ZEVs from Figure 1 that have migrated to second owners is unknown, typical car ownership patterns suggest that most ZEVs are still with their original owners. Average vehicle financing terms tend to be six to eight years (Blackley, 2020a; Montoya, 2020). New ZEVs are more often leased, including in company fleets, rather than purchased or financed, which could mean lower average first-owner periods (Reed, 2020). Assuming the average ZEV use by original drivers is four to five years, about 12%–19% of the 10 million ZEVs sold (primarily those sold from 2010 to 2016) may have been resold as used vehicles by the start of 2021. As long as the new ZEV market continues to grow year-over-year as expected, the number of new sales will continue to outpace the number of ZEVs entering the used market.

There are significant differences between new and used vehicle owners and how they use their vehicles. New vehicle owners are generally more affluent than the general population. The median income of new U.S. vehicle buyers is $80,000 to $87,000, about 60% to 74% higher than the national average income of $50,000 (Wernle, 2015; Thompson, 2013). An older study indicated new vehicle buyers' income of about $73,000, approximately 50% higher than used vehicle buyers' average income of $48,000 (Paszkiewicz, 2003).

The distinction between new and used vehicle owners' income is linked to many other factors that are also likely to impact used ZEV uptake. Those with lower incomes are more likely to rent rather than own homes, are more likely to live in multifamily homes rather than detached homes, and are less likely to have access to a garage (U.S. Census, 1997, 2021; U.S. Department of Energy, 2017). Lower-income households tend to buy less expensive and older vehicles, own fewer vehicles per household, and own vehicles for shorter durations (Bauer et al., 2021). New vehicles also tend to be driven substantially more than older vehicles. Average new vehicles are driven over 14,000 miles per year over the first six years, approximately 30% greater than the 10,800 miles driven per year by vehicles seven to sixteen years old (Oak Ridge National Laboratory, 2021).

DEMOGRAPHIC DYNAMICS FOR USED ZEVS

As indicated, new vehicles, and especially new ZEVs, tend to be in relatively affluent households. Several studies provide additional details regarding demographic and buying patterns. In California, Muehlegger and Rapson (2018) found that between 2011 and 2015, households earning less than $100,000 per year represented 72% of new and used gasoline vehicle purchases compared to 44% of new and used electric vehicle purchases. In addition, they find Black and Latino car buyers made up 41% of new and used gasoline vehicle purchases, but only 12% of new and used EV purchases. The analysis also indicates that low-income buyers are less likely to buy electric vehicles, and when they do, they are more likely to be used. Still, Turrentine, Tal, and Rapson (2018) find no clear signs of market access discrimination of minority groups in California, but recommend continued education efforts and assessments of incentives and barriers concerning the used market (Turrentine, Tal, & Rapson, 2018).

Other studies indicate additional patterns related to the distributional and equity impacts of the development of the used ZEV market. One study of electric vehicle uptake in disadvantaged communities (DACs), defined as having economic barriers and a high environmental burden, finds that uptake of new and used electric vehicles is lower than in non-DACs, and that electric vehicle sales tend to be concentrated among higher-income, higher-educated homeowners (Canepa, Hardman, & Tal, 2019). Another study finds ZEV uptake is correlated with income, education, charging infrastructure availability, and moderate commuting times (Wee, Coffman, & Allen, 2020). Some of the income-based disparity in ZEV purchasing is due to most electric vehicles on the market being luxury models. For example, in the United States, data through 2019 shows the rate of purchase of Teslas as a proportion of all vehicles is 15 times higher in the top 20% of zip codes by income than in the lowest 20% of zip codes by income (Atlas EV Hub, 2020). This compares to purchase rates of 5.7 times higher for high-income versus low-income zip codes for the Nissan Leaf, 4.3 times higher for the Chevrolet Bolt, 3 times higher for the Chevrolet Volt, and roughly twice as high for new gasoline vehicles.

Studies in Europe show used electric vehicle buyers have greater barriers than new buyers due to lower income and more limited charging availability. A 2019–2020 survey of nearly two thousand electric vehicle owners in the Netherlands found that 39% of electric vehicles purchased by those with below-average income are used, compared to 23% for those making average income, and 10% for those making more than three times the average (Duurkoop et al., 2021). A survey of car buyers' consideration of electric vehicles in Germany reveals that both new and used car buyers have concerns about electric range; but for used car buyers, the high purchase price was also a top barrier. Furthermore, the survey found 60% of new and 38% of used car buyers can park their own car in a garage, thus having potential access to home charging, and 16% of new and 39% of used car buyers typically parked on the street (Deutsche Automobil Treuhand, 2021).

MARKET DEVELOPMENTS FOR USED ZEVS

Although most ZEVs have been purchased by new car buyers who experience fewer barriers than the general population, ZEVs are beginning to re-enter the market as much less expensive used vehicles. Used ZEVs will become more affordable over time through the combined effects of depreciation and lower operating costs than conventional vehicles. Several trends are presented below to show aspects of the used ZEV market in 2021, including the differing growth and scale of multiple markets.

China. China has the most ZEVs, including many of the highest ZEV-uptake local markets in the world. In China, used ZEV sales grew by over 84% from 2019 to 2020, compared to an increase of 104.5% in the new ZEV market over the same period (Tiantian Pai, 2020). In the city of Shenzhen, the national leader in new ZEV uptake, used electric vehicle sales represented 6.7% of the second-hand car market in 2020 (Tiantian Pai, 2020). Between 2015 and 2017, electric vehicles made up 6%-10% of the new vehicle market (Hall, Cui, Rajon Bernard, Li, & Lutsey, 2020), suggesting that electric vehicles are migrating from new to second owners after approximately 3–5 years. According to China auction data, 63% of all electric vehicle transactions stayed within the local market, meaning that over one-third migrated to other markets. Local transactions accounted for 58% of the electric vehicle transactions in Shenzhen, 78% in Tianjin, and 77% in Shanghai (Tiantian Pai, 2020).

France. In France, used electric vehicle registrations increased by 48% in 2019 to a total of about 30,000 (AVERE France, 2020). For comparison, there were approximately 63,000 new electric vehicles sold in France in 2019, and 188,000 in 2020 (EV-Volumes, 2021). New electric vehicle annual sales in France first reached 30,000 sales in 2016, indicating used EV sales lag new sales by about 3 years. This suggests short ownership periods push electric vehicles from their first to second owner within 3 years. The models that were most popular in the used ZEV market closely matched the most popular new ZEVs from several years earlier - e.g., the battery electric Renault Zoe the battery electric Nissan Leaf, and the plug-in hybrid Mitsubishi Outlander (AVERE France, 2020).

Germany. A compilation of data on the new and used vehicle markets in Germany reveals that the used ZEV market is growing much more slowly than the new ZEV market: The share of new passenger cars that are electric has increased from 1% in 2016, to 3% in 2019, and to 14% in 2020. In contrast, the share of used passenger cars that are electric increase from 0.1% in 2016, to 0.3% in 2019, and to 0.6% in 2020 (Kraftfahrtbundesamt, 2018; Kraftfahrtbundesamt, 2020; Kraftfahrtbundesamt, 2021). While the total used vehicle market is about twice the size of the new vehicle market, used electric vehicle sales were just one tenth of new electric vehicles in Germany (Wappelhorst, 2021a). This shows the migration of electric vehicles in Germany from the first owner or lessee to the second is occurring quite slowly compared to France. This also may, to some extent, reflect that many ZEVs initially registered in Germany are exported to other markets, a trend examined below.

Norway. A used vehicle sales platform in Norway found that of the 470,000 used cars sold in the country in 2019, about 38,000, or 8%, were used electric vehicles (Finn.no, 2020). The used volume of 38,000 electric vehicles represents twice as many electric vehicles as were listed on the Finn.no platform in 2017. Based on the Finn.no data, the used electric vehicle market reflects the new electric vehicle market in Norway from 3 to 4 years earlier, as well as additional imported used electric vehicles. For comparison, there were approximately 79,000 new electric vehicles sold in Norway in 2019, and 105,000 in 2020 (EV-Volumes, 2021). New electric vehicle annual sales in Norway first surpassed 38,000 in 2016, suggesting that annual used EV sale lags new sales by about 3–4 years.

United Kingdom. In the United Kingdom, electric passenger cars have rapidly increased from 2.5% of new vehicle sales in 2018 to 11% to 2020 (EV-Volumes, 2021). In 2018, 2.3% of used car transactions were electric vehicles (Kumar, 2019) which rose to 15% of the used market in December 2020, the highest share ever recorded (Bradshaw, 2020). As of March of 2021, there were 7,500 used electric vehicles for sale in the United Kingdom, compared to 1,500 vehicles from a year earlier (Aucock, 2021). For comparison, new electric vehicle annual sales in the United Kingdom first surpassed 10,000 in 2014, and reached 175,000 in 2020 (EV-Volume, 2021). This roughly suggests that the annual used electric vehicle sales market lags new sales by over 6 years.

United States. In the United States, reported used electric vehicle inventory for sale increased from 13,219 in July 2020 to 19,634 as of March 2021, indicating 50% growth over 8 months (Recurrent, 2021). iSeeCars analyzed 54,000 used electric vehicle sales from 2019 and 2020 and found that the Nissan Leaf, the Tesla Model S, and the Fiat 500 were the most popular, representing over 50% of the used electric market (Blackley, 2020b). This growth compares to the over 300,000 new electric vehicles annual sales in 2020 (EV-Volumes, 2021). For another comparison, new electric vehicle annual sales in the United States first surpassed 18,000 in 2011 and 50,000 in 2012 (EV-Volumes, 2021).

Based on the data gathered above, approximate comparisons between the new and used ZEV market are possible. Used ZEV sales tend to be about 5%–15% of the new ZEV sales, and the growth in used ZEV market sales and sales shares tend to lag the new ZEV market by about 3–6 years. Markets with more company fleet leases and generally shorter ownership periods have new ZEVs migrating to used ZEVs within 3–4 years (Lopez, 2019). Norway, where new ZEV sales have been substantially higher than elsewhere, is the exception, as used ZEV sales there are already more than 35% of new ZEV sales. Norway provides an indication of how other markets could reach a similar phenomenon where used ZEV volume approaches new ZEV growth. The Norway case occurred after years of policy support led to most new vehicles sold being ZEVs for multiple years, and with substantial used ZEV imports.

CROSS JURISDICTION USED ZEV DYNAMICS

The import and export of used ZEVs can significantly affect the availability of used ZEVs within different markets. Market research revealed that imports and exports of used ZEVs were particularly impactful in certain markets like Germany, where there were exports of used ZEVs, and Norway, where there were imports of used ZEVs.

The California market is the largest ZEV market within the United States and has implemented the strongest ZEV policy and incentive support (Bui, Slowik, & Lutsey, 2020). An analysis of electric vehicles in California shows that the presence of new electric vehicle purchase incentives correlates with a net outflow of 5% of its used electric vehicles to states without incentives (Turrentine, Tal, & Rapson, 2018). The study uses a relatively small data sample, so the net electric vehicle outflow from California could be higher. Automakers are motivated to sell more new electric vehicles in California due to its Zero Emission Vehicle regulation, and they tend to make more electric models available to prospective new car buyers there as a result. Over time, publicly available data show that electric vehicle demand in neighboring markets, such as Arizona, Nevada, and Oregon, has drawn in a relatively small amount of those used electric vehicles.

During 2020, there were approximately 8,000–9,000 used electric vehicle exports from Germany (Autovista, 2021). For context, annual new electric vehicle sales in Germany in 2020 amounted to 390,000 and cumulative new electric vehicle sales over 2011–2020 amounted to over 688,000. As a result, 2020 used electric exports amount to 2% of annual new sales, or 1% of cumulative new sales, in Germany. Norway was by far the most prominent destination for those exports, accounting for nearly 3,000, or about 35%, of the used electric vehicle exports from Germany. This can partially be explained by differences in fiscal policy. Norway offers larger fiscal incentives, including for the purchase and annual operation, and nonfinancial incentives for both new and used electric vehicles (EAFO, 2021).

Norway receives a substantial number of used ZEV imports, in part due to Germany's exports. Norway imported over 55,000 used electric vehicles through July 2021 (Elbil Statistikk, 2021). Overall, used electric vehicle imports make up 13% of the approximate 420,000 cumulative electric vehicles in Norway. Of those imports, up to a third have been imported from Germany, followed by the United States, South Korea, and Sweden (Doyle, 2019).

These examples imply that new ZEVs are deployed where policy support is highest, and then migrate across borders only in what appears to be limited circumstances. The cases identified with the most used ZEV exports involve just 2% (Germany) and 5% (California) of the volume of annual new ZEV sales being exported. In large part, the reasons that markets are attractive for new ZEVs are the same reasons they are attractive for used ZEVs. New ZEVs are mostly sold in countries with policies to overcome the prevailing uptake barriers of ZEV model availability, higher cost, charging convenience, and consumer understanding. For used EVs, strong incentives also play a major role, such as in the case of Norway. Despite limited used ZEV trade so far, many markets, such as Costa Rica and New Zealand, are more dependent generally on used vehicles and therefore used ZEV flows seem likely to play a larger role in these countries' transport decarbonization plans.

PROJECTED USED ZEV PRICES AND FUEL SAVINGS

As identified above, used ZEV purchasers are likely to be more cost-conscious than early adopting new ZEV buyers. As a result, the price of used ZEVs is among the most foundational factors in the success of the used ZEV market over time. The prices of used ZEVs are the product of how quickly the technology cost declines in new vehicles, and how those reduced costs translate to lower resale vehicle prices when ZEVs enter the used market.

