WORKING PAPER 2022-01

JANUARY 2022

Cost of electric commercial vans and pickup trucks in the United States through 2040

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Keywords: Total cost of ownership, parity, electric vehicles, pickup trucks, vans

Introduction

This paper presents a total cost of ownership assessment of battery-electric Class 2b and 3 commercial vehicles between 2020 and 2040 benchmarked against the corresponding costs of gasoline and diesel powertrains. Class 2b and 3 vehicles, defined as commercial vehicles with a gross vehicle weight rating of 8,500 lbs–14,000 lbs,[1] make up the largest portion of the commercial vehicle fleet in the United States. This vehicle class, comprised largely of vans and pickup trucks, accounts for over two-thirds of registered commercial vehicles, and roughly one quarter of diesel and gasoline consumed across all commercial vehicle classes (U.S. Energy Information Administration, 2021).

While the current market for zero emission commercial vehicles is nascent, there has been growing interest in the deployment of electric Class 2b and 3 vehicles from both the supply and demand side. Several major original equipment manufacturers (OEM), alongside numerous startups, have announced plans to introduce several electric pickup truck and van models in the coming years (see Figure 1). Consumer interest in the electric market for pickup trucks and vans is also clear—as of September 2021, over 130,000 preorders have been made for the Ford F-150 Lightning electric pickup truck five months after its announcement in May 2021 (Joey Klender, 2021). Amazon also ordered 100,000 electric delivery vans from Rivian in 2019, which are intended to be in operation by 2024 (Hawkins, 2019). In comparison, just 120 electric commercial trucks across all weight classes were registered in the United States in 2020 (Sharpe et al., 2020; Sharpe & Buysse, 2021).

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[1] Class 2b vehicles have a gross vehicle weight rating of 8,500-10,000 lbs, Class 3 have a gross vehicle weight rating of 10,000-14,000 lbs.

Acknowledgements: With thanks to Simon Mui (Natural Resources Defense Council), Rick Rykowski and Chet France (Environmental Defense Fund), and Dave Cooke (Union of Concerned Scientists) for their useful comments to this analysis. Also, a special thanks to Nic Lutsey (General Motors), and Ben Sharpe, Felipe Rodríguez, and Dale Hall from the ICCT for their guidance and constructive comments.

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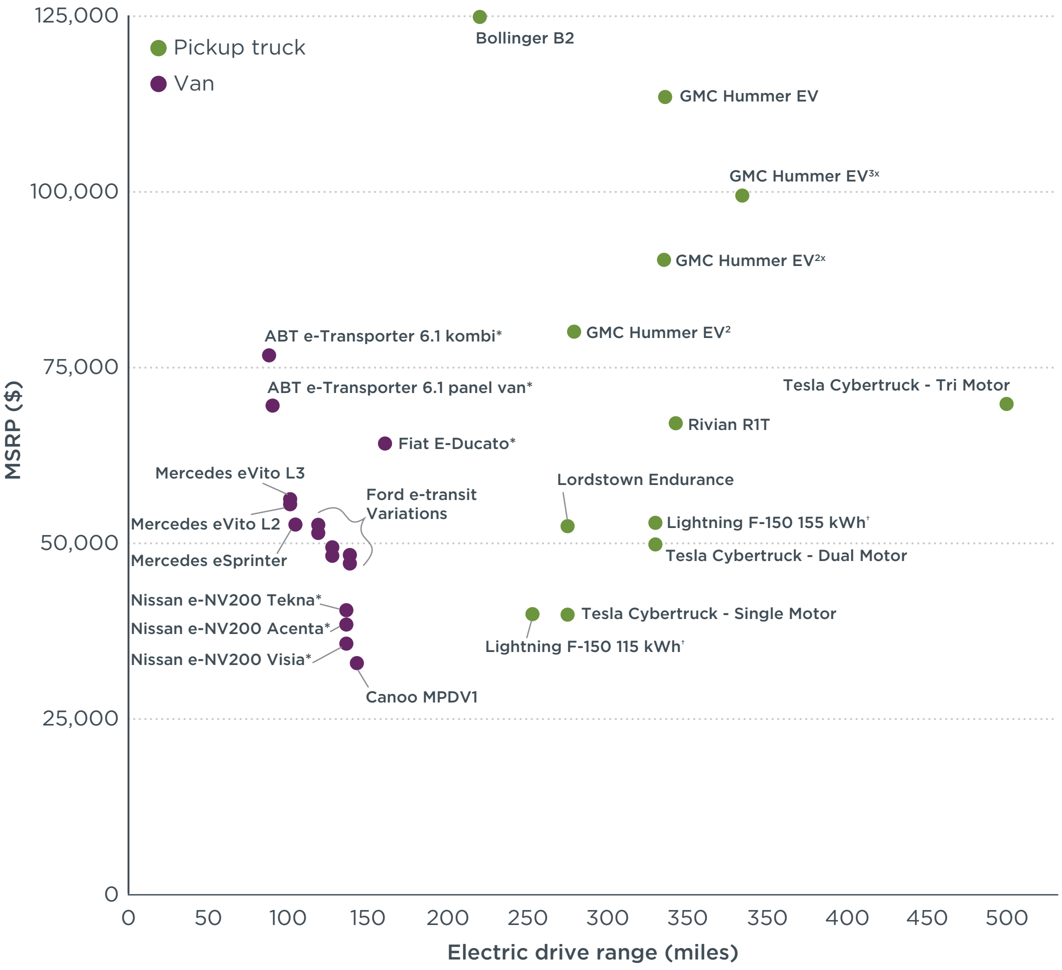

Figure 1. Manufacturer suggested retail price (MSRP) for battery-electric Class 2b and 3 vehicles and corresponding electric drive ranges based on manufacturer announcements. The figure excludes electric pickup trucks and vans where no information was available on either price or electric drive range. The list of sources are available in the Appendix of this paper.

* Vehicles which have not been announced for sale in the United States but are available in the European Union or the United Kingdom. MSRP for these vehicles are thus based on European prices and converted to dollars using the exchange rates of 1 EUR = 1.16 USD and 1 GBP = 1.36 USD.

† The Lightning F-150 has a reported unladen weight of 6,500 lbs and a planned payload capacity of 2,000 lbs, resulting in a potential gross vehicle weight rating of 8,500 lbs. If the final payload capacity is any lower than this, it may be classified as a light-duty vehicle.

The growing commercialization of electric Class 2b and 3 vehicles indicate that a shift toward zero emission battery-electric technology for pickup trucks and vans is under way. The use profile and daily range puts commercial pickup trucks and vans in a prime position for this technology transition. In California, the daily activity of Class 2b and 3 vehicles has been reported to average 61.7 miles with an upper threshold of 250 miles (Brown et al., 2021). A study looking at driving trends of 94 delivery vans conducted by the National Renewable Energy Laboratory corroborated these findings with 90% of daily driving distance below 100 miles with a maximum of 260 miles (Wlakowicz et al., 2014). Forrest et al. (2020) found that with sufficient access to level II chargers, 72%–97% of all vehicle miles travelled of Class 2b and 3 vehicles could be met with a battery electric powertrain with an electric range between 100 and 200 miles. A recent survey by the North American Council for Freight Efficiency (NACFE) found that 98% of Class 3 vehicles had a daily range below 150 miles (NACFE, 2018)

However, the speed of uptake is tailored, in part, by the economic viability of the technology relative to conventional vehicles. Battery and additional electrical component costs render a comparatively high price relative to conventional internal combustion engine (ICE) pickup trucks and vans which have an average manufacturer suggested retail price (MSRP) of $41,000 and $47,000 respectively (Price Digests, 2021).[2] However higher drivetrain efficiency in an electric vehicle results in lower fuel costs alongside maintenance cost reductions as low as 40% (Burnham et al., 2021) which contribute to lowering the total cost of ownership.