Used electric vehicle prices. Available research on the declining cost of new electric vehicles costs and differential resale prices versus conventional vehicles are applied in the analysis below to assess how used electric vehicle prices decline over time. New electric vehicles prices are declining due to improved battery and power electronic technology, higher production volume, and lower manufacturing cost. Indirect costs are also decreasing as development costs are spread over higher volumes of vehicles produced. As a result, new electric vehicle prices are approaching those of comparable conventional vehicles. An important distinction is that short-range electric vehicles with smaller battery packs reach price parity sooner than longer-range electric vehicles.

Several sources provide bottom-up estimations of how these various dynamics effect new electric vehicle prices for battery electric and plug-in hybrid vehicles. Electric vehicles with ranges up to 200 miles (320 kilometers [km]) reach price parity around 2024–2027, and longer-range vehicles of 300–400 miles (481–640 km) reach parity around 2028–2031 (Lutsey & Nicholas, 2019; Lutsey, Cui & Yu, 2021). These analyses indicate that markets like China, where conventional vehicles are less expensive due to smaller combustion powertrains, price parity is reached more slowly than in markets with larger conventional vehicles like the United States. The analyses also found that larger vehicles like sport utility vehicles and pickups reach price parity more slowly than smaller passenger cars.

Used electric vehicle prices, in turn, depend on the depreciation of new electric vehicle prices as they age. Electric vehicle depreciation rates tend to be greater than those of conventional vehicles, although longer-range Tesla vehicles have shown the highest resale values (Guo & Zhou, 2019). A potential reason for this is electric vehicle technology is rapidly improving, making prospective electric vehicle buyers more drawn toward new models with increased range and performance and reduced cost. Further motivation comes from new electric vehicles in most major electric vehicle markets being eligible for purchase incentives of thousands of dollars, reducing the effective difference between new and used electric vehicles.

Applying the vehicle price evaluation frameworks in Bauer, Hsu, & Lutsey (2021) and Burnham et al. (2021) to updated data on the projected new vehicle prices allows us to assess used electric vehicles' relative depreciation and the timing of their price parity with conventional vehicles. To analyze the U.S. situation, new vehicle ownership of five years is assumed, and average annual mileages was retrieved from Oak Ridge National Laboratory (2021). New vehicle prices from National Academies of Sciences, Engineering, and Medicine (2021) and depreciation rates from Burnham et al. (2021) was applied to estimate average new and used vehicle prices for conventional and electric vehicles. The depreciation rates result in conventional vehicles reaching a residual value of half the original new vehicle price by the fourth year of ownership, compared to the third year for electric vehicles.

Figure 2 shows the projected U.S prices for new (dashed lines) and used (bold lines) vehicles by class (car and sport utility vehicle) from 2020 to 2030. Incentives are excluded to show the estimated price without state and federal incentives that are eligible for some, but not all, electric models and households. As shown, with electric vehicles migrating to the used market, and with electric vehicles' slightly higher depreciation rate, new and used vehicle buyers see electric vehicle price parity at approximately the same time. Price parity is first reached for 200-mile electric vehicles in 2025 (cars) and 2026 (sport utility vehicles), and then one year later (2026 and 2027, respectively) for 300-mile electric vehicles. Due to somewhat higher electric vehicle depreciation, used car buyers also see electric vehicle price parity in the same year for each vehicle class.

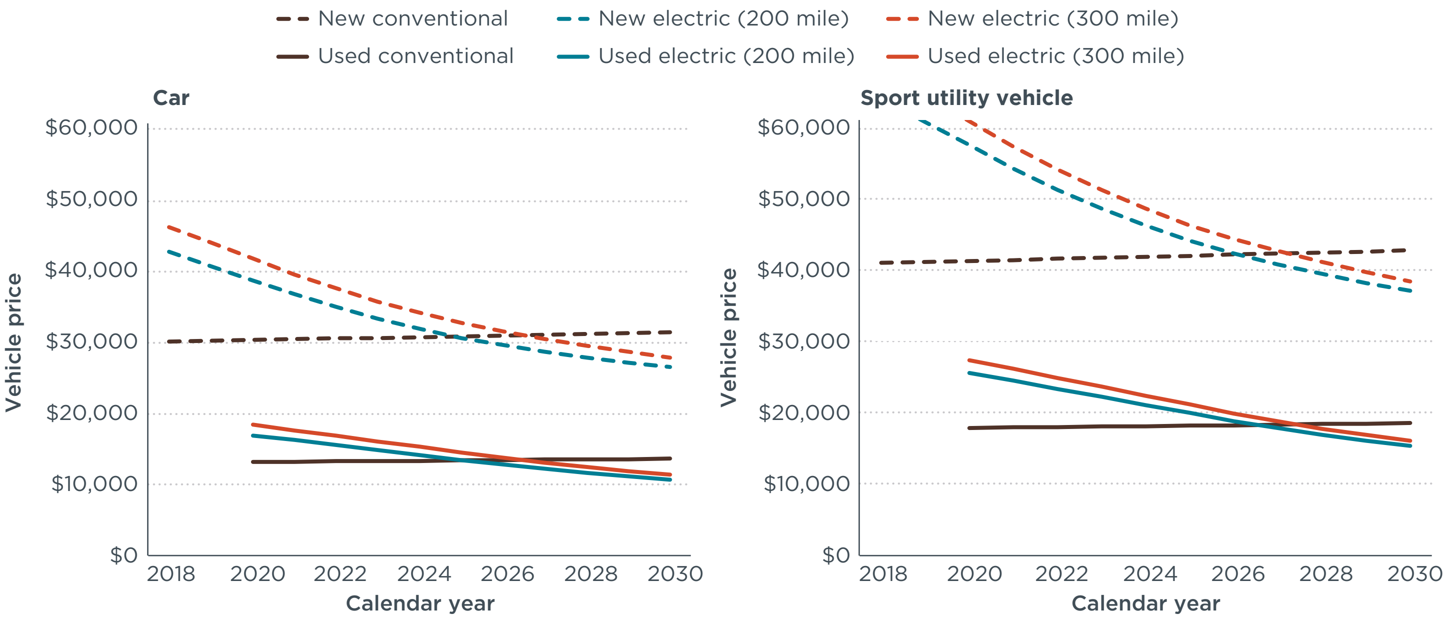

Figure 2. Projected new and used conventional and electric vehicle prices in the United States.

Tracking specific examples from Figure 2 shows how depreciation effectively negates the difference in electric and conventional vehicle costs as the vehicles age. The average prices of new electric cars in 2020 is $39,000 (200-mile range) and $42,000 (300-mile range), or 28%–38% higher than the average conventional vehicle costing $30,000. The same cars, sold as used five years later, have nearly the same price: the conventional vehicle is $13,400, the 200-mile electric vehicle is $13,500, and the 300-mile electric vehicle $14,500. A similar analysis finds that the resale price of a 2020 Chevrolet Bolt (238-mile electric) compares favorably to a gasoline Chevrolet Cruze by 2024 (Bauer, Hsu, & Lutsey, 2021).

Using the same evaluation as above, new vehicle prices and depreciation rates in China were combined to assess used electric vehicle prices over time. China's electric vehicle market has several similarities with the U.S. market, including declining new electric vehicle prices, increasing availability of electric vehicles with longer ranges, and consumer purchasing incentives. The depreciation rates are somewhat higher in China compared to the United States, possibly due to heightened concerns about battery degradation and safety issues ("Ministry of Industry," 2020). After one year of ownership, Tesla models depreciated at similar rates to conventional vehicles, while other top-selling electric vehicles have 5%–20% higher depreciation rates (Yiche, 2021).

Figure 3 shows the China vehicle prices for new (dashed lines) and used (bold lines) vehicles by class (car and sport utility vehicle) from 2020 to 2030. The higher electric vehicle depreciation rates in China result in used electric vehicles reaching price parity with used conventional vehicles sooner than new vehicles, generally by two to three years. New vehicle buyers see price parity for 300-km electric vehicles in 2026 (cars) and 2027 (sport utility vehicles), compared to used vehicle buyers experiencing price parity for 300-km electric vehicles in 2025 (cars) and 2024 (sport utility vehicles). For 500-km electric vehicles, new car buyers see price parity with conventional vehicles later than 2030, while used vehicles reach parity around 2027. This example shows how higher electric vehicle depreciation helps the used electric market, but this this equates to poorer resale value when new car buyers sell their vehicle. It is not yet clear how the used ZEV depreciation rate could change, or eventually impact new and used ZEV demand, over the long-term.

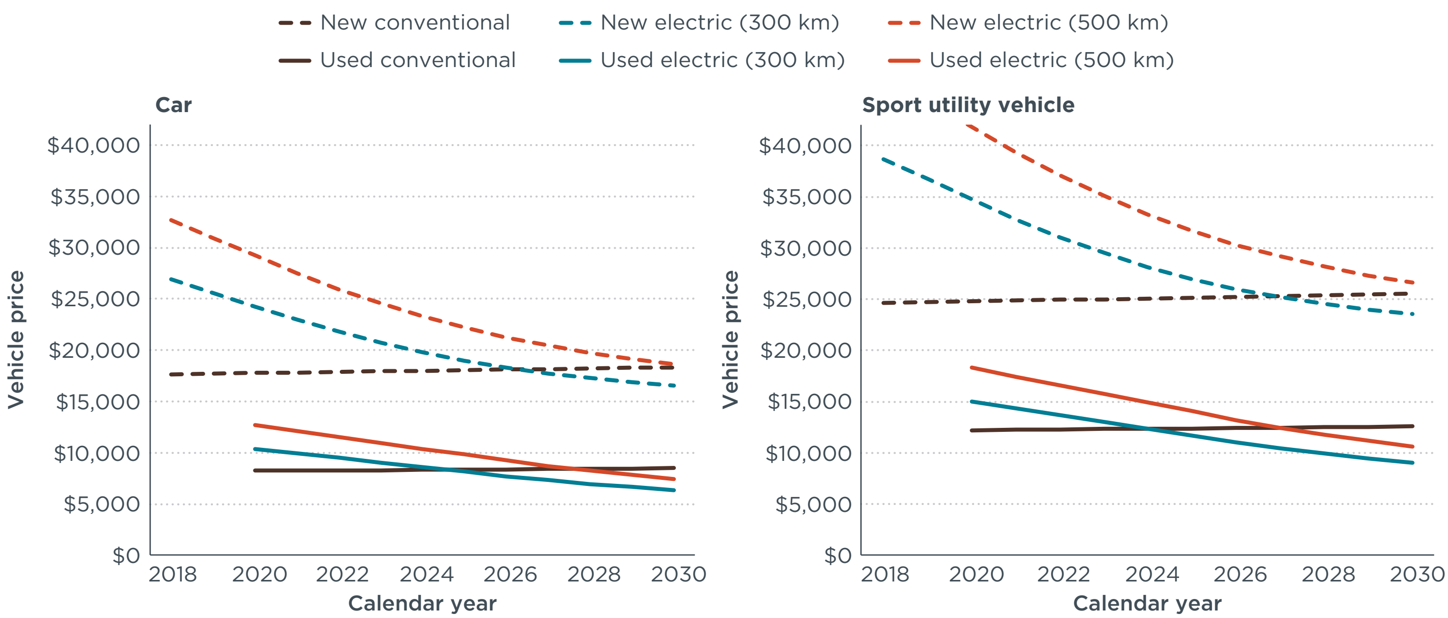

Figure 3. Projected new and used conventional and electric vehicle prices in China.

To an extent, Norway demonstrates what the future may look like for a more mature used electric vehicle market. Norway's large financial incentives have artificially created price parity and spurred large new and used electric vehicle markets. Incentives and tax benefits for new electric vehicles are effectively passed on to the growing used market. Analysis of data from Finn.no indicates that most electric models depreciate similarly to comparable gasoline models of the same vehicle age (Mullis, M.E., 2021). When correcting for mileage driven, electric vehicles depreciated somewhat more quickly. However, Tesla models tended to depreciate more slowly than other electric models due to continued strong demand and limited supply in Norway. Furthermore, the tracking of Norwegian government fleet of 1,000 vehicles revealed that the residual used car value of fully electric vehicles increased from 45% to 58% of their original new vehicle price, compared to gasoline vehicles, which declined from 62% in 2014 to 50% in 2020 (Larsen, 2021).

Used electric vehicle ownership costs. Expenses incurred during vehicle use, like fueling costs and maintenance, can also be an important aspect for used vehicle drivers' interest in ZEVs. Research focusing on the United States and the United Kingdom found substantial savings from used electric vehicle ownership compared with conventional vehicles. Used electric vehicle owners in the United States could save $600 annually from a combination of lower fuel and maintenance costs (Bauer et al., 2021a). Five-year-old plug-in electric vehicles could save 11%–17% in annual ownership costs relative to a comparable conventional car, and the savings increase to 17%–22% for seven-year-old vehicles (Harto, 2020). Another study shows the ownership savings from average 5.5-year-old used EVs versus comparable gasoline cars are about $500 to $1,100 (Busch, 2021). In the United Kingdom, the ownership costs of second-ownership electric vehicles, at five years old, are £2,600 to £3,200 ($3,600 to $4,600) less than comparable conventional vehicles (Kumar, 2019).

As indicated above, cost and fuel savings can have a much greater relative impact for used, rather than new, vehicle owners because these vehicle owners tend to have lower income and be more cost-conscious. Based on Bauer et al (2021a), Figure 4 shows the relative electric vehicle ownership costs (i.e., vehicle purchase, fuel, maintenance, and insurance) in the context of U.S. household income. As shown, electric vehicles annual ownership savings amount to 7% of income for a low-income household (less than $25,000), compared to less than 1% for a high-income household ($150,000 or greater).

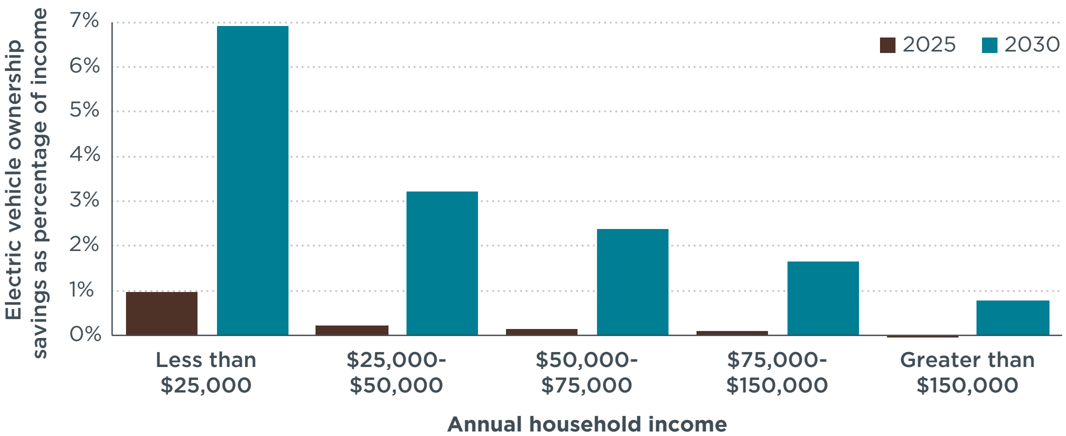

Figure 4. Savings as percentage of income from owning an electric vehicle in comparison to a gasoline vehicle, by income group.

Figure 4 shows that, after upfront vehicle price parity is reached across vehicle segments in 2030, broader vehicle ownership benefits are achieved across all income groups from driving an electric vehicle. The same study considered the implications across U.S. households and found that, as soon as 2025, 45% of households could save on vehicle ownership costs by replacing at least one of their vehicles by an electric vehicle, rising to 95% of households by 2030 (Bauer et al., 2021a). More broadly, this analysis of vehicle ownership costs shows how expanding ZEV technology access in lower-income drivers can provide disproportionately greater benefits. This indicates that when barriers to used ZEV uptake are overcome, there's an opportunity to achieve broader ZEV benefits.

ANALYSIS OF USED ZEVS, 2020–2050

A critical question for future ZEV policy and charging infrastructure planning is how quickly ZEVs will diffuse across the entire stock of all vehicles. The associated new and used ZEV populations and driving dynamics are modeled, based on the expected growth in new ZEVs, new vehicle ownership patterns, the migration of ZEVs to the used market, and their driving patterns in the decades ahead. The analysis for global vehicles through 2050 is based on a vehicle stock-turnover model that tracks electric vehicle uptake (Lutsey, 2015) with updates on global ZEV policy and market developments (Cui, Hall, Lutsey, 2020; Wappelhorst, 2021b). As such, the analysis of used ZEVs begins with how quickly electric vehicles are being deployed in new vehicle fleets around the world. Light-duty vehicle sales growth is assumed to reach pre-pandemic levels by 2022, and then see annual growth reduced from 3% to 1% over 2023–2050, with higher growth values in faster-growing economies and slower values in Europe and North America.

Figure 5 shows the share of global light-duty vehicle sales over time. Overall, global electric vehicle sales share is projected to grow from 4% in 2020, to 35% in 2030, to 80% in 2040, and to 100% in 2050. Strong regulatory frameworks, including direct electric vehicle requirements and vehicle CO_2 regulations in China, Europe, and North America through 2030, are expected to drive near-term volume, followed by growth in other markets. Markets are assumed to transition to 100% ZEV share of new vehicle sales proportionally faster and slower based on their 2020 uptake. For example, Europe is expected to reach 100% ZEVs by 2035, with leading markets, such as Norway, reaching it sooner, and slower-uptake markets, such as those in Eastern Europe, reaching it later. The United States and China markets are expected to reach 100% ZEVs by 2040, compared to many other markets around the world by 2050.

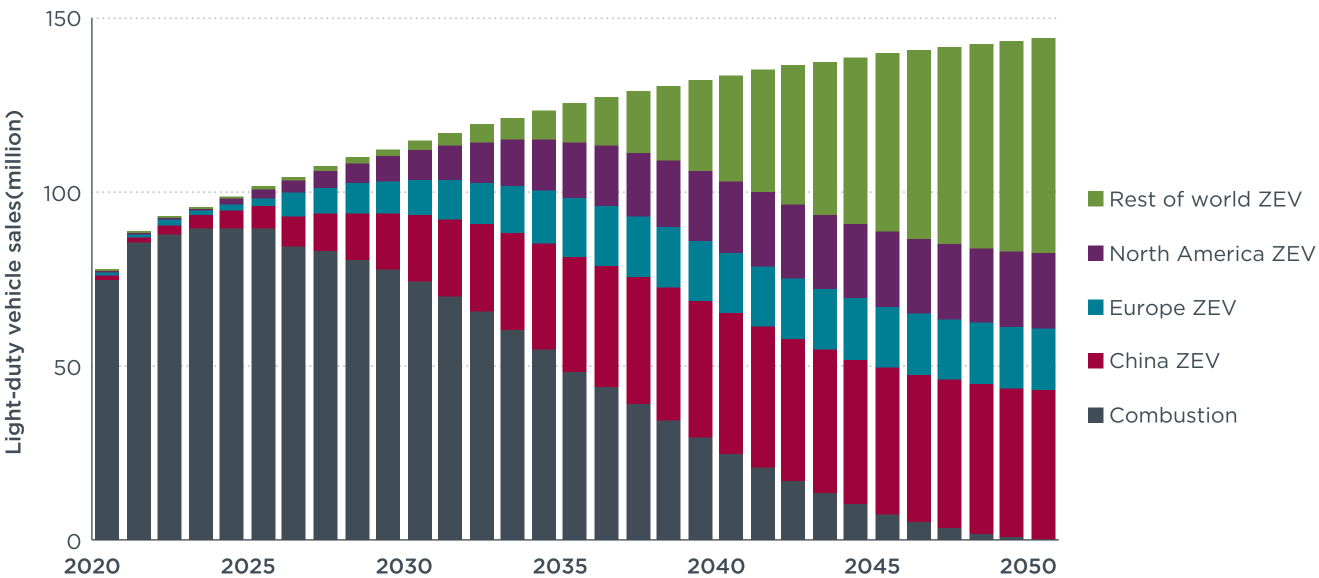

Figure 5. Global new light-duty vehicle shares that are combustion and zero-emission vehicles, with ZEV shares by major region.

The analysis of the vehicle fleet tracks the migration of new ZEVs into the used ZEV market. An average five-year ownership period is generally assumed, except in Europe where four years is assumed due to shorter-duration company leases being more common there versus more longer-term private vehicle ownership elsewhere. These ownership periods reflect how first owners of ZEV tend to keep their vehicles, on average, for shorter periods than conventional vehicle drivers. In addition, vehicle retirement and annual driving statistics from the various markets are applied, which result in median vehicle lifetimes of 14–16 years across the various markets (Oak Ridge National Laboratory, 2021; Lutsey et al., 2021). The vehicle stock-turnover model, in turn, estimates vehicle population and mileage by age and technology type.

Figure 6 shows the corresponding number of ZEVs that are owned by the first vehicle owner and those that are used ZEVs owned by second or later owners for 2020, 2025, and 2030 in four major regions. As shown, the greatest overall ZEV volumes are in

China, followed by Europe and the United States, and used ZEVs account for a greater percentage of the total ZEVs over time. By 2030, because new sales are growing so quickly in each market, the used ZEVs still represent relatively few of the total ZEVs. The China market grows from 4 million ZEVs (6% used) in 2020 to 90 million ZEVs (25% used) in 2030. With shorter typical ownership periods, the Europe market grows from 2.7 million ZEVs (17% used) in 2020 to 50 million ZEVs (29% used) in 2030. In this scenario, ZEVs increase globally from 10 million (12% used) in 2020 to over 184 million (24% used) in 2030. The first year that used ZEVs exceed first-owner ZEVs are in the late 2030s for Europe, early 2040s in China and North America, and after 2050 in the rest of the world.

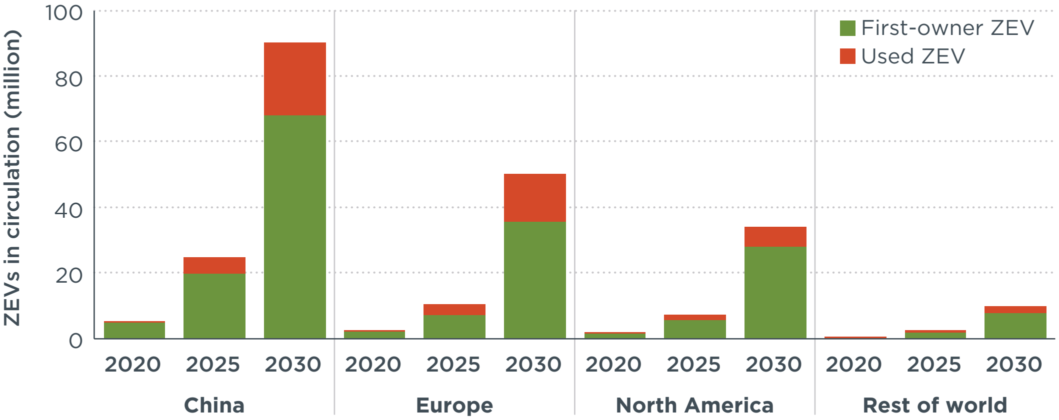

Figure 6. First-owner and used zero-emission vehicles by region for 2020, 2025, and 2030.

Figure 7 shows that, as the global vehicle population grows from 2020 to 2050, ZEVs increasingly make up a larger portion of the vehicle fleet, and a greater percentage of ZEVs are used ZEVs. As the global fleet increases from approximately 1.4 billion vehicles to nearly 2 billion vehicles over 2020–2050, the ZEV share increases from 1% in 2021 to 82% in 2050. Of those ZEVs, the percentage that are being driven by the second-or-later owners increases from 12% in 2020, to 24% in 2030, to 47% in 2040, and to 61% in 2050. Although used ZEV growth is relatively low through 2028, the volume increases seven-fold from 23 million to 168 million over 2028–2035. The first year that ZEVs surpass combustion vehicles is 2041, and the first year that used ZEVs surpass first-owner ZEVs is 2043. The first year that used ZEVs overtake the overall stock of combustion vehicles is 2045.

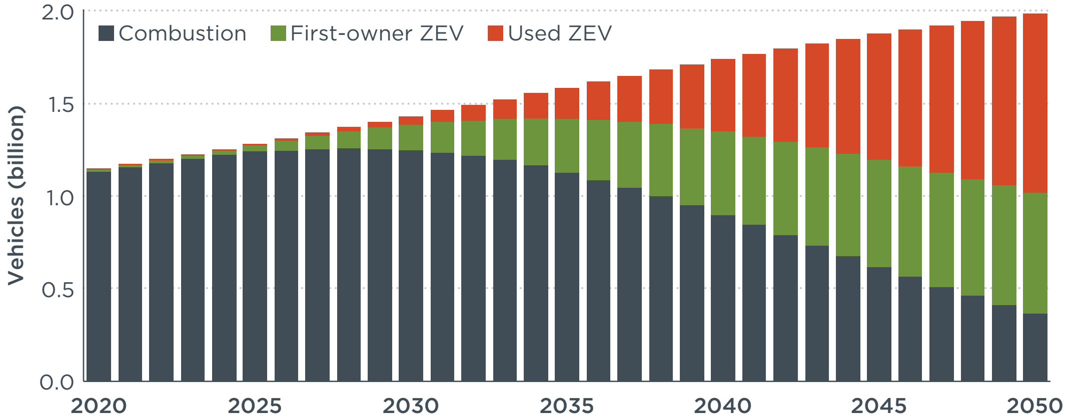

Figure 7. Global vehicle population, broken down by combustion, first-owner zero-emission vehicles, and used zero-emission vehicles over 2020-2050.

These trends regarding used ZEVs are further analyzed to understand the effect on annual kilometers traveled across the regions. The resulting breakdown of vehicles by combustion engine vehicles, new ZEVs, and used ZEVs is similar to the results above. The number of vehicle kilometers traveled by used ZEV owners, as a percentage of all ZEVs, increases from 10% in 2020, to 20% in 2030, to 40% in 2040, and to 52% in 2050. These are slightly lower percentages than for the used ZEV vehicle population shown in Figure 7. This small delay between vehicle population and vehicle kilometers traveled made up by used ZEVs is due to new vehicles being driven more on average annually in their first 4–5 years of ownership, than older vehicles.

The average age distribution of zero-emission vehicles over time is another way to understand the future used ZEV market. Figure 8 shows the distribution of global combustion and zero-emission vehicles by age since original purchase for 2020, 2030, and 2040. As shown, the number of new ZEVs entering the market continues to outpace older ZEVs that are more than 6 years old. The average age of all vehicles in the world remains approximately 8 years. As new combustion vehicles are phased out in most markets between 2020 and 2040, the average age of ZEVs increases from 2 years to 5 years, while the average combustion vehicle age increases from 8 years to 11 years.