To assist in understanding the state of the market and its expected evolution, this paper analyzes the projected cost of battery-electric and plug-in hybrid electric Class 2b and 3 vehicles in the United States, focusing on the estimated year in which both purchase price and total cost of ownership (TCO) parity is achieved relative to their gasoline and diesel counterparts. We conduct a bottom-up cost component analysis with particular focus on the battery prices alongside other electric propulsion systems.

While cost remains an important factor in determining the uptake of electric vehicles, there are several additional factors influencing consumers' decision-making, including model availability, recharging infrastructure, range anxiety, environmental concerns, brand loyalty, and vehicle comfort. As such, attractive TCO economics and purchase price parity are only a subset of the phenomena impacting the rate at which society transitions to zero-emission vehicles, and should not be relied on as the sole indicator of significant market uptake.

The remainder of this work is structured as follows: first we introduce the key assumptions surrounding the fixed and variable costs of combustion engine and battery electric pickup trucks and vans. We then present our cost projections through 2040 of purchase price and TCO, identifying the year of parity where applicable. We then introduce a discussion surrounding the sensitivity analysis applied to our model estimates. Finally, we conclude with some key messages of our work.

Vehicle cost analysis

In this analysis, we separate Class 2b and 3 vehicles into two categories—vans and pickup trucks. This distinction is made primarily as pickup trucks and vans are both configured very differently and often have different use profiles which has a significant bearing on costs. ICE vehicles are disaggregated by fuel type—gasoline and diesel—to account for differing engine, aftertreatment, and fuel costs.

This study assesses battery-electric vehicle (BEV) types with four milage ranges: 100-miles (BEV100), 200-miles (BEV200), 300-miles (BEV300), and 400-miles (BEV400). This variety of electric drive ranges covers the majority of upcoming pickup truck and vans shown in Figure 1. As discussed above, the majority of daily driving distances of Class 2b and 3 vehicles fall under 200 miles. Thus, while a BEV200 would cover most daily drive ranges, we still explore the cost potential of higher ranging vehicles to align with the upcoming Class 2b and 3 electric vehicles. Plug-in hybrid electric vehicles (PHEVs) are split by gasoline and diesel and are assumed to have a 50-mile all-electric range (PHEV50). Both the vehicle's TCO and purchase price are

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[2] All monetary values reported in this paper are adjusted for inflation and presented in terms of constant 2020 U.S. dollars.

analyzed over the period of the vehicle's first owner, which is assumed to be five years for all vehicle types, based off stakeholder information derived from Birky et al. (2017).[3]

Internal combustion engine vehicle cost components

Vehicle prices for gasoline and diesel vehicles, excluding PHEVs, are calibrated to the manufacturer's suggested retail price (MSRP) averaged across over 1,200 models of Class 2b and 3 vehicles from the Truck Blue Book (Price Digests, 2021). A histogram of the costs in $5,000 price bins is shown in Figure 2. There is a range in prices across these vehicles based on characteristics such as axle configuration, engine size and power, fuel type, transmission, gross vehicle weight rating (GVWR), brand, and cab type. In the figure we limit our grouping to fuel and vehicle type to represent average vehicle MSRP across these categories.

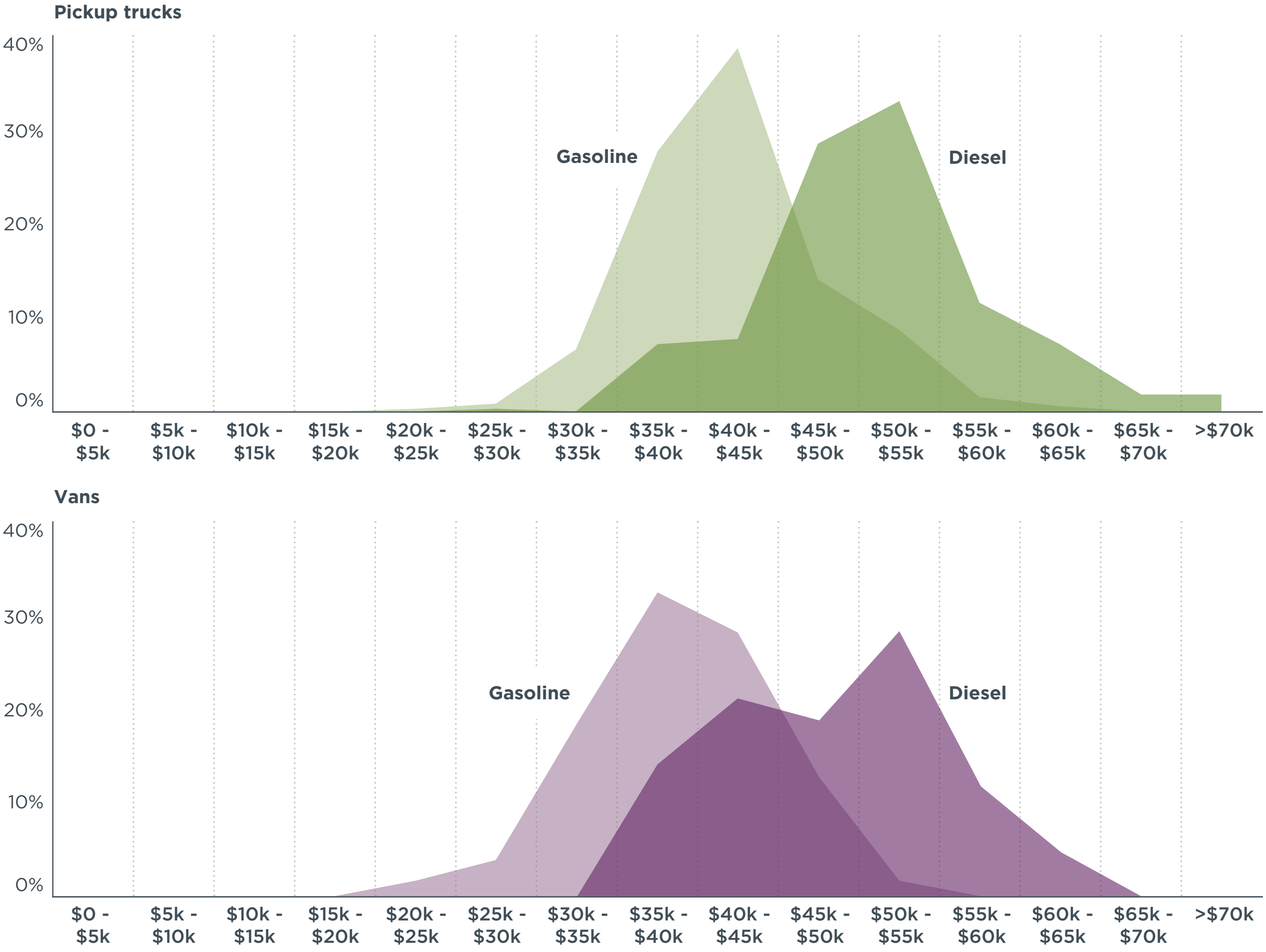

Figure 2. Share of 2020 gasoline and diesel Class 2b and 3 vehicles across MSRP bins in $5k increments. Source: (Price Digests, 2021).

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[3] We are unaware of any literature that suggests that EVs are owned by their first owner for a different period of time compared to their gasoline and diesel counterparts.

The average MSRP for a 2020 model van is $38,700 with a gasoline powertrain and $48,600 for a diesel powertrain. Gasoline and diesel pickup trucks average $42,100 and $51,300, respectively, and on average, pickup trucks are 7.5% more expensive than vans.

ICE powertrains are split into three cost components—engine, transmission, and aftertreatment system—based on data from the National Highway Traffic Safety Administration Compliance and Effects Modeling System (EPA & NHTSA, 2016). These values represent the average characteristics of the respective Class 2b and 3 technologies weighted by 2016 sales, the last year that detailed data was available. Powertrain costs are calculated by accounting for different engine configurations, including the number of cylinders, the presence of a turbocharger, and additional technologies such as variable valve timing. Transmission costs are calculated by weighting the average numbers of gears and whether the transmission is automatic or manual.