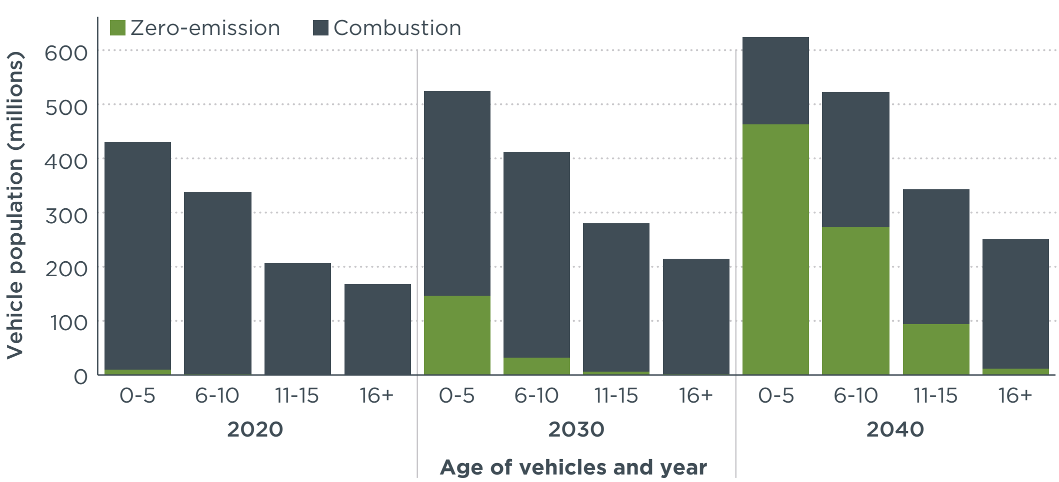

Figure 8. Global vehicle population of zero-emission and combustion vehicles by age (in years since original vehicle purchase) for 2020, 2030, and 2040.

The global data used for Figure 8 are based on the region-specific analysis. Faster ZEV uptake markets, like Europe, have higher percentages of older ZEVs by 2040 compared to markets with slower ZEV uptake, such as developing economies through the rest of the world. In Europe, ZEVs that are over ten years old will increase to 4% of all ZEVs (1.8 million of 50 million) in 2030 and to 19% (32 millions of 172 million) by 2040. In China, ZEVs that are over ten years old will increase to 3% in 2030 and to 12% in 2040. In other markets, due to slower new ZEV uptake, ZEVs over ten years old will increase to 3% of the total in 2030, and to 5% in 2040. These increasing volumes of older ZEVs lead to important implications for used ZEV durability, which is addressed in the following section.

USED ZEV TECHNICAL CHARACTERISTICS

The number of older ZEVs in the market will naturally increase over time, presenting questions related to their technical durability, including warranties, battery degradation, and maintenance costs. As indicated in Figure 8, the number of ZEVs globally that are over ten years old increases from nearly zero in 2020, to over 6 million by 2030, and to over 100 million in 2040. Although these older ZEVs represent a small portion of ZEVs globally (3% in 2030 and 13% in 2040), these aging ZEVs still have high potential value to deliver many zero-emission miles, and it remains important that the used ZEV owners continue to have a positive experience and appropriate expectations about their vehicles' reliability and performance.

VEHICLE AND BATTERY WARRANTY

ZEV reliability is important to ensure a positive experience for used ZEV drivers and to maximize the lifetime use of ZEVs. Since very few ZEVs have aged beyond ten years old as of mid-2021, there are still outstanding questions regarding used ZEV's long-term technological reliability. One indication of automakers' expectation regarding reliability is the warranties they offer for the vehicle and battery.

Many of the early electric vehicle models sold between 2011 and 2016 had low real-world battery durability and electric range. The highest-selling battery electric vehicle in the United States and other early ZEV markets in those years was the Nissan Leaf, which had an air-cooled battery system with a nominal battery capacity of 24 kilowatt-hours (kWh), and delivered a 73–84-mile consumer label electric range (U.S. Department of Energy, 2021a). In addition to standard vehicle warranty, a model year 2011-2012 Nissan Leaf was warrantied against battery capacity loss below approximately 70% of vehicles' original range for up to 60 months or 60,000 miles, whichever came first (InsideEVs, 2013). Frequent direct current fast charging and frequent deep discharges (i.e., greater than 80% of the full battery capacity) were associated with greater battery degradation. By 2016, Nissan Leaf models introduced with a 30-kWh battery had an increased warranty coverage to 96 months or 160,000 km (InsideEVs, 2016).

Table 1 summarizes elements of warranties offered on several high-selling 2020 electric vehicle models globally and comparable conventional vehicles. As shown, companies are typically providing the same powertrain coverage for comparable battery electric and conventional vehicles. Typical warranties cover the powertrain for 4–5 years or 80,000–97,000 kilometers (km), whichever comes first. Hyundai and Tesla stand out with longer powertrain warranties up to 8-10 years or 161,000 km. Electric vehicle batteries are typically warranted for manufacturing defects to 8 years or 161,000 km. Most battery warranties cover battery repairs or replacements if capacity loss exceeds 30% within the warranty period; the exception is the Chevrolet Bolt, which does not specify a capacity loss. The original warranty coverage is typically transferred to the second owner; the Hyundai Kona (conventional and electric) is an exception, providing the subsequent owner a new warranty of 5 years or 97,000 km. These models demonstrate increased warranty coverage relative to earlier electric models.

Table 1. Warranty elements of electric and comparable conventional vehicles.

Electric vehicle models				Gasoline models	
Model	Powertrain	Battery	Battery coverage for capacity loss	Model	Powertrain
Chevrolet Bolt	5 years or 97,000 km	8 years or 160,000 km	No	**Chevrolet Cruze**	5 years or 97,000 km
Nissan Leaf	5 years or 97,000 km	8 years or 161,000 km	Yes	**Nissan Altima**	5 years or 97,000 km
Tesla 3	8 years or 161,000 km	Standard: 8 years or 161,000 km Long range: 8 years or 192,000 km	Yes	**BMW 3-series**	4 years or 80,000 km
Hyundai Kona	10 years or 161,000 km	10 years or 161,000 km	Yes	**Hyundai Kona**	10 years or 161,000 km
Tesla Y	8 years or 161,000 km	Standard: 8 years or 160,000 km Long range: 8 years 192,000 km	Yes	**BMW X3**	4 years or 80,000 km
Audi e-tron	4 years or 80,000 km	8 years or 161,000 km	Yes	**Audi Q5**	4 years or 80,000 km
Tesla S	8 years or 161,000 km	8 years or 240,000 km	Yes	**BMW 5-series**	4 years or 80,000 km
Tesla X	8 years or 161,000 km	8 years or 240,000 km	Yes	**BMW X5**	4 years or 80,000 km

Note: Information is based on manufacturer manuals and website information for U.S.-version models in 2021.

BATTERY RELIABILITY

Most electric vehicle reliability questions for used ZEV owners are linked to the effects of aging on battery performance. Batteries' state-of-health, often measured as the percentage of original capacity, can degrade as vehicles age due to several factors, including cell chemistry, type of charging used, driving habits, and weather conditions. Battery durability has generally increased in line with the warranty trends indicated above.

Battery capacity loss. The major market trend toward increased electric vehicle range and advances in battery technology have greatly affected battery durability. Globally, electric vehicle battery capacity has increased from about 25 kWh in 2012 to over 50 kWh in 2019 (Jin et al, 2021). The median range of electric vehicles sold in 2020 in the United States surpassed 250 miles and exceeded 200 miles on average in the United Kingdom, up from less than half those levels in 2011 (U.S. Department of Energy, 2021b; Lusher, 2019). This trend reduces the need for frequent deep discharges and for as much DC fast charging. Battery architecture and battery management systems are also improving, in turn allowing more charging to 90%-95% of capacity with less degradation over the vehicle life.

As ZEVs are expected to be driven for typical vehicle lifetimes of 15-20 years and over 300,000 kilometers, tracking long-term battery durability will be critical for the second-and-later vehicle owners. Although relatively few electric vehicles have been driven for more than 200,000 km or 10 years, limited data provide a picture of the improving battery durability over time. The testing of 2012 Nissan Leafs at 50,000 miles indicated a 23%–27% drop in battery capacity, from 23 kWh to 17–18 kWh (Idaho National Laboratory, 2014). More recent trends indicate lower degradation. Analysis of a fleet database that includes models from year 2012 up to 2019 indicates an average degradation of 1.5% to 2.3% per year (Argue, 2020; Geotab, 2021). Tesla models with 240,000 to 320,000 kilometers have experienced degradation of between 10% and 15% (Lambert, 2018, 2020; Kane, 2020). Additional survey data on the Tesla Model S shows a 10%, or roughly 1% annually, capacity loss after 161,000 km (100,000 miles) (Plug In America, 2021a).

Industry announcements indicate that battery range and durability is likely to continue improving due to battery technology improvements, thereby reducing related concerns for future used ZEV owners. General Motors, in partnership with LG Chem, has announced that its new Ultium battery will provide up to 644 km range on a full charge (General Motors, 2020). The battery supplier SK innovation has announced the upcoming release of a battery capable of 1,000 km (600 miles) on a full charge (SK Innovation, 2020). Contemporary Amperex Technology Co Ltd (CATL) stated it is ready to deploy a battery that can last 2 million kilometers (1.2 million miles) over its lifetime ("Million mile battery," 2020). This implies that the battery will far outlive the vehicle lifespan and therefore be able to cover used ZEV owners and have valuable uses after the vehicle is retired.

Vehicle maintenance and repair cost. Vehicle expenses, including maintenance cost, can be an important consideration for drivers of used vehicles. Several studies indicate that used U.S. electric vehicle owners can reduce their maintenance and repair cost by approximately half, saving about $200-$500 annually (Bauer et al., 2021a; Harto, 2020; New York City, 2019). Used electric vehicle ownership in the United Kingdom is similarly estimated to save £170 ($236) annually compared to conventional vehicles (Kumar, 2019). Maintenance savings from ZEVs are achieved through a lack of required oil changes, lack of spark plug and air filter replacements, reduced need for braking parts replacement or service due to regenerative braking systems, and reduced engine and transmission service (New York City, 2019). Because such vehicle operating expenses make up a greater fraction of ownership costs, the relative savings from maintenance costs for used ZEV owners are greater than for new ZEVs, for which depreciation is a larger cost (Harto, 2020). These studies indicate that, as ZEV upfront costs decline, lower income used ZEV owners can capitalize on broader operating cost savings.

Battery replacement. Beyond the question of battery degradation, battery failure could be an even larger issue for older electric vehicles. At this still-early stage in global ZEV deployment, battery replacements have not been a frequent occurrence. Based on two models for which there is the most data, vehicle owner surveys indicate that 4% of 2011 Nissan Leaf vehicles (13 out of 324) and 6% of 2013 Tesla Model S vehicles (16 out of 278) received battery replacements (Plug in America, 2021a). Data were not available regarding how many of those replaced battery packs were covered under the original manufacturer warranties. As discussed above, new versions of these vehicle models now have longer warranty coverage than 2011 and 2013 models.

In cases where battery replacements are not covered by warranties, severely degraded or failed batteries can sometimes be refurbished. For example, a Nissan Leaf owner could purchase a refurbished 24-kWh battery for $2,800, instead of spending twice that much for a new battery (Voelcker, 2017). Several on-line articles indicate the cost of new replacement batteries, not including labor, could range from $5,000 for smaller packs like the Nissan Leaf to $15,000 for larger packs like Tesla (Greencars, 2021; Find my Electric, 2021). Due to continued battery improvements, the replacement costs, although substantial, are likely to be far lower in the future. For a first owner of a seven-year-old 250-kilometer range electric car, a battery replacement in 2032 could cost $1,800 (Lutsey, Cui, & Yu, 2021). It is not yet clear whether battery replacements will ultimately be more or less frequent than comparable costly major parts replacements (e.g., engine, transmissions, and emission-control sytems) for conventional vehicles.

Technology lag. The fast pace of ZEV technology improvements naturally means that the used ZEV market will typically receive technology that is at least five years old. In addition, there will be millions of vehicles in various regions that are over ten years old. Markets in China, Europe, and North America will see ZEVs more than 10 years old surpass 5% of their markets' ZEVs in the early 2030s, and surpass 10% in the late 2030s. With used ZEV owners receiving 5-year-old and eventually technology that is more than 10 years older than new ZEV owners, this leads to questions about the vehicle and charging technology to which they will have access.

While a used ZEV could be just half of the original new vehicle purchase price with fuel and maintenance costs that are half of a comparable conventional vehicle, there is a trade-off. A used electric vehicle may have an electric range up to 30%–40% lower than new electric vehicles due to older technology. Factoring in some level of battery degradation, electric range may be further reduced.

In addition, while a used ZEV buyer has the benefit of a much larger charging network than a new ZEV owner 5 years earlier, the time lag results in potential mismatches between vehicle and charging infrastructure that warrant further attention. In Europe and the United States, manufacturers have largely moved to the Combined Charging System (CCS) charging inlet for their newer ZEV models (Halvorson, 2020). This means that there are hundreds of thousands of equipped with the competing CHAdeMO fast charging standard with a lower fraction of available charging infrastructure available to them. Because used ZEV owners are more likely to not have home charging access, they would rely more on the public charging infrastructure, including more fast charging. This potential mismatch provides added motivation for policy efforts to standardize charging equipment, a topic further addressed below.

Despite some of the limitations described above, used ZEVs may still ultimately be attractive for households that typically buy used vehicles. However, it is nonetheless important to assess how the used ZEV market is evolving in order to direct resources to the foremost consumer barriers. Such policy questions are considered in the following section.

POLICY APPROACHES TO SUPPORT USED ZEVS

Based on the assessment of the used ZEV market dynamics above, this section discusses policy approaches to support a successful used ZEV market. Potential policies described include those implemented through mid-2021, those in the planning or implementation stages, and novel ideas for potential future policies to address barriers. The approaches include regulations, pilot projects, charging infrastructure, purchase incentives, consumer awareness, and gathering data to inform evolving policies.