Because of their lean burn and variable air-to-fuel ratio over their operating map, diesel engines require a very different and more expensive emission control aftertreatment systems than stoichiometric gasoline engines. Before 2010, nitrogen oxide (NO_x) emissions control approaches for diesel engines mostly relied on in-cylinder NO_x reduction. Since then, manufacturers have transitioned to the synergistic integration of engine and fuel combustion advancements, as well as the introduction of aftertreatment systems for controlling NO_x emissions. The use of selective catalytic reduction (SCR) on medium- and heavy-duty diesel engines became widespread in 2010 to meet the U.S. Environmental Protection Agency (EPA) regulatory requirements. NO_x emissions are also reduced through approaches such as retarded injection timing, multiple injection events and injection rate shaping, exhaust gas recirculation (EGR), charge air cooling, alternative combustion modes, cylinder deactivation, and better thermal management of aftertreatment costs. In addition, modern diesel powertrains limit particulate matter emissions using a diesel particulate filter (DPF), and a diesel oxidation catalyst (DOC) is also typically used to control other pollutant emissions. Aftertreatment systems are less complex for gasoline engines, which can largely meet emission standards using a three-way catalyst (TWC) that oxidizes hydrocarbon and carbon monoxide emissions and reduces NO_x.

We price aftertreatment costs based on a previous ICCT assessment (Posada et al., 2012). For gasoline vehicles we assume a TWC, an on-board oxygen sensor, and multi-point fuel injection. For diesel engines we assume a technology combination of DOC, DPF, and SCR. To update these values to the current state-of-the-art, we applied a learning curve consistent with U.S. EPA (2010), reducing diesel aftertreatment costs 10% by 2020 from 2011 values derived from the ICCT analysis, arriving at a cost of $2,906 per vehicle in 2020. Gasoline aftertreatment technologies have already reached maturity and so we do not assume any further cost reductions beyond the values derived from Posada et al. (2012) of $794 per vehicle.

Indirect costs, which are all of the costs associated with the production of the vehicle excluding the direct costs, such as research and development, marketing, building premises costs, salaries, and profit margins, are derived from the Regulatory Impact Assessment from the U.S. EPA and the U.S. Department of Transportation (DOT) (EPA & DOT, 2016). This impact assessment set indirect costs of low complexity vehicles in the near term (2020) as 24% and in the long term (2030) as 19%. Assembly costs covering the manufacturing and assembly of the chassis are calibrated in such a way that the final price of the vehicle equates to current market values, depicted in Figure 2. Vehicle tax was set at a national average of 7% (DOT, 2018).

The operational characteristics of ICE vehicles were collected from various sources to perform TCO calculations. Baseline (i.e., 2020) vehicle fuel economy and mileage also come from U.S. EPA and U.S. DOT (2016), and includes a mileage degradation factor to account for the steady decrease in usage as the vehicle ages. Mileage is assumed equal across vans and pickup trucks at an annual rate of 21,600 miles in the first year and average reductions of 7% per year. Fuel efficiency improvements are assumed to be 2.5% per year, which is required to comply with the current Phase 2 fuel efficiency and greenhouse gas regulation for heavy-duty vehicles. This corresponds to a 16% overall reduction between model years 2021 and 2027. The costs associated with the fuel-saving technologies necessary to meet these efficiency improvements are also sourced from the U.S. EPA and U.S. DOT Regulatory Impact Assessment (EPA & DOT, 2016).

For gasoline and diesel pump prices, we used the reference case fuel price projection from the U.S. Energy Information Administration's Annual Energy Outlook (U.S. Energy Information Administration, 2021). The high oil price and low oil price scenarios marked the bounds of our sensitivity analysis discussed later. Future fuel prices are discounted using a constant rate of 5% for each year beyond the purchase year.

Maintenance costs are based on a collection of manufacturer's recommended maintenance schedules for 22 various Class 2b and 3 vehicles over 10 years (Car Edge, 2021) and divided by the assumed mileage to yield a $/mile maintenance value. The assumed maintenance costs are $0.135/mile for pickup trucks and $0.128/mile for vans. Insurance costs are assumed at a monthly cost of $2 per $1,000 of the vehicle's value.

Electric vehicle cost components

A key element for a cost comparison between ICE vehicles and electric vehicles (EVs) lies in the representation of the battery costs, making up a significant proportion of the total purchase price. In the light-duty vehicle (LDV) market, for example, battery costs comprised between 25% and 50% of total vehicle manufacturing costs in 2018, dependent on vehicle class and range (Lutsey & Nicholas, 2019).

To determine the battery pack size for each of our EV vehicle classes, we first estimated the EV efficiency in terms of kWh/mile based on the battery size and electric drive ranges derived from existing vehicle models and OEM announcements.[4] The battery pack size was then determined through the product of the efficiency and the electric range of each vehicle class. We assume a decreasing pack-to-cell ratio with increasing battery pack energy capacity, resulting in lower per-kilowatt-hour costs for larger battery packs.

The real price of lithium-ion battery cells today has declined by 97% since their initial commercialization in 1991 (S. Ziegler & E. Trancik, 2021). This reduction in costs has outpaced previous projections; for example, a detailed collection of published forecasts compiled in 2015 by Nykvist and Nilsson (2015) projected the cost of lithium-ion battery packs for use in battery electric vehicles to fall within the range of $200/kWh to 450/kWh by 2020. Our literature review of current battery costs placed the actual value to be in the range of $100/kWh to 200/kWh in 2020.

A summary of these battery costs derived from several recent technical studies and automaker statements is shown in Figure 3. This review compiles sources that assume various battery chemistries and compositions and is limited to studies that have taken

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[4] A full list of these efficiencies is available in the Appendix.

place in the last five years to present a state-of-the-art assessment. The methods of projection used in each of the technical studies included apply a variety of different cost projection approaches. The most common approach forecasts values based on one learning factor, such as cumulative or annual battery sales, battery production, installed capacity, and patents. Some studies also apply a multi-factor approach whereby price reductions are derived based multiple learning factors.

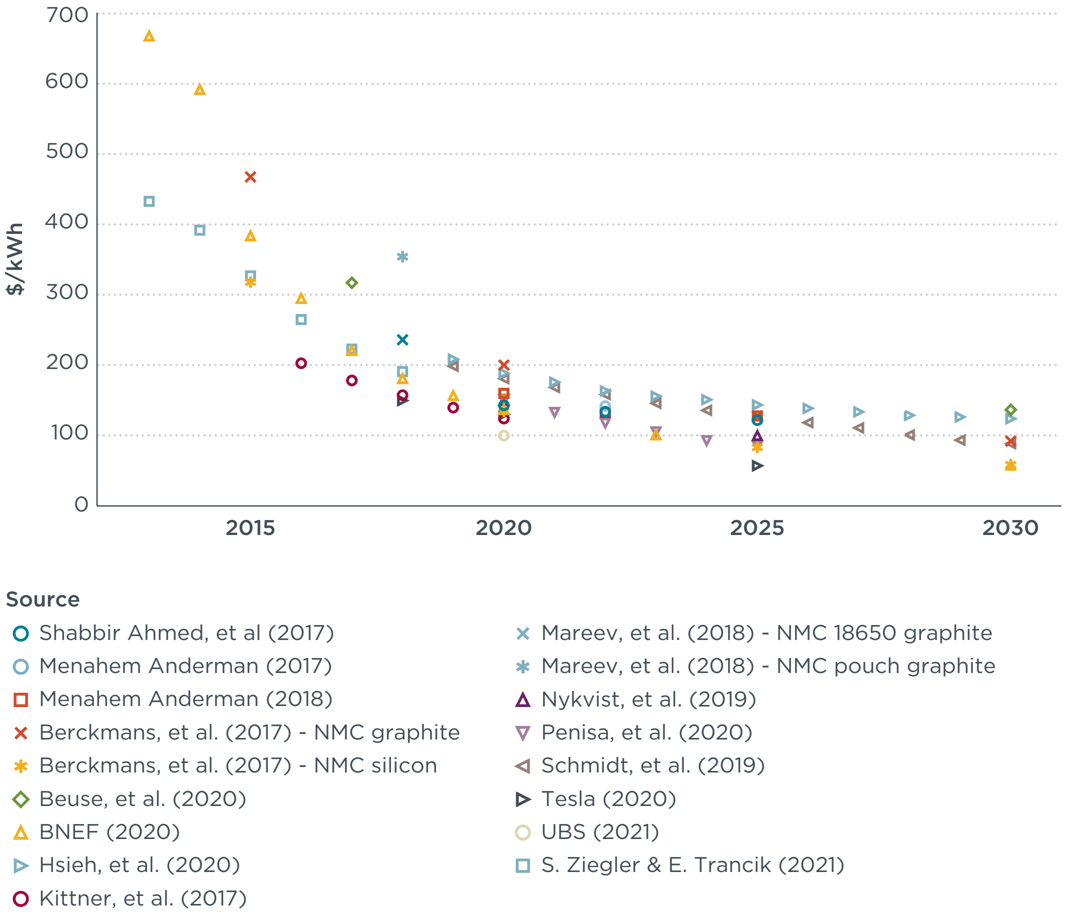


Figure 3. Battery pack cost estimates by various industry and academic sources.

We used our literature review to guide our cost assessment for lithium-ion batteries, applying the averaged cost projections for 2025 and 2030 to form our central scenario and applying the maximum and minimum values to our sensitivity analysis. Based on this review, we apply an average battery price of $118/kWh in 2025 and $93/kWh in 2030. Few studies had a scope extending beyond 2030, so we applied the learning curves developed by Mauler et al. (2021) averaging an annual 3.5% price reduction in the period 2030–2035 and 3% reduction for 2035–2040. Table 2 provides a full list of battery pack specifications and cost assumptions used in the analysis.

Table 2. BEV and PHEV technical characteristics.

		Efficiency (kWh/mile)			Battery pack size (kWh)			Battery pack cost ($/kWh)		
		2020	2030	2040	2020	2030	2040	2020	2030	2040
Van	**BEV100**	0.37	0.35	0.32	37	35	32	164 [106-232]	99 [62-146]	72 [45-105]
	BEV200	0.38	0.35	0.33	76	71	66	150 [97-212]	91 [57-134]	66 [41-97]
	BEV300	0.39	0.36	0.34	116	108	102	142 [92-201]	86 [54-127]	62 [39-91]
	BEV400	0.39	0.37	0.35	157	148	138	142 [92-201]	85 [53-126]	61 [38-90]
	PHEV50 Gas	0.37	0.35	0.32	19	17	16	177 [115-250]	107 [67-158]	77 [48-113]
	PHEV50 Diesel	0.37	0.35	0.32	19	17	16	177 [115-250]	107 [67-158]	77 [48-113]
Pickup truck	**BEV100**	0.46	0.43	0.40	46	43	40	160 [103-226]	97 [60-142]	70 [44-103]
	BEV200	0.46	0.43	0.41	93	87	81	146 [95-207]	89 [55-130]	64 [40-94]
	BEV300	0.47	0.44	0.41	141	132	124	142 [92-201]	85 [53-126]	61 [38-90]
	BEV400	0.48	0.45	0.42	191	179	167	142 [92-201]	85 [53-126]	61 [38-90]
	PHEV50 Gas	0.45	0.42	0.40	23	21	20	173 [112-245]	105 [65-154]	76 [47-111]
	PHEV50 Diesel	0.45	0.42	0.40	23	21	20	173 [112-245]	105 [65-154]	76 [47-111]

Note: Values in brackets under battery pack cost define the lower and upper bounds of the cost ranges used in this analysis based on the literature review presented in Figure 3.

For power electronics other than the battery, little information is available due to the low presence of electric Class 2b and 3 vehicles currently on the market. To address this data gap, we use the UBS teardown of a Chevrolet Bolt (UBS, 2017) to quantify the $/kW of each of the power electronics components. These values are scaled by the average power of vans (198 kW) and pickup trucks (291 kW), which is derived from the Compliance and Effects Modeling System (U.S. EPA & NHTSA, 2016). Assumed cost reduction by 2025 relative to 2017 is also derived from the UBS teardown analysis for each non-battery component, linearly interpolating for interim years. The resulting costs are presented in Table 3.

Table 3. Power electronics systems costs for vans and pickup trucks used in this analysis

	2017		2025	
	Van	Pickup truck	Van	Pickup truck
Thermal management	$348	$513	$313	$461
Power distribution module	$348	$513	$411	$605
Inverter	$970	$1,429	$654	$886
Electric drive module	$1,671	$2,460	$1,039	$1,530
DC converter	$209	$308	$187	$275
Controller	$71	$105	$64	$94
Control module	$129	$191	$117	$172
High voltage cables	$466	$687	$420	$619
On-board charger	$380	$560	$285	$420
Charging cord	$209	$308	$188	$277
Total	**$5,070**	**$7,466**	**$3,885**	**$5,637**

Indirect vehicle costs are derived from the Regulatory Impact Assessment from the U.S. EPA and U.S. DOT (EPA & DOT, 2016). We apply an indirect cost multiplier with a medium level of complexity in the near-term (2020) of 39%, indicating that some level of R&D is still required for battery-electric technologies. This indirect cost multiplier is linearly interpolated gradually out to 2030 to align with the long-term complexity factor assigned of 29% as the adoption of EVs becomes more widespread and less R&D investment is required. The cost elements of tax, insurance, and vehicle assembly are not impacted by the powertrain and thus follow the same calculation process as for ICE vehicles.

Utility factors, which estimate the ratio of mileage driven in an EV relative to a comparable conventional vehicle, are derived using the methodology developed by Bradley and Quinn, (2010) who derived normative utility functions based on results from of driving habits derived from the National Household Transportation Survey. Applying their methods yield utility factors of 0.87 for a BEV100, 0.95 for a BEV200, 0.98 for a BEV300, 0.98 for a BEV400, and 0.69 for a PHEV50. This means, for example, that a BEV100 will have sufficient range to cover 87% of daily driving ranges of Class 2b and 3 vehicles. To compensate for the miles that these vehicles are unable to cover, we assume a conventional fueled vehicle will be deployed to account for the shortfall, applying the overall $/mile value determined from the ICE portion of this model to the annual vehicle miles travelled (VMT) unable to be covered by electric vehicles.

Maintenance and repair costs are generally lower for BEVs due to costs associated with engine oil replacement and maintenance of the exhaust and emissions control systems, amongst others. Detailed analysis of the LDV market in Germany suggests that the maintenance of BEVs are approximately 20% lower on a per km basis (Propfe et al., 2012). A teardown conducted by UBS put maintenance costs of electric vehicles at 40%–60% lower than conventional ICE vehicles (UBS, 2017). However, very little information is available on the maintenance cost disparity between electric and conventional Class 2b and 3 vehicles. Reports from DHL in Germany put the savings for urban freight in the range of 20%–30%. (Taefi et al., 2016). In the United States, comments from electric truck OEMs in response to a drayage truck manufacturer survey reported a 50% disparity in maintenance costs relative to diesel counterparts, although little real-world evidence is available to confirm this. In addition, the duty cycles and maintenance schedules of heavy freight trucks are significantly different in Class 2b and 3 vehicles (Patrick Couch et al., 2018). We apply the same per mile cost disparity as Argonne National Laboratory's Comprehensive Total Cost of Ownership model (Burnham et al., 2021), which applies a 40% difference for commercial freight vehicles relative to ICE vehicles.

Electricity prices projections were derived from the Annual Energy Outlook (U.S. Energy Information Administration, 2021) applying the reference case for our base scenario. Finally, we assume a one-to-two ratio of chargers to vehicles and that the cost of a high-power level II charger plus installation is $3,000. As with conventional fuels, future fuel prices are discounted using a constant rate of 5% for each year beyond the purchase year.