ASSURANCE PROVISION TO SUPPORT USED ZEVS

ZEVs have largely been introduced into the market in response to vehicle environmental performance standards, in particular vehicle carbon dioxide (CO_2) emission standards and ZEV regulations. Although such regulations typically apply only to new vehicles, there could be some opportunities to adapt these regulations, or develop additional regulations, to support the development of a healthy used ZEV market.

In most jurisdictions, only new ZEVs can contribute to manufacturer compliance with CO_2 and ZEV regulations. By also making used ZEVs eligible for meeting regulatory requirements, vehicle manufacturers can be incentivized to also support the used ZEV market. This approach was adopted for the first time in Québec, where manufacturers can receive partial ZEV credits for selling used ZEVs (Government of Québec, 2021). California is considering allowing up to 5% of automakers' ZEV regulation compliance credit in years 2026–2031 to come from Environmental Justice credits, for which used ZEVs (those sold in 2026–2028) that come off leases and are re-sold in California could potentially be eligible (California Air Resources Board, 2021a).

Separate regulations can also be considered to provide transparency on battery life to educate and reassure ZEV driver on battery state-of-health. Consumers may fear that when a new ZEV enters the used market, its battery has severely degraded and is therefore no longer reliable (Halvorson, 2021b). To address these concerns, California and the United Nations Economic Commission for Europe (UNECE) are drafting regulations that would require dealerships to display the battery state-of-health of used ZEVs in terms that are easily understandable to prospective buyers (California Air Resources Board, 2021b; UNECE, 2021). To reduce implementation costs and reduce confusion, such certification programs would ideally be standardized across jurisdictions and developed in consultation with automakers.

Additional regulations are also under consideration to ensure battery durability as vehicles age. To instill greater confidence in prospective used ZEV buyers, governments can implement minimum threshold requirements for battery durability and performance. California, the UNECE, and the European Union are currently developing such regulations (California Air Resources Board, 2021b; European Commission, 2020, UNECE, 2021). California's approach would require that 2026-and-later battery electric and fuel cell models maintain at least 80% of certified test-cycle range for 10 years or 150,000 miles. UNECE's proposal would require that electric vehicles retain at least 70% of their rated usable energy after a period of up to 8 years or 161,000 km, which appears conservative given the above discussion of battery reliability (UNECE, 2021). These requirements would help ensure that batteries have substantial lifetime and sufficient range for a more successful experience for second-hand ZEV owners.

Other measures could be considered if greater support to instill confidence in used ZEV buyers was warranted in the future. In cases where difficulties related to finding battery replacements, even if rarely needed, were undermining the used ZEV market, governments could use pilot projects or offer programs to partially cover the cost of a battery replacement. The California Zero Emission Assurance Project, signed in 2018, offers rebates for the purchase of a replacement battery or a fuel cell (Assembly Bill No. 193 – 2018). California is also considering setting a minimum battery warranty requirement that would cover capacity loss exceeding 20% of the battery initial capacity. This reflects how longer warranties can effectively reduce potential used ZEV buyer concerns (Pedrosa & Nobre, 2018).

Right-to-repair laws are also under consideration, as the ability to repair older ZEVs could affect their attractiveness and resale value in the marketplace. While ZEVs typically require less maintenance and battery failures are rare, repairability is a potential concern; in circumstances where out-of-warranty battery repairs are prohibitively expensive, this would cut the ZEVs potential lifetime short. Some jurisdictions are working to facilitate repairs, including battery recycling and refurbishment options, by requiring manufacturers to publicize the material and chemistry used to manufacture their battery. Massachusetts has expanded its right-to-repair laws, requiring all manufacturers to share standardized data information on ZEV parts with licensed auto repair businesses (Bill H.4302 - Commonwealth of Massachusetts, 2020). Similarly in the European Union, the European Commission has proposed the creation of either a digital platform or a battery passport where manufacturers would disclose battery data to facilitate third party recycling and repurposing operations (European Commission, 2020). The Commission is also looking to strengthen regulations for readily removable batteries to ensure that they can be recycled (EU Commission, 2020). These are important measures since several manufacturers, including Tesla and Volkswagen, are looking into further advancing structural integrated battery design for future electric vehicle models (Halvorson, 2021a).

Finally, standardization of chargers could also be an important way to support the used ZEV market. One issue that could emerge with lack of standardization is if most early ZEVs have a particular DC fast charging outlet and protocol that becomes less popular over time. For example, with more electric vehicles with CHAdeMO intlets before 2016, the shift to more SAE CCS Combo public charger in networks through 2025 could leave used ZEV owners with fewer charging options. In the near term, governments can mitigate these related issues by allocating financial resources that ensure legacy charger inlets remain available. In the longer term, governments could consider standardizing DC fast charging vehicle inlets and requiring interoperability for information and payment protocols. Governments can also use grants, funding, and cost-sharing programs to reinforce such charging standards. California has proposed standardizing the SAE CCS 1 inlet for all 2026 and subsequent vehicle models. Governments can also consider encouraging manufacturers to develop and sell adapters between existing and new DC fast charging standards that ensure compatibility with older ZEV models, a feature also included in California's proposed regulation (California Air Resources Board, 2021c).

USED ZEV PURCHASING SUPPORT

Purchasing incentives can address the upfront cost barrier of used ZEVs. As analyzed above, declining used ZEV prices will make them more affordable than conventional vehicles around 2025–2028. Until then, upfront vehicle price will remain a challenge for cost-conscious used ZEV buyers, and incentives would make them financially attractive. Used ZEV incentives would ideally follow well-tested principles for effective incentive design, including availability at the point of sale, easily administered, clearly understandable for car dealers and buyers, and continued monitoring and evaluation (Yang et al., 2016; Jenks et al., 2018; Hardman et al., 2017; Narassimhan and Johnson, 2018; Greenlining, 2021; NYSERDA, 2021a). Incentives for used ZEVs could also benefit from equity provisions. For example, governments have linked incentives to maximum ZEV price or maximum income, increased ZEV incentive awareness campaigns, and scrappage programs to used ZEVs (Government of the Netherlands, 2020; Oregon Department of environmental Quality, 2021; Government of Connecticut, 2021; French Minister of the Ecologic Transition, 2021; California Air Resources Board, 2019).

A few jurisdictions have included used ZEVs under their existing incentive programs, which had previously only focused on new ZEVs. France offers a €1,000 ($1180) for the purchase of used BEVs, and Germany provides €5,000 ($6,000) for used BEVs and €3,750 ($4,500) for used PHEVs (France Public Service, 2021a; Federal Office for Economic Affairs and Export Control, 2021). In the province of Québec, consumers can receive a rebate of up to $4,000 for the purchase of a used BEVs (Government of Québec, 2020). New Jersey and the state of Washington have a sale tax exemption for used ZEV purchases (New Jersey Department of Environmental Protection, 2021; Washington Department of Revenue, 2021). Tax exemptions could be an especially good idea for used ZEVs to make the incentive clear and at the point of sale. Financing assistance mechanisms such as low interest loans, loan-loss guarantees, or price reduction vouchers are also tools that can be used to address the upfront cost barrier of used ZEVs (Greenlining, 2020; GO-Biz 2020). In Scotland, The Low Carbon Transport Loan program provides interest-free loan of up to £20,000 ($28,300) for the purchase of a used ZEV (Government of Scotland, 2021). In California, the Clean Vehicle Assistance Program offers grants and loans for the purchase of a new or used ZEV (Beneficial State Foundation, 2021).

Additional jurisdictions have put in place a scrappage programs applicable for used ZEVs. In France, consumers can receive an incentive of up to $5,950 (5,000 €) for scrapping their old vehicle (French Minister of the Ecologic Transition, 2021). In California, the Clean Cars 4 All program is a similar scrappage incentive, which combined with the Enhanced Fleet Modernization program (EFMP), offers up to $9,500 to residents that live in participating districts and that meet certain income requirements (Clean Air Resources Board, 2019). Similarly, in Ontario, Canada, drivers can receive a $1,000 incentive for replacing an old vehicle with a used electric vehicle (PlugNDrive, 2021)

Limited available data indicates that these types of incentives and loan support are critical for many ZEV purchases. A survey on California Vehicle Assistance program conducted in 2020 revealed that 90% (of a total of 298 responses received) would have not purchased their new or used electric vehicle if the California Vehicle Assistance grant did not exist. The survey also found that 45% (of a total of 168 responses received) would not have purchased their new or used electric vehicle if the program did not provide loan assistance (Center for Sustainable Energy, 2019). A combined evaluation of the California's Clean Car 4 All and the Enhanced Fleet Modernization Program found that they have retired close to 8,000 old conventional vehicles, replacing them with electric vehicles. The report also revealed that of the 11,317 household participants, 88% made less than or equal to 225% of the federal poverty-level income, or $12,880 to $44,660 depending on household size (California

Air Resources Board, 2020). The findings from those three programs suggest that fiscal incentives, loans, and scrappage programs can support used ZEV uptake, especially for low-income car buyers.

Non-fiscal incentive programs like toll exemptions, access to high occupancy lanes, and parking fee exemptions can also support the new and used ZEV market. In Costa Rica, for example, following the revision of its 2016 ZEV incentive law, used ZEV owners have free parking access in designated areas (Republic of Costa Rica, 2018). Similar such policies are also widely implemented by many local governments in high ZEV-uptake markets (Bui et al., 2020; Hall et al., 2020). Several studies find that non-fiscal based mechanisms are effective in increasing new ZEV uptake (Hardman et al., 2017; Narassimhan and Johnson, 2018), though data are still scarce for how these policies could impact the used ZEV market. Through consumer purchasing surveys, for example, governments can continue to evaluate the effects of various programs on used ZEV purchasing experiences over time.

Although targeted incentives for used ZEVs will be important, governments need to balance the associated outlays with available resources. Several major parameters can help guide limited government resources and expenditures.

Incorporating best practices applied in effective new ZEV incentive programs is warranted for used ZEV programs. Governments can start with smaller pilot programs to evaluate their effectiveness before ramping up to greater scale. Several principles for effective incentive design, such as setting eligibility criteria on maximum household income or maximum vehicle price can ensure effective targeting. As used ZEVs reach price parity with conventional vehicles, governments could consider phasing down incentives over time with more restricted eligibility or requirements or decreasing financial support. More broadly, governments can allocate specific percentages of their overall ZEV incentive program budget, based on their tracking of how ZEVs migrate from new to used, as analyzed above. Generally, providing the incentives as tax exemptions and setting programs for several years at a time can be more stable for the market and for managing government resources.

Several additional tools might be especially important in managing government support for used ZEVs. To reduce the possibility of used ZEV incentives being exploited with frequent re-selling, governments can tie the vehicle owner's name to the subsidy received for a given period. In the Netherlands, a recipient of a new ZEV incentive is tied to the vehicle for three years; if the new ZEV is sold earlier, the owner could be required to repay part of the subsidy (Netherlands Enterprise Agency, 2021). Governments can monitor key details about the small but growing number of used ZEVs. Tracking the balance of new and used ZEVs is important to understand related trends, including the percentages of ZEVs that are with their first owner, received a new ZEV rebate, and received a used ZEV rebate. Additional information, for example via surveys of ZEV owners linked with their receiving the incentive, can help understand how essential the incentive was and can be used to track trends in its importance for used ZEV purchases over time.

Although large scale detailed ZEV data tracking efforts have not yet been done beyond the first ZEV owner, governments could explore such tracking for several reasons. Tracking data on ZEVs would help governments to assess any potential questions about double counting (e.g., a ZEV incentivized twice), how the used ZEV incentive might be impacting the used ZEV prices, or if dealers or private car sellers are increasing the used ZEV price due to available incentives. Such tracking would also allow states to understand how much of the ZEVs' lifetime miles were driven within their jurisdiction, which could be important to justify the continuation of, or any modifications to, the incentives. Tracking ZEV prices, mileage, and incentives for each ZEV sale or re-sale could conceivably be done through national or state vehicle registration agencies. Governments could explore such tracking practices while used ZEVs receiving the incentives are relatively few in order to assess the cost and value of continuing such tracking systems over time. The more costly the used ZEV support programs become, the greater the need is to closely track their effects.

CHARGING INFRASTRUCTURE ACCESS

Research consistently confirms a link between new ZEV uptake and the availability of charging infrastructure (Hall and Lutsey, 2017; Narassimhan and Johnson, 2018). Especially within remote areas and low-income communities, such infrastructure is often lacking (Hsu and Fingerman, 2021; Transport & Environment, 2020). Access to charging infrastructure will be critical for used ZEV uptake, especially as used ZEV drivers are more likely to have less access to convenient home charging and less control over any such property improvements. Policies and targeted infrastructure investments can help address these barriers.

Charging needs for multifamily homes, where used vehicle drivers are less likely to have home charging access, can be facilitated by right-to-charge laws that allow renters to install a charger at their place of residence. Several jurisdictions like France or the states of California and Colorado have already proposed such laws (California Civil Code, 2020; Colorado Revised Statutes, 2020; France Public Service, 2021b). Additionally, several governments and electric utilities are directing investments to support charger installations in multifamily homes. In France, owners of multifamily rental housing can receive up to €960 ($1,122) or % 50 of the charger installation cost. Similarly in Texas, the utility Austin Energy provides a rebate of up to $4,000 or 50% of the charger installation cost for multifamily homes (Austin Energy, 2021a). In the state of New York, the Charge Ready NY program offers a $4,000 rebate per charging port for the installation of public and multifamily charging stations, including an extra $500 incentive for installations in low-income areas (NYSERDA, 2021b).