Purchase price analysis

Figure 4 presents the individual vehicle cost components addressed in this study across each technology area for 2020, 2030, and 2040. Current BEV prices for vans range from $47,000–$68,000 across 100–400-mile ranges, and $54,000–$80,000 for pickup trucks. In comparison, the current cost of a gasoline and diesel van, including tax, is $45,000 and $56,000, respectively, and the cost of a gasoline and diesel pickup truck is $49,000–$60,000, respectively.

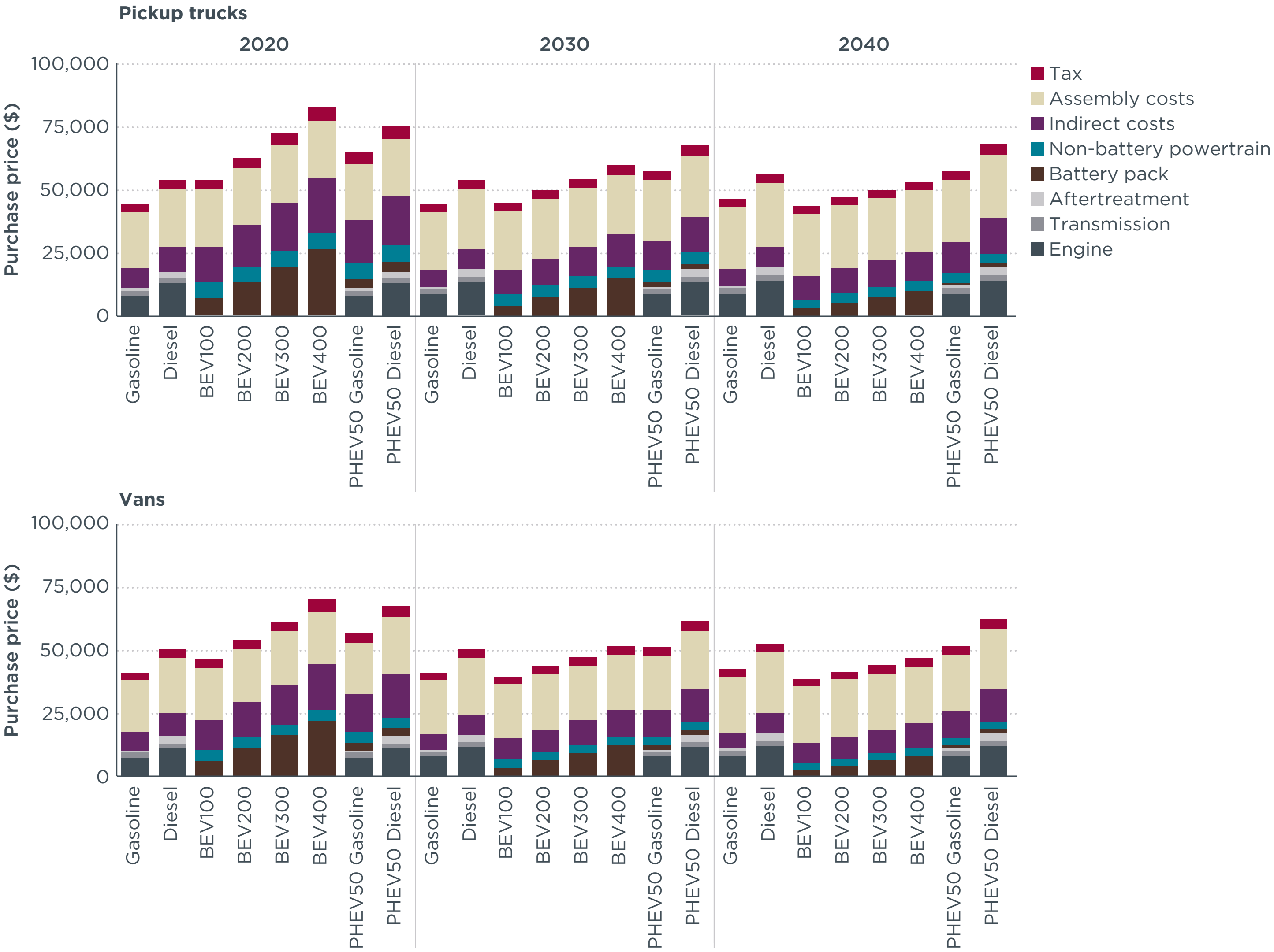


Figure 4. Vehicle cost by technology and component in 2020, 2030, and 2040.

Electric powertrain costs currently comprise between 23% and 41% of total vehicle manufacturing costs for BEVs, with a higher share for larger battery sizes. Reductions in battery costs drive down this share to 19%–38% by 2030 and 15%–30% by 2040. In comparison, powertrain costs for the internal combustion engine are 26% of total vehicle manufacturing costs for a gasoline vehicle, and 34% for a diesel vehicle.

Largely driven by continued reductions in battery prices, vehicle price reductions through 2040 are greatest for long-range vehicles with larger battery packs due to electric powertrain accounting for higher proportional costs. Vans and pickup trucks with a 400-mile range experience a drop in prices of 27% and 29% by 2040 relative to 2020, while for 200-mile models the reductions are reduced to 20% and 22%, respectively. Price reductions for PHEVs are less significant due to smaller-sized batteries, which do not benefit much from reduced battery costs, and range from 9%–12% over the same period. Due to the additional costs from technology improvements required to comply with current and future fuel economy and pollutant emission standards, conventional ICE vehicles increase in price by 4.5% by 2040 relative to 2020.

Figure 5 shows the year of purchase price parity for each technology. All full BEVs achieve parity with diesel pickup trucks and vans by 2036. This is not the case for gasoline powertrains, as the rate of BEV and PHEV purchase price reductions is slowed post-2030. This is due to limitations in the overall potential reduction in battery-electric prices linked with a stabilizing of the indirect costs for BEVs as the additional need for R&D reduces in parallel with general market adoption. The point of purchase price parity between BEVs and gasoline hits 10–15 years later than diesel. The larger power ratings and a generally greater gross vehicle weight rating of pickup trucks adds to vehicle cost due to the requirement of larger batteries to enable roughly the same range as BEV van counterparts.

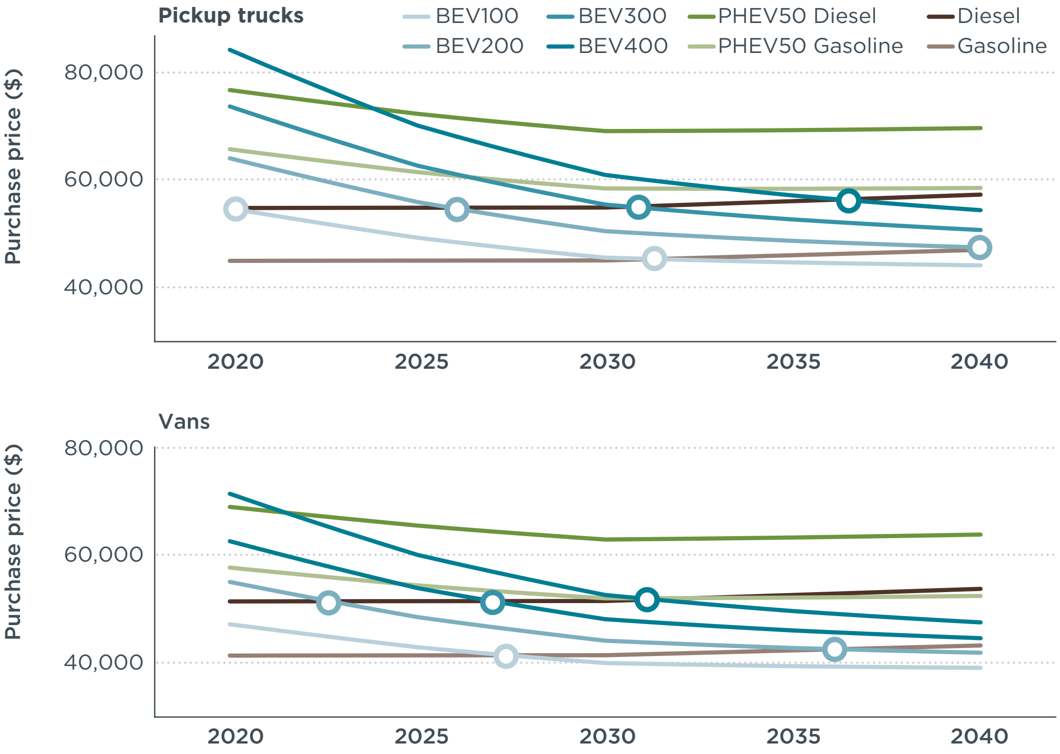


Figure 5. Purchase price parity by vehicle technology. Points denote the year of crossover between BEV and ICE technologies.

A feasibility analysis from Forrest (2019) finds that with access to sufficient charging infrastructure, over 95% of Class 2b and 3 ICE vehicles could be replaced with a battery electric powertrain with an electric range of 200 miles. As such, focusing on the 200-mile range classes, purchase price parity with the relatively more expensive diesel powertrain for vans and pickup trucks is expected in 2023 and 2026, respectively. Through continued expected battery and electrical component cost reductions in the next decade, purchase price parity with gasoline vehicles is achieved 13 years later for vans, in 2036, and 14 years later for pickup trucks, in 2040.

Purchase prices of PHEVs fail to achieve parity with their conventional counterparts before 2040. The reason behind the slow convergence with purchase price parity of PHEVs is two-fold. The battery cost component of a PHEV is relatively small compared to a BEV, and the significant battery cost reductions enjoyed by BEVs is much smaller for PHEVs. Furthermore, in addition to the costs of battery packs and power electronics, PHEVs also bear the costs of the internal combustion engines and emissions aftertreatment systems.

Total cost of ownership analysis

Vehicle choice is not determined by purchase price alone, and considerations are given to the total operating costs, which are generally lower for BEVs compared to their ICE counterparts due to lower maintenance, higher overall powertrain efficiencies, and lower fuel costs. We calculate the total cost of ownership (TCO) of each technology by combining vehicle costs, presented in Figure 4, with operating costs and evaluating through the lifetime of the first owner, assumed to be five years. Fleet operators who renew their fleets less often than this, such as is seen with government owned fleets (Birky et al., 2017), would see an earlier point of TCO parity, and vice-versa for shorter lifetime periods. The combination of these costs are presented in Figure 6 and the years of TCO parity are shown in Figure 7.

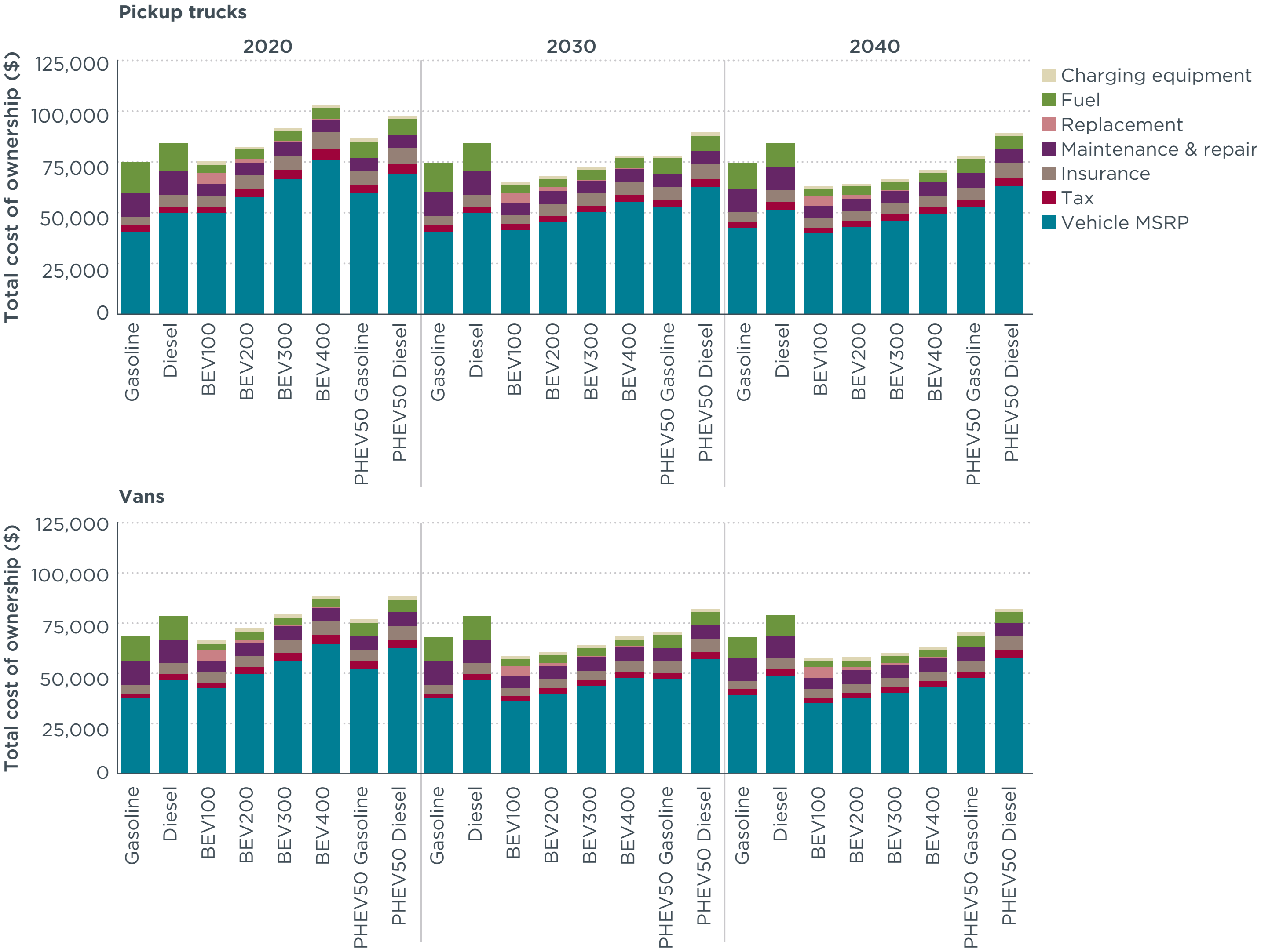
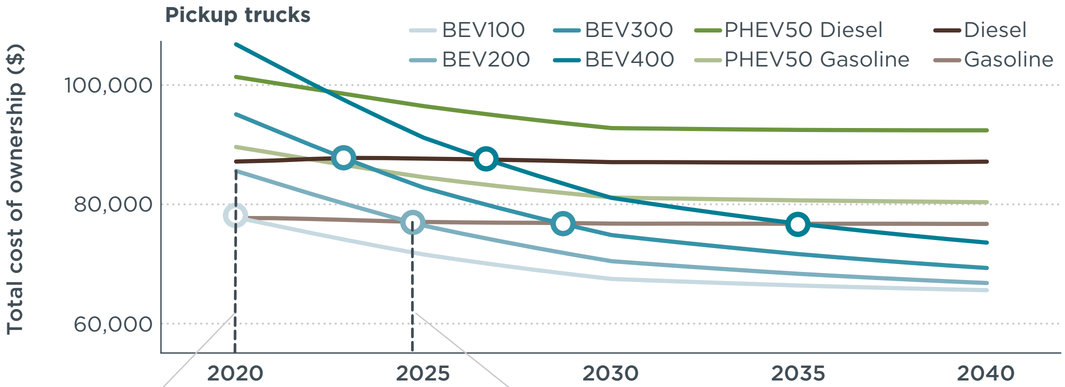
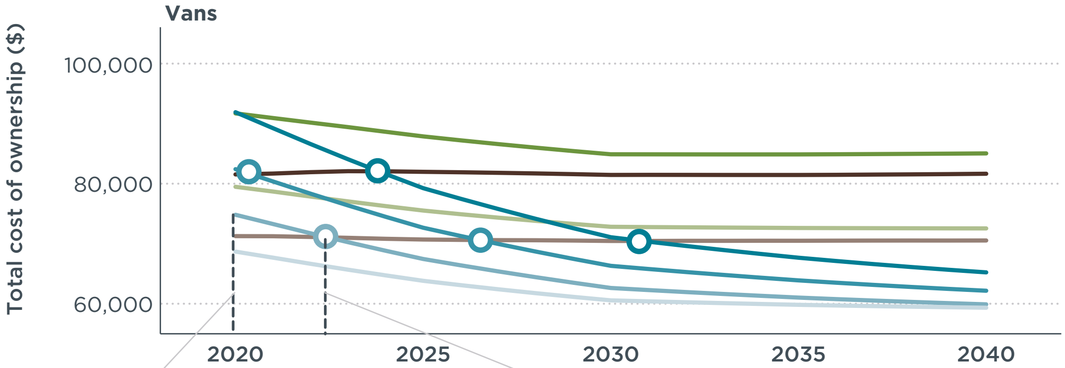