Some jurisdictions have set requirements to direct investments towards low-income areas, where used vehicle buyers are more prevalent. The Massachusetts utility Eversource was directed to allocate 10% of its $45 million public electric vehicle charging infrastructure investment in low-income communities (Eversource, 2019). Two California utilities allocate 25% to 50% of their charging infrastructure investments toward disadvantaged communities (PG&E 2018; Edison International, 2021). Governments can also update building codes to ensure new or retrofitted buildings, including multifamily homes, are equipped with charging infrastructure. In San Francisco, California, the 2017 revised building code requires that 100% of parking spaces in new commercial and residential buildings be accessible to electric vehicle charging. Of these, 10% must be ready for immediate use, while the remainder must have conduit for future installations (Ordinance No. 92-17 San Francisco Green Building and Environment Codes).

Data on these new programs are not yet available to evaluate their effectiveness or lessons learned. In the United States, research indicates that far more chargers at multifamily homes is needed and 30% of public infrastructure investments should be directed to low- and moderate-income communities to provide equitable charging infrastructure access through 2030 (Bauer et al., 2021b).

In addition to physical access to ZEV infrastructure, there is also a need to ensure that the cost of charging is cheaper than gasoline or diesel. While home charging typically offers the lowest electricity rates, low-income communities have limited access to home chargers. This indicates the importance of ensuring affordable rates at public locations. In this effort, many jurisdictions have adopted different forms of time-varying electricity pricing schemes such as Time of Use rating (or TOU). Under these schemes, consumers are encouraged to charge their EVs during periods where the price of electricity is low (Nicholas, 2018; Amin et al., 2020). In the United States, PG&E, an investor-owned utility company, offers TOU rate plans in public locations which include retailers, fast-charging stations, and workplaces (PG&E, 2021). Data to understand the effectiveness of these initiatives, especially regarding underserved communities, are not yet available.

CONSUMER AWARENESS AND EDUCATION

Consumer awareness programs have supported increased ZEV understanding and demand. Like other ZEV policies that have focused on the new ZEV market, there are opportunities to expand and tailor these programs to similarly support the used ZEV market. Several practices could help understand and support used ZEVs.

One such opportunity is for improved used ZEV buyer experiences at dealerships (Sierra Club, 2021). Conducting surveys to analyze early dealerships' experience in selling used ZEVs can help identify best practices for selling used ZEVs effectively. These could be done by federal or state agencies, or with public-private partnerships. Further, governments and public-private ZEV consumer outreach platforms could host information at their websites that clearly identify which dealerships are certified to sell and service ZEVs, including contact information for the specific ZEV-focused specialist salespersons, to help buyers find supportive dealerships. Dealer training programs can ensure dealerships have the proper competence to educate buyers about used ZEVs, including issues like battery reliability, available incentives, and charging options. Such programs already exist within the new ZEV market (e.g., the PlugStar Electric Vehicle Dealer Training) and can be adapted to used ZEVs (Plug in America, 2021b).

Electric utilities are also well positioned to support used ZEVs. They could make use of their already existing mailing list database to send educational material on used ZEVs to their consumers. One utility has worked with local auto dealers and has created an on-line EV buyer's guide with information on electric models available, purchasing incentives, home charging rebates, and available public charging plans (Austin Energy, 2021b).

Governments can also collect improved data on used ZEVs. Online car platforms are the main providers of used ZEV data, but the data remain limited. Improved data will allow expert car buyer media outlets, as well as consumers, to better understand the ZEV purchase proposition. To educate and enable improved used ZEV car-shopping research, governments and the private sector can collect and make data on used ZEVs publicly available. For governments, a first step would be to analyze ZEV registration data and publish aggregated anonymous results that help in understanding ZEV change of ownership patterns. Partnerships between the public and private sectors to collect used ZEV statistics (e.g., models available, number of registrations, distance traveled) would also produce insights to support future policy needs. Such information could be shared under platforms like the Northeast Model Repository or the California Energy Commission Vehicle Population Dashboard (California Energy Commission, 2021; Drive Change Drive Electric, 2021).

Another potential action to support the used ZEV market is vehicle labeling. In the new ZEV market, some jurisdictions use labels or tags to provide upfront information to prospective consumers, such as on availability of incentives, fuel savings, and maintenance costs. A similar concept can be applied within the used ZEV market, where the label could additionally provide information on battery state-of-health, electric range, battery warranty status, charging connector capabilities, or practices to take care of the battery (Hall and Shorthouse, 2021).

Especially in markets with limited new ZEV supply, used ZEVs can also provide an outreach opportunity. In markets like Costa Rica and New Zealand, used ZEV imports lead to the creation of electric mobility associations that promote ZEV technologies. Similarly, *community-based outreach through* trusted leader groups could help inform, train, and educate consumers on ZEV technologies and their benefits. Such support can take many forms, including organizing test-drive events, launching public education campaigns, debunking common ZEV myths, technical assistance, and support on how to apply for a used ZEV incentive (Greenlining, 2021).

SUMMARY OF ACTIONS TO SUPPORT USED ZEVS

The overall analysis of this report shows how the used ZEV market presents an opportunity to make ZEV technologies accessible to all. Yet, many unknows and challenges will need to be addressed to harness this opportunity. Table 2 summarizes recommended actions to support the used ZEV market, from small-scale initiatives to various forms of support for used ZEV drivers. A general pilot project approach is critical in the early stages of the used ZEV market, along with measures aiming to collect and track data. It will also be important to define measures of success to ensure that used ZEV market meets its expected objectives. Based on tracking of the used ZEV market, jurisdictions can increasingly develop durability or repair regulations, purchasing support programs, charging infrastructure programs, and consumer awareness campaigns. Continuous data tracking will also be important to inform further refinement and the progressing scaling down of various policies, as ZEVs become mainstream over time.

Table 2. Summary of actions to support the used ZEV market.

Type	Objective	Action
Pilot projects	• Raise awareness and increase purchases of ZEVs in used vehicle-buying households • Identify metrics and track effectiveness of projects	• Develop small-scale initiatives to support used ZEVs (e.g., rebates, loan assistance, scrappage, charging installation, non-fiscal perks) • Conduct surveys, focus groups, and community engagement before and after pilots to understand barriers for prospective used ZEV drivers • Collect, share, and track data on used ZEV receptiveness, transactions, charging access, charging behavior, prices, annual and lifetime mileage, and functionality (e.g., vehicle range, battery state-of-health)
Assurance provisions	• Increase consumer confidence in buying used ZEVs • Ensure high vehicle lifetime and maximize zero-emission miles per vehicle	• Require vehicle-specific transparency and certification regarding battery state-of-health over vehicle lifetime • Incorporate ZEV durability and charging standardization provisions in regulations and government support programs • Encourage greater durability, reparability, and warranty coverage by publishing transparent data on government ZEV fleets, conventional vehicle maintenance and repair costs, and battery state-of-health as ZEVs age
Purchasing support	• Make used ZEVs less costly than used conventional vehicles	• Provide incentives and loan support where ZEVs are more expensive than conventional vehicles and where purchase support is essential, based on pilot projects and ZEV purchasing behavior surveys • Further target used ZEV incentive support to lower-income individuals and areas with low ZEV uptake and poor air quality
Charging Infrastructure access	• Ensure access to home and public charging in low income and rural areas	• Develop strategies (e.g., utility investments, local building codes) that prioritize investments and affordable charging prices in multifamily homes and public locations for underserved ZEV markets • Apply information from pilot projects and data tracking to target support where used ZEV charging is most critical
Awareness and education	• Increase awareness of and receptiveness to purchasing used ZEVs	• Conduct public-private consumer awareness campaigns, and dealership training, publish data on used ZEVs, and perform community-based outreach • Target awareness activities based on data tracking regarding the top barriers of used ZEV durability, cost, charging, etc.

CONCLUSIONS

The used ZEV market offers an important opportunity to expand access to ZEVs to a far greater population of drivers then simply new ZEV buyers. However, it also presents several clear challenges. Governments should consider several new actions to track, understand, and support the growing used ZEV market. Underpinning the recommendations are several critical elements regarding used ZEV prices and the increasing ZEV volume over time, as analyzed above. The main findings of this analysis are summarized below:

The used ZEV market provides an opportunity for more affordable ZEVs. Faster advancements in ZEV technology results in faster depreciation compared to conventional combustion engine vehicles. This dynamic causes used ZEVs to reach price parity with used conventional vehicles in the 2025-2028 timeframe. Furthermore, previous research found that used ZEV drivers could generate substantial maintenance and fuel cost savings compared to used conventional vehicle drivers. In the U.S, five-year-old plug-in electric vehicles could save 11% to 17% in annual ownership costs relative to a comparable conventional car, and the savings increase to 17% to 22% for seven-year-old vehicles (Harto, 2020). In the United Kingdom, the ownership costs of a five years old second ownership ZEV are £2,600 to £3,200 ($3,600 to $4,600) less than comparable conventional vehicles (Kumar, 2019).

Small-scale programs can fill information gaps and refine policies for a successful used ZEV market. While the volume of used ZEVs is still low, small-scale programs and pilot projects are critical to develop and track the key data metrics to define success in the used ZEV market; these could include incentives, infrastructure deployments, and targeting programs in priority areas. As explained on Table 2 above, the data gathered from these projects can be used to identify subsequent actions involving greater scale and cost. Based on tracking of the used ZEV market, jurisdictions can expand or modify regulations, purchasing support programs, charging infrastructure programs, and consumer awareness campaigns. The continuing collection and tracking of data trends will allow for refining or scaling down the various policies as used ZEVs become more mainstream over time.

Reliability requirements and assurance provision measures could increase confidence and demand for used ZEVs. The number of older ZEVs in the market will inherently increase over time even as technology rapidly develops, raising concerns regarding different technological aspects such as battery degradation, fast charging access, or maintenance costs. Although early evidence indicates that batteries and other components of electric vehicles have better longevity compared to conventional vehicles, many consumers are uncertain given the novelty of the technology and well-publicized issues for select models in early years. Over time, policies and regulations that aim to strengthen ZEV durability (e.g., longer warranties, right to repair laws) could help older ZEVs to remain on the roads for an even longer period. Measures that guaranty access to charging (especially in multifamily homes) and that maintain fast charging compatibility with older ZEV models will also be important.

By the early 2040s, used ZEVs could surpass first-owner ZEVs. Figure 9 shows the global growth of the used ZEV stock in comparison with new, first-owner ZEVs through 2045, along with annotations on the evolution of the market. Through the 2020s, the stock of used ZEVs increases but remains far smaller than the stock of first-owner ZEVs. Between 2028 and 2035, the population of used ZEVs increases more sharply, from 23 million to 168 million, with used ZEVs reaching upfront cost parity with comparable used conventional vehicle models around 2025-2028. As used ZEVs surpass first owner ZEVs by the early 2040s, they become mainstream options. Considering their successful advancements as of 2021, markets in Europe are likely to move through this progression faster, while emerging economies with few first-owner ZEVs in 2021 will be slower. Through the market stages shown, used ZEV policy support can phase down over time as the market matures.

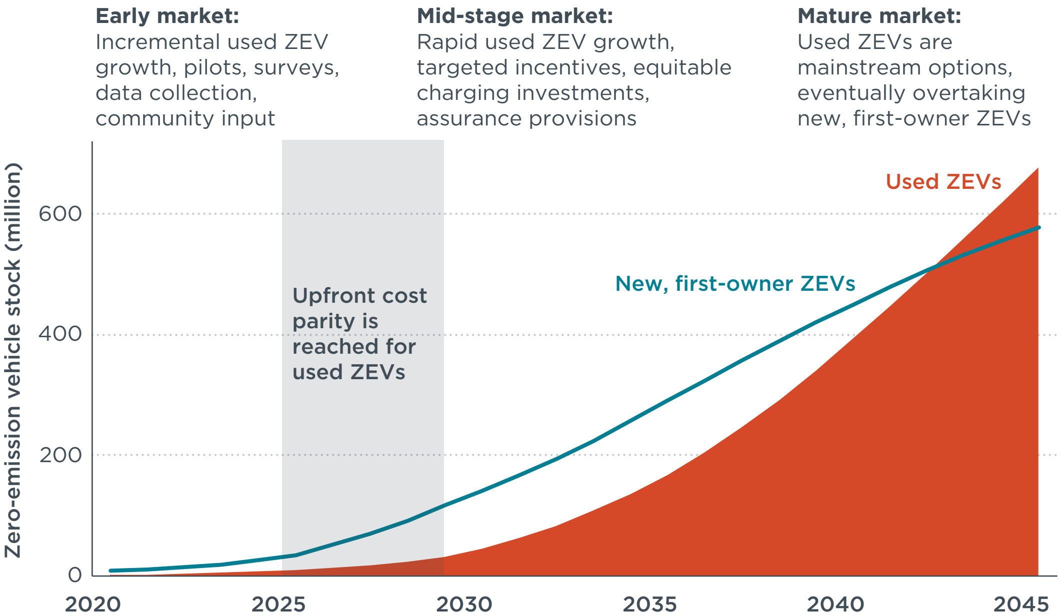

Figure 9. Stages in the global growth of the used zero-emission vehicle market.

Although the unique barriers associated with the used ZEV market present challenges for governments in the transition to ZEVs, this growing market offers the potential to make the benefits of ZEVs accessible across all vehicle-driving households. This research identifies barriers for the used ZEV market, assesses the time frame for the growing scale of used ZEVs, and offers policies and actions to provide continuing support. As the research indicates, continued tracking of various consumer metrics will be required to refine policies, incentives, charging infrastructure, and campaigns over time given the uncertainties at this early stage of the market. The report is primarily focused on government actions, but electric power utilities, automakers, dealers, community leaders, and non-profits can also play important outreach roles to bolster confidence in ZEVs. As the ZEV market continues to grow and mature, the lessons from leading markets will continue to be critical in ensuring that the uptake of used ZEVs, and therefore the broader transition to electric mobility, is successful around the world.