Figure 6. Total cost of ownership by technology, including running costs, in 2020, 2030, and 2040



It's already cheaper to own a 200-mile range electric pickup truck than a diesel version

...and by 2025 it'll be cheaper than a gasoline version



It's already cheaper to own a 200-mile range electric van than a diesel version

...and by 2023 it'll be cheaper than a gasoline version

Figure 7. Total cost of ownership parity by vehicle technology. Points denote the year of crossover between BEV and ICE technologies.

For conventional vehicles, cost reductions due to vehicle efficiency improvements are almost completely offset by increases in overall vehicle manufacturing costs. As such, the TCO for conventional diesels over the 2020–2040 timeframe remain constant for both vans and pickup trucks, and reduce by 1% for gasoline powertrains. BEVs experience significant TCO reductions over the same time frame, largely driven by vehicle up-front cost reductions, which decrease by 14%–16% for 100-mile range vehicles and 29%–31% for 400-mile range vehicles.

Calculated fuel costs for ICE vehicles over the five-year ownership period range between $12,800 and $15,900 in 2020. Total annual fuel costs are relatively lower in diesel powertrains than gasoline despite higher diesel fuel prices as diesel powertrains have between 20% and 23% higher fuel efficiency than their gasoline counterpart across vans and pickup trucks. The fuel costs for BEVs is significantly lower, ranging from $3,500 to $5,200 per year. As such, the annual fuel costs for ICE Class 2b and 3 vehicles are roughly three times more expensive than that of BEVs. Total maintenance for ICE vehicles is in the range of $11,700–$12,300 over the five-year ownership period, while BEV technologies amount to $6,100–$6,900. However, BEVs are faced with additional costs not relevant to ICEs, such as replacement miles for cases where low mileages cannot sufficiently achieve the desired driving range of a conventional vehicle (accounted for through the utility function described above) and charging equipment costs which include installation.

The lower operating costs of BEVs relative to their ICE counterparts result in TCO parity of all vehicle classes achieved in the 2020–2040 timeframe, with the exception of PHEVs. Notably, all BEVs achieve TCO parity by 2035. The BEV200, which was shown above to be feasible in replacing over 95% all ICE Class 2b and 3 vehicles, is already cheaper to own over a five-year period than a diesel van and pickup truck. The year of TCO parity of the BEV200 with the relatively cheaper gasoline powertrain is achieved by 2023 for vans and by 2025 for pickup trucks. Thus, within the next five years, it will be feasible and more cost effective to own a Class 2b or 3 BEV than a gasoline or diesel powertrain vehicle.

As with purchase price parity, the high costs of having a dual-technology powertrain prevent PHEVs from reaching TCO parity with their fossil fuel equivalent—i.e., the PHEV50 Gasoline vehicle never achieves TCO parity with the gasoline category.

Payback periods

Fleet operators may adopt a technology before TCO parity is reached if that technology can provide a return on investment in a timeframe that is economically attractive. In this context, payback period is the amount of time that it takes a technology's fuel savings to offset the additional expenses associated with purchasing that technology. A survey of stakeholders related to Class 2b and 3 vehicles found acceptable payback to be between three and five years (Birky et al., 2017).

Figure 8 shows the payback period for BEVs and PHEVs compared to the average cost of a conventional diesel or gasoline van or pickup truck. PHEVs are only compared to the corresponding fossil fuel powertrain.

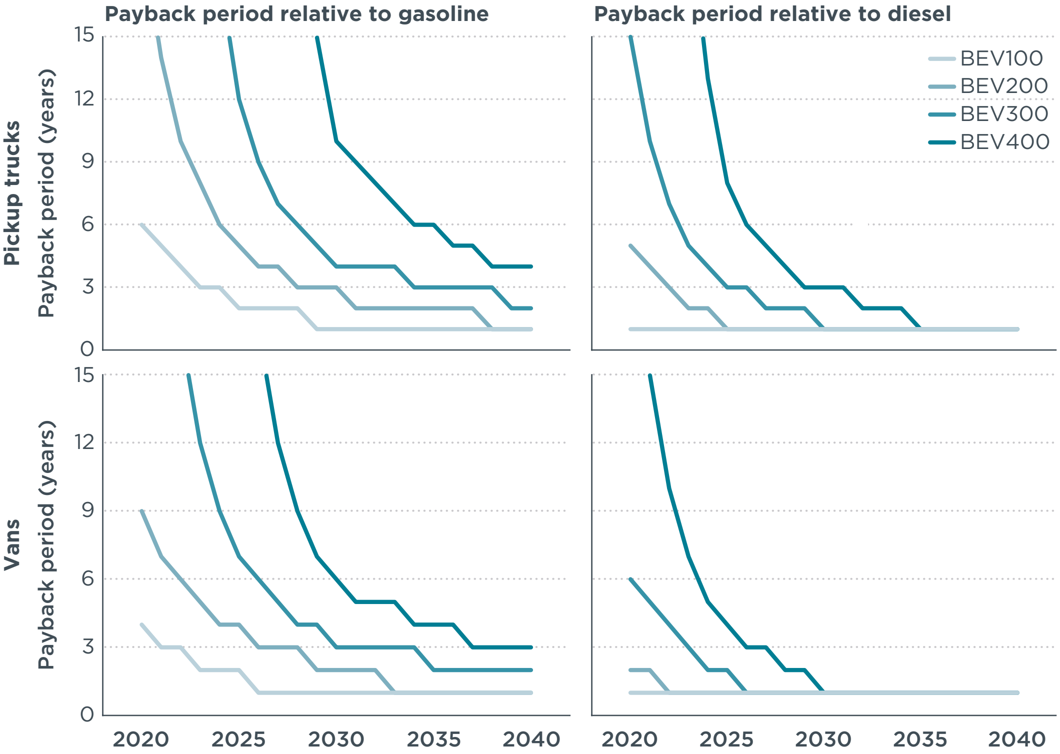


Figure 8. Payback period for BEVs and PHEVs relative to their ICE counterpart.

By 2029, all BEVs in the analysis have a payback period of less than five years compared to diesel powertrain vehicles, and by 2032, this falls to three years. Both the BEV200 pickup truck and van already have a payback of less than five years compared to diesel powertrains, and by 2022, the payback period is reduced further to three years. Compared to relatively cheaper gasoline powertrains, achieving the same payback comes later, crossing the three-year threshold in 2026 for vans and 2028 for pickup trucks. The payback period of PHEVs doesn't fall below 15 years, which is the upper bound of fleet ownership of Class 2b and 3 vehicles (Birky et al., 2017). Considering fleet operators' desire for relatively short payback periods, Class 2b and 3 PHEV vehicles are not profitable relative to their ICE counterpart.