REFERENCES

An act to enhance, update and protect the 2013 motor vehicle right to repair law, Bill H.4302 (2020). Retrieved from the Commonwealth of Massachusetts https://malegislature.gov/Bills/191/H4302

Amin, A., Tareen, W.U.K., Usman, M., Ali, H., Bari, I., Horan, B., Mekhilef, S., Asif, M.,Ahmed, S., Mahmood, A. (2020). A review of optimal charging strategy for electric vehicles under dynamic pricing schemes in the distribution charging network. *Sustainability 12 (23),10160.* https://doi.org/10.3390/su122310160

Argue, C. (2020). What can 6,000 electric vehicles tell us about EV battery health (blog post). *Geotab*. https://www.geotab.com/blog/ev-battery-health/

Association Nationale pour le Développement de la Mobilité Électrique (AVERE France). (2020, January 27). Annual barometer: sales of used electric vehicles jumped by + 55% in 2019. Retrieved from https://www.avere-france.org/publication/barometre-annuel-les-ventes-de-vehicules-electriques-doccasion-ont-bondi-de-55-en-2019/

Atlas EV Hub. (2020). *State EV registration data*. Atlas EV Hub. https://www.atlasevhub.com/materials/state-ev-registration-data/

Aucock, R. (2021, March 4). Used EV 'revolution' now underway. *Motoring Research*. https://www.motoringresearch.com/used-cars/used-ev-revolution-underway/

Austin Energy. (2021a). Multifamily charging. Retrieved from https://austinenergy.com/ae/green-power/plug-in-austin/multifamily-charging

Austin Energy. (2021b). There are 44 electric vehicles available. Discover yours. Retrieved from https://ev.austinenergy.com

AutovistaGroup. (2021, February 9). Who will buy Europe's used-electric cars. Retrieved from https://autovista24.autovistagroup.com/news/who-will-buy-europes-used-electric-cars/

Bauer, G., Hsu, C-W., Lutsey, N. (2021a). *When might lower-income drivers benefit from electric vehicles? Quantifying the economic equity implications of electric vehicle adoption.* Retrieved from International Council on Clean Transportation https://theicct.org/publications/EV-equity-feb2021

Bauer, G., Hsu, C-W., Nicholas, M., and Lutsey, N. (2021b). *Charging up America: assessing the growing need for US charging infrastructure through 2030.* Retrieved from the International Council on Clean Transportation https://theicct.org/publications/charging-up-america-jul2021

Beneficial State Foundation. (2021). Clean Vehicle Assistance. Retrieved from https://cleanvehiclegrants.org/about-us/

Blackley, J. (2020a). How long do people keep their cars? *iSeeCars.com*. Retrieved from https://www.iseecars.com/how-long-people-keep-cars-study

Blackley, J. (2020b). The most popular used electric vehicle. *iSeeCars.* Retrieved from https://www.iseecars.com/cars-for-sale#section=studies&study=tesla-sales

Bradshaw, M. (2020, December 19). Breakthrough underway for electric vehicles as used sales grow to 15% of market, says BuyaCar. *Pronounce Media.* Retrieved from https://pronounce.media/press-release/breakthrough-underway-for-electric-vehicles-as-used-sales-grow-to-15-of-market-says-buyacar/ifm-independent-forecourt-magazine/2020-12-10/3083

Bui, A., Slowik, P., & Lutsey, N. (2020). Update on electric vehicle adoption across U.S. cities. Retrieved from the International Council on Clean Transportation https://theicct.org/publications/ev-update-us-cities-aug2020

Burnham, A., Gohlke, D., Rush, L., Stephens, T., Zhou, Y., Delucchi, M., Birky, A., Hunter, C., Lin, Z., Ou, S., Xie, F., Proctor, C., Wiryadinata, S., Liu, N., and Boloor, M. (2021). *Comprehensive Total Cost of Ownership Quantification for Vehicles with Different Size Classes and Powertrains*. Retrieved from U.S. Department of Energy Office of Scientific and Technical Information https://doi.org/10.2172/1780970

Busch, C. (2021). *Used Electric Vehicles Deliver Consumer Saving Over Gas Cars*. Retrieved from Energy Innovation https://energyinnovation.org/publication/used-electric-vehicles-deliver-consumer-saving-over-gas-cars/

California Air Resources Board. (2019). Clean Cars 4 All. Retrieved from https://ww2.arb.ca.gov/our-work/programs/clean-cars-4-all

California Air Resources Board. (2020). *EMFP retire and replace program statistics*. Retrieved from https://ww2.arb.ca.gov/sites/default/files/2021-03/2020_q4_%20EFMP%20Website%20Statistics%20Tables%20Cumulative.pdf

California Air Resources Board. (2021a). Advanced Clean Cars II Workshop. https://ww2.arb.ca.gov/events/public-workshop-advanced-clean-cars-ii-0

California Air Resources Board. (2021b). Advanced Clean Cars II Workshop. Retrieve from https://ww2.arb.ca.gov/events/public-workshop-advanced-clean-cars-ii

California Air Resources Board. (2021c). Public Workshop on Advanced Clean Cars II. Retrieved from https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii-meetings-workshops

California Civil Code, Chapter 2: hiring of real property (2020). Retrieved from https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=CIV&division=3.&title=5.&part=4.&chapter=2.&article=

California Governor's Office of Business and Economic Development (*GO-Biz*). (2020). *Driving Towards Equity: Getting the Most Out of Used ZEVs.*

California Legislative Information, Assembly Bill No. 193 - Chapiter 363 (2018). Retrieved from https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB193&qut

California Energy Commission. (2021). *California Energy Commission Zero Emission Vehicle and Infrastructure Statistics.* Retrieved from https://www.energy.ca.gov/zevstats

Canepa, K., Hardman, S., & Tal, G. (2019). An early look at plug-in electric vehicle adoption in disadvantaged communities in California. *Transport Policy, 78, 19–30.* https://doi.org/10.1016/j.tranpol.2019.03.009

Center for Sustainable Energy. (2019). *Clean Vehicle Assistance Program Adoption Survey Report*. Retrieved from the Beneficial State Foundation https://cleanvehiclegrants.org/program-data/

Colorado Revised Statutes, Title 38 Property real and personal (2020). Retrieved from https://leg.colorado.gov/sites/default/files/images/olls/crs2020-title-38.pdf

Cui, H., Hall, D., and Lutsey, N. (2020). *Update on the global transition to electric vehicles through 2019* (working paper). Retrieved from the International Council on Clean Transportation https://theicct.org/sites/default/files/publications/update-global-EV-stats-sept2020-EN.pdf

Deutsche Automobil Treuhand. (2021). *DAT report 2021.* Retrieved from https://www.dat.de/news/dat-report-2021/

Doyle, A. (2019, March 21). From California to Oslo: foreign subsidies fuel Norway's e-car boom, for now. *Reuters*. Retrieved from https://www.reuters.com/article/us-autos-norway-insight/from-california-to-oslo-foreign-subsidies-fuel-norways-e-car-boom-for-now-idUSKCN1R20HN

Drive Change, Drive Electric. (2021). Explore available electric cars. Retrieved from https://driveelectricus.com/explore-electric-cars/

Duurkoop, T., Hiep, E., Van Biezen, M., and Van Dam, J. (2021). *The national EV and driver survey.* Retrieved from the National Service for enterprising Netherlands (RVO) https://www.rvo.nl/sites/default/files/2021/02/Het%20nationaal%20EV%20en%20berijdersonderzoek_0.pdf

Elbil Statistikk. (2021). Cumulative EV registrations by make and model. 2021-02-27. Retrieved from https://elbilstatistikk.no

Edison International. (2021). SCE launches program to install 38,000 EV chargers. https://energized.edison.com/stories/sce-launches-program-to-install-38-000-ev-chargers

Eversource. (2019). *Sustainability report.* Retrieved from https://www.eversource.com/content/docs/default-source/community/sustainability-report.pdf?sfvrsn=4174d162_12

EV-Volumes. (2021). *EV Data Center*. Retrieved from http://www.ev-volumes.com/datacenter/

European Alternative Fuels Observatory (EAFO). (2021). *Norway*. Retrieved from https://www.eafo.eu/countries/norway/1747/incentives

European Commission. (2020). *Regulation of the European Parliament and of the council concerning batteries and waste batteries, repealing directive 2006/66/ec and amending regulation (EU) No 2019/1020.* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0798

Federal Office for Economic Affairs and Export Control. (2021). Electromobility. Retrieved from https://www.bafa.de/DE/Home/home_node.html

Find my Electric. (2021). Tesla battey replacement cost explained. Retrieved from https://www.findmyelectric.com/blog/tesla-battery-replacement-cost-explained/

Finn.no. (2020). Many choose diesel. Retrieved from https://www.finn.no/motor/artikler/bil/flere-velger-dieselbil

French Minister of the Ecologic Transition. (2021). Prime a la conversion des vehicles et bonus écologique 2021. Retrieved from https://www.primealaconversion.gouv.fr/dboneco/accueil/

France Public Service. (2021a). Bonus écologique pour une voiture ou une camionnette électrique ou hybride. Retrieved from https://www.servicepublic.fr/particuliers/vosdroits/F34014

France Public Service. (2021b). Particulier quelles aides à l'installation d'une borne de recharge pour un véhicule électrique. Retrieved from https://www.servicepublic.fr/particuliers/vosdroits/F34014

General Motors. (2020, March 4). GM reveals new ultium batteries and a flexible global platform to rapidly grow its ev portfolio. Retrieved from https://media.gm.com/media/us/en/gm/home.detail.html/content/Pages/news/us/en/2020/mar/0304-ev.html

Geotab. (2021). Electric vehicle battery degradation tool. Retrieved from https://www.geotab.com/fleet-management-solutions/ev-battery-degradation-tool/

Government of Connecticut. (2021). The Connecticut hydrogen and electric automobile purchase rebate (CHEAPR). Retrieved from https://portal.ct.gov/DEEP/Air/Mobile-Sources/CHEAPR/CHEAPR---Home

Government of the Netherlands. (2020). Government gazette of the kingdom of the Netherlands. Retrieved from https://zoek.officielebekendmakingen.nl/stcrt-2020-28162.html

Government of Québec. (2020) Electric vehicles. Retrieved from https://vehiculeselectriques.gouv.qc.ca/english/rabais/ve-occasion/conditions-rabais-vehicule-occasion.asp

Government of Québec. (2021). Québec leads the way with its ZEV standard. https://www.environnement.gouv.qc.ca/changementsclimatiques/vze/feuillet-vze-reglement-en.pdf

Government of Scotland. (2021). Funding for electric vehicles. Retrieved from https://www.netzeronation.scot/take-action/electric-vehicles/funding-electric-vehicles

Greencars. (2021). Definitive guide to electric car batteries. Retrieved from https://www.greencars.com/guides/definitive-guide-to-electric-car-batteries-range

Greenlining. (2021). Electric vehicles for all: an equity toolkit. Retrieved from https://greenlining.org/resources/electric-vehicles-for-all/#_ftn1

Guo, Z. and Zhou, Y. (2019). Residual value analysis of plug-in vehicles in the United States. *Energy Policy*, Volume 125, Pages 445-455. https://www.osti.gov/biblio/1494668

Hall, D., Cui, H., Rajon Bernard, M., Li, J., & Lutsey, N. (2020). *Electric vehicle capitals: cities aim for all-electric mobility*. Retrieved from the International Council on Clean Transportation https://theicct.org/publications/electric-vehicle-capitals-update-sept2020

Hall, D., and Lutsey, N. (2017). *Emerging best practices for electric vehicle charging infrastructure*. Retrieved from the International Council on Clean Transportation https://theicct.org/publications/emerging-best-practices-electric-vehicle-charging-infrastructure

Hall, P., and Shorthouse, R. (2021). *Driving uptake: maturing the market for battery electric vehicles*. Retrieved from BrightBlue http://brightblue.org.uk/wp-content/uploads/2021/02/maturing-the-market-for-battery-electric-vehicles.pdf

Halvorson, B. (2020, July 16). Nissan's move to CCS fast charging makes CHAdeMO a legacy standard. *Green Car Reports*. Retrieved from https://www.greencarreports.com/news/1128891_nissan-s-move-to-ccs-fast-charging-makes-chademo-a-legacy-standard

Halvorson, B. (2021, July 24). EV startup canoo has a structural battery- but it's not Tesla approach. *Green Car Reports*. Retrieved from https://www.greencarreports.com/news/1132705_ev-startup-canoo-has-a-structural-battery-but-it-s-not-tesla-s-approach

Hardman, S., Chandan, A., Tal, G. and Turrentine*, T.* (2017). The effectiveness of financial purchase incentives for battery electric vehicles – A review of the evidence*. Renewable and Sustainable Energy Reviews, Volume 80*. Retrieved from https://doi.org/10.1016/j.rser.2017.05.255

Harto, C. (2020). *Electric vehicle ownership costs: today's electric vehicles offer big savings for consumers*. Retrieved from Consumer Report https://advocacy.consumerreports.org/wp-content/uploads/2020/10/EV-Ownership-Cost-Final-Report-1.pdf

Hsu, C., and Fingerman, K. (2021). Public electric vehicle charger access disparities across race and income in California. *Transport Policy*, 100, 59-67, https://doi.org/10.1016/j.tranpol.2020.10.003

Idaho National Laboratory. (2014). DC fast charge effects on battery life and performance study – 50,000-mile update. Retrieved from https://www.energy.gov/sites/prod/files/2015/01/f19/dcfc_study_fs_50k.pdf

Incentives and Promotion for Electric Transport, No 9518/2018 of the Legislative Assembly of The Republic of Costa Rica (2018). Retrieved from http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?nValor1=1&nValor2=85810

InsideEVs. (2016, January 6). Battery capacity loss warranty chart for 2016 30 kwh Nissan Leaf. https://insideevs.com/news/326563/battery-capacity-loss-warranty-chart-for-2016-30-kwh-nissan-leaf/

Jenks, C., Van horn, G., Slawsky, L., and Hill, S. (2018). *Toolkit for advanced transportation policies improving environmental, economic, and social outcomes for states and local governments through transportation.* Retrieved from M.J. Bradley & Associates: https://www.mjbradley.com/sites/default/files/mjba_transportation_toolkit.pdf

Jin, L., He, H., Cui, H., Lutsey, N., Wu, C., Chu, Y., Zhu, J., Xiong, Y., Liu, X. (2021). *Driving a green future: a retrospective review of china's electric vehicle development and outlook for the future*. Retrieved from the International Council on Clean Transportation. https://theicct.org/publications/china-green-future-ev-jan2021

Kane, M. (2020). Check out this official tesla model s/x battery capacity degradation chart. *InsideEVs*. Retrieved from https://insideevs.com/news/429818/tesla-model-s-x-battery-capacity-degradation/

Kraftfahrtbundesamt. (2018). *Vehicle approvals (FZ) new registrations, changes of ownership, decommissioning of Motor vehicles and motor vehicle trailers.* Retrieved from https://www.kba.de/DE/Statistik/Produktkatalog/produkte/Fahrzeuge/fz18_nu_uebersicht.html?nn=3514348

Kraftfahrtbundesamt. (2019). *Changes in ownership of cars in 2019 according to selected fuel types, absolute.* Retrieved from https://www.kba.de/DE/Statistik/Produktkatalog/produkte/Fahrzeuge/fz18_nu_uebersicht.html?nn=3514348

Kraftfahrtbundesamt. (2020). *Transfer of ownership of motor vehicles and Motor vehicle trailers - monthly results.* Retrieved from https://www.kba.de/DE/Statistik/Produktkatalog/produkte/Fahrzeuge/fz18_nu_uebersicht.html?nn=3514348

Kumar, C. (2019). *Going electric: how everyone can benefit sooner.* Retrieved from the Green Alliance https://green-alliance.org.uk/going_electric_how_everyone_can_benefit_sooner.php

Lambert, F. (2018, April 14). Tesla battery degradation at less than 10% after over 160,000 miles, according to latest data. *Electrek*. Retrieved from https://electrek.co/2018/04/14/tesla-battery-degradation-data/

Lambert, F. (2020, June 12). Tesla data shows battery degradation is limited but not all packs are created equal. *Electrek*. Retrieved from https://electrek.co/2020/06/12/tesla-data-battery-degradation-limited-mileage-packs-equal/

Larsen, K. (2021). Norway electric fleet data. Personal communication.

Lopez, S. (2020). *Company cars: how European governments are subsidizing pollution and climate change*. Retrieved from Transport & Environment https://www.transportenvironment.org/discover/company-cars-how-european-governments-are-subsidising-pollution-and-climate-change/

Lusher, T. (2019). *Average electric vehicle range exceeds 200 miles*. Retrieve from Cornwall-insight https://www.cornwall-insight.com/press/average-electric-vehicle-range-exceeds-200-miles/

Lutsey, N. (2015). *Global climate change mitigation potential from a transition to electric vehicles.* Retrieved from the International Council on Clean Transportation https://theicct.org/publications/global-climate-change-mitigation-potential-transition-electric-vehicles

Lutsey, N., Cui, H., Yue, R. (2021). *Evaluating electric vehicle costs and benefits in china in the 2020–2035 time frame.* Retrieved from the International Council on Clean Transportation https://theicct.org/publications/ev-costs-benefits-china-EN-apr2021

Lutsey, N., and Nicholas, M. (2019). *Update on electric vehicle costs in the United States through 2030*. Retrieved from the International Council on Clean Transportation https://theicct.org/publications/update-US-2030-electric-vehicle-cost

A million-mile battery from China could power your electric car. (2020, June 7). *Bloomberg*. Retrieved from https://www.bloomberg.com/news/articles/2020-06-07/a-million-mile-battery-from-china-could-power-your-electric-car

Ministry of Industry and Information Technology: further strengthen the safety supervision of new energy vehicles. (2020, November 28). *People's Daily Online.* Retrieved from https://app.www.gov.cn/govdata/gov/202005/28/459059/article.html

Montoya, R. (2020). How long should a car loan be? *Edmunds*. https://www.edmunds.com/car-loan/how-long-should-my-car-loan-be.html

Muehlegger, E., Rapson, D. (2018). *Understanding the distributional impacts of vehicle policy: who buys new and used alternative vehicles?* [NCST research report].Retrieved from Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-18-10. https://itspubs.ucdavis.edu/publication_detail.php?id=2920

Mullis, M.E. (2021, April 16). Big rift about used diesel cars: goes fastest on the market now. *nettavisen.no*. Retrieved from https://www.nettavisen.no/okonomi/stor-rift-om-brukte-dieselbiler-gar-raskest-pamarkedet-na/s/12-95-3424111564

Narassimhan, E., & Johnson, C. (2018). The role of demand-side incentives and charging infrastructure on plug-in electric vehicle adoption: analysis of US states. *Environmental Research Letters*, *13*(7), 074032. https://doi.org/10.1088/1748-9326/aad0f8

National Academies of Sciences, Engineering, and medicine. (2021). *Assessment of technologies for improving light-duty vehicle fuel economy—2025-2035*. Retrieved from The National Academies Press https://doi.org/10.17226/26092

National Research Council. (2013). *Transitions to alternative vehicles and fuels*. Retrieved from The National Academies Press https://doi.org/10.17226/18264

New Jersey Department of Environmental Protection. (2021). Sales and Use of Tax Exemption. Retrieved from https://www.state.nj.us/treasury/taxation/zevnotice.shtml

New York City. (2019, March 8). Reducing maintenance costs with electric vehicles. *NYC Fleet Newsletter, Issue 255*. Retrieved from https://www1.nyc.gov/assets/dcas/downloads/pdf/fleet/NYC-Fleet-Newsletter-255-March-8-2019-Reducing-Maintenance-Costs-With-Electric-Vehicles.pdf

New York State Energy Research and Development Authority (NYSERDA). (2021a). Drive clean rebate primary statistics. Retrieved from https://www.nyserda.ny.gov/All-Programs/Programs/Drive-Clean-Rebate/Rebate-Data/Rebate-Stats

New York State Energy Research and Development Authority (NYSERDA). (2021b). Charge ready NY**.** Retrieved from https://www.nyserda.ny.gov/All%20Programs/Programs/ChargeNY/Charge%20Electric/Charging%20Station%20Programs/Charge%20Ready%20NY

Nicholas, M. (2018). *Ensuring driving on electricity is cheaper than driving on gasoline*. Retrieved from the International Council on Clean Transportation https://theicct.org/publications/ensuring-driving-on-electricity-cheaper-than-gasoline

Oak Ridge National Laboratory. (2021). *Transportation energy data book: Edition 38*. Retrieved from https://tedb.ornl.gov/data/

San Francisco Green Building and Environment Codes - Requirements for Installation of Electric Vehicle Chargers, Ordonnance No. 92-17 (2017). Retrieved from https://sfbos.org/sites/default/files/o0092-17.pdf

Oregon Department of Environmental Quality. (2021). OCVRP background and goals. Retrieved from https://www.evrebate.oregon.gov/ocvrp-background

Pacific Gas and Electric Company (PG&E). (2018). CPUC approves new PG&E projects to help accelerate electric vehicle adoption in California. https://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20180605_cpuc_approves_new_pge_projects_to_help_accelerate_electric_vehicle_adoption_in_california_

Pacific Gas and Electric Company (PG&E). (2021). Business Electric Vehicle rate plans. Retrieved from, https://www.pge.com/en_US/small-medium-business/energy-alternatives/clean-vehicles/ev-charge-network/electric-vehicle-rate-plans.page

Paszkiewicz, L. (2003). The cost and demographics of vehicle acquisition. Retrieved from the Bureau of Labor Statistics https://www.bls.gov/cex/anthology/csxanth8.pdf

Pedrosa, G., Nobre, H. (2018, January 18). Second-hand electrical vehicles: a first look at the secondary market of modern EVs. *International Journal of Electric and Hybrid Vehicles*. https://doi.org/10.1504/IJEHV.2018.097378

Plug in America. (2021a). Battery survey. Retrieved from https://survey.pluginamerica.org/

Plug in America. (2021b). PlugStar electric vehicle dealer training. Retrieved from https://survey.pluginamerica.org/

PlugNDrive. (2021). Scrappage incentive program. Retrieved from https://www.plugndrive.ca/used-electric-vehicles-scrappage/

Recurrent. (2021). *Used electric car buying report*. Retrieved from https://www.recurrentauto.com/research/used-electric-vehicle-buying-report

Reed, P. (2020). 5 reasons to lease — not buy — your electric car. *Nerdwallet*. Retrieved from https://www.nerdwallet.com/article/loans/auto-loans/5-reasons-lease-not-buy-electric-car

SK Innovations. (2020, October 22). InterBattery 2020: SK Innovation aims to be the leader in the core battery technologies of safety, charging speed, and rang. Retrieved from https://skinnonews.com/global/archives/2262

Slowik, P., Hall, D., Lutsey, N., Nicholas, M., and Wappelhorst, S. (2019). *Funding the transition funding the transition to all zero-emission vehicles.* Retrieved from the International Council on Clean Transportation https://theicct.org/publications/funding-ZEV-transition

Tiantian Pai. (2020, December14). Daily car auction data: new energy second-hand car transaction volume increased by over 84% year-on-year. Retrieved from https://m.ttpai.cn/zixun/meiti-386972

Thompson, D. (2013, September 6). The dubious future of the American car business—in 14 charts. *The Atlantic*. Retrieved from http://www.theatlantic.com/business/archive/2013/09/the-dubious-future-of-the-american-car-business-in-14-charts/279422/

Turrentine, T., Tal, G., & Rapson, D. (2018). *The Dynamics of Plug- in Electric Vehicles in the Secondary Market and Their Implications for Vehicle Demand, Durability, and Emissions*. Retrieved from UC Davis National Center for Sustainable Transportation https://ncst.ucdavis.edu/research-product/dynamics-plug-electric-vehicles-secondary-market-and-their-implications-vehicle

United Nations Economic Commission for Europe (UNECE). (2021). Electric Vehicles and the Environment. Retrieved from https://wiki.unece.org/pages/viewpage.action?pageId=2523151

U.S. Census. (1997). In and around the home: Housing profile. Retrieved from https://www.census.gov/prod/99pubs/ahb-9901.pdf

U.S. Census. (2021). Quarterly residential vacancies and homeownership, first quarter 2021. U.S. Department of Commerce. Retrieved from https://www.census.gov/housing/hvs/files/currenthvspress.pdf

U.S. Department of Energy. (2017). Fact #958: January 2, 2017 sixty-three percent of all housing units have a garage or carport. Retrieved from https://www.energy.gov/eere/vehicles/fact-958-january-2-2017-sixty-three-percent-all-housing-units-have-garage-or-carport

U.S. Department of Energy. (2021a). Fuel economy. Retrieved from https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=30979&id=32154&id=33558&id=34699

U.S. Department of Energy. (2021b). Median Driving Range of All-Electric Vehicles Tops 250 Miles for Model Year 2020. Retrieved from https://www.energy.gov/eere/vehicles/articles/fotw-1167-january-4-2021-median-driving-range-all-electric-vehicles-tops-250

Voelcker J. (2017). New life for old Nissan Leaf electric car: battery replacement and what it took. *Green Car reports.* Retrieved from https://www.greencarreports.com/news/1111264_new-life-for-old-nissan-leaf-electric-car-battery-replacement-and-what-it-took

Wappelhorst, S. (2021a). The role of the used car market in accelerating equal access to electric vehicles (blog post). Retrieved from the International Council on Clean Transportation https://theicct.org/blog/staff/used-EVs-equal-access-apr2021

Wappelhorst, S. (2021b). *Update on government targets for phasing out new sales of internal combustion engine passenger cars*. Retrieved from the International Council on Clean Transportation https://theicct.org/publications/update-govt-targets-ice-phaseouts-jun2021

Washington Department of Revenue. (2021). Clean alternative fuel and plug-in hybrid vehicles sales/use tax exemptions. Retrieved from https://dor.wa.gov/content/clean-alternative-fuel-and-plug-hybrid-vehicles-salesuse-tax-exemptions

Wee, S., Coffman, M., & Allen, S. (2020). EV driver characteristics: Evidence from Hawaii. *Transport Policy*, *87*, 33–40. https://doi.org/10.1016/j.tranpol.2019.12.006

Wernle, B. (2015). Car buyers getting older, richer, NADA economist says. *Automotive News*. Retrieved from https://www.autonews.com/article/20150804/RETAIL03/150809938/car-buyers-getting-older-richer-nada-economist-says.

Yang, Z., Slowik, P., Lutsey, P., and Searle, S. (2016). *Principles for effective electric vehicle incentive design.* Retrieved from the International Council on Clean Transportation https://theicct.org/publications/principles-effective-electric-vehicle-incentive-design

Yiche. (2020). *Analysis of China's car value retention rate in 2020 SUV models are indeed more valuable*. Retrieved from https://news.yiche.com/duochedaogou/20210122/1813652291.html