Sensitivity analysis

Our model results are widely dependent on a series of assumed projections which are key in understanding the total purchase price and total cost of ownership of EVs and ICEs. Most notably, significant doubts remain related to the evolution of battery prices, which comprise a considerable amount of the vehicle purchase price. Our assumptions for battery prices are based off the average of the reported sources from literature and automaker estimates (see Figure 3), yet the actual price of lithium-ion batteries has largely outpaced historic projections discussed previously.

To account for such uncertainty, we introduced a sensitivity analysis in our model which applied a stochastic approach creating 2,000 iterations of value combinations across a series of variables. We applied this sensitivity analysis to in our model to battery prices, fuel prices, vehicle mileage, and vehicle efficiency. For battery prices, our bounds were chosen based on the literature review presented in Figure 3, whereby we iterated between a low cost of $41/kWh and a high cost of $98/kWh by 2030. The intermediate values were linearly interpolated from the baseline price to these values over this period and the same learning curves for 2030–2040 described above were applied to the selected value. For fuel prices, we iterated the 2050 values for electricity, diesel, and gasoline between the low and high price scenarios applied in the RIA, linearly interpolating from the baseline values used. This presented a range between $.110/kWh and $.114/kWh for electricity, $2.53/gallon and $5.59/gallon for diesel, and $2.24/gallon and $4.68/gallon for gasoline. Vehicle mileage was varied by ±20% across all vehicles. The efficiency of battery electric Class 2b and 3 vehicles was subject to a high degree of uncertainty, as the market is particularly nascent relative to the LDV market. We performed a literature review of all electric efficiencies available based on OEM announcements for Class 2b and 3 vehicles (available in the Appendix) and varied the average values by ±20%. The results of this sensitivity exercise are presented in Figure 9.

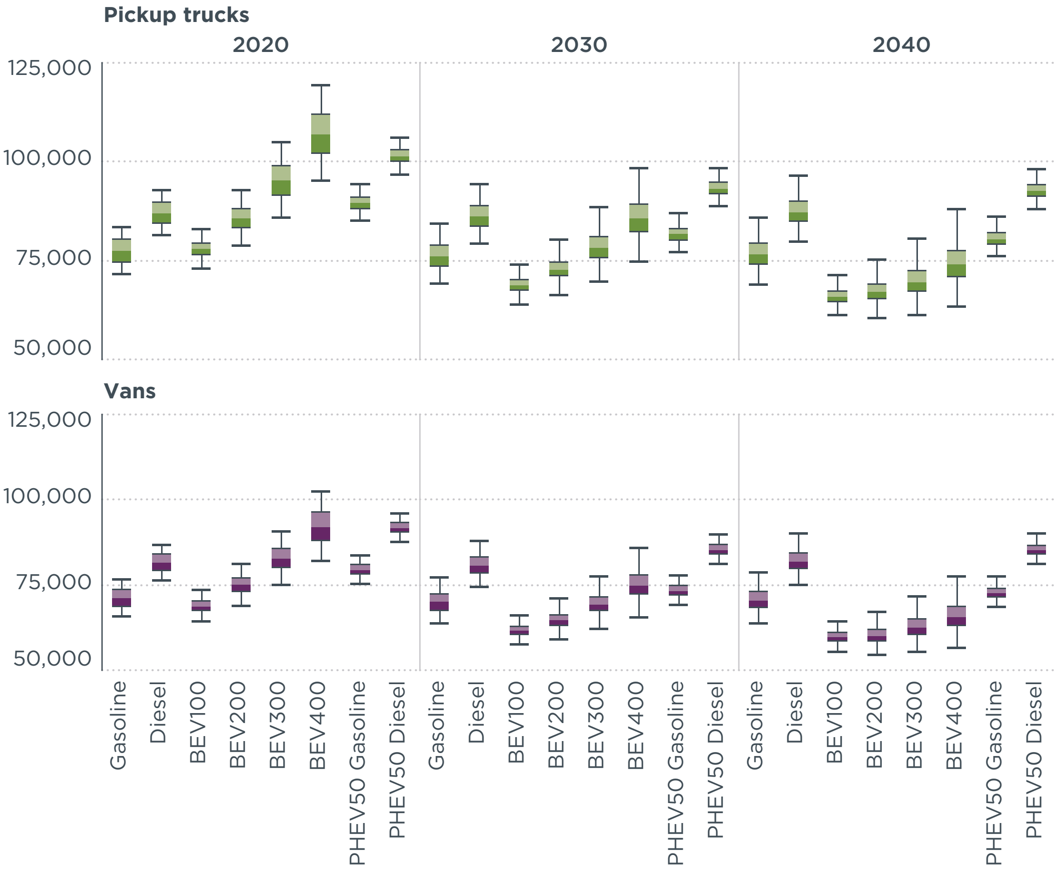


Figure 9. Sensitivity analysis of TCO values for pickup trucks and vans across 2020, 2030, and 2040.

Uncertainty surrounding battery costs increases the range of values of TCO for larger range vehicles. This uncertainty is further increased as the efficiency of BEVs reduces with battery size (see Table 2), rendering longer-range BEVs more sensitive to variations in fuel price. Uncertainty is lower in shorter range BEVs, with upper and lower bounds for the BEV100 and BEV200 as gasoline and diesel vehicles. Notably, the 95th percentile of the TCO for the BEV200 remains lower than the 5th percentile of both gasoline and diesel powertrains across both vehicle categories by 2030. Thus, allowing for a degree of uncertainty with fuel prices, mileages, and battery price evolution, there is a strong degree of confidence that a BEV200 pickup truck and van will be cheaper to own than an ICE vehicle by 2030.

Conclusion and discussion

This paper estimates the purchase price, total cost of ownership, and the payback period for four types of BEVs and two types of PHEVs in the Class 2b and 3 vehicle categories, which is comprised mostly of commercial pickup trucks and vans. While electrification has been slow to emerge in this area, the relatively low daily driving range compared to other commercial vehicle classes makes this sector prime for a technology shift to zero-emission technology in the coming years.

We find that the current BEV prices for vans range from $47,000 to $68,000 across 100-mile–400-mile ranges compared to $45,000 for a gasoline van and $56,000 for a diesel van. Current BEV prices for pickup trucks range from $54,000 to $80,000 across the same electric drive ranges, compared to $49,000 for a conventional gasoline and

$60,000 for a conventional diesel pickup truck. Lower running costs significantly reduce this price disparity when considering the total cost of ownership. Over a five-year period, the total cost of owning a BEV van range from $69,000 to $92,000, compared to $71,000 for a gasoline van and $82,000 for a diesel van. For a BEV pickup truck, the total costs of ownership over the same period costs $78,000–$107,000 compared to $78,000 for a gasoline pickup truck and $88,000 for a diesel pickup truck.

Projected reductions in battery prices through 2040, and increased regulation of the conventional market, narrow this gap significantly, and TCO parity is achieved at varying rates for different range vehicles. These key findings are summarized as follows:

Total cost of ownership parity for electric vans and pickup trucks with a range of up to 200 miles is achieved in the next five years. Seventy-two percent to ninety-seven percent of vehicle miles travelled by Class 2b and 3 vehicles could be met by a 200-mile range electric vehicle (Forrest et al., 2020). Our TCO analysis has shown that it is already cheaper to own a BEV200 van or pickup truck than its diesel counterpart. Battery and additional electrical component cost reductions expected in the coming decade contribute to TCO parity of 200-mile range electric vans with gasoline vehicles in 2023 and parity in 2025 for pickup trucks.

By 2030, BEVs with a range up to 200 miles will have a payback period of less than three years. When it comes to new technology investments, many fleet operators are constrained by the amount of time necessary to make back their initial investment. Most operators look for payback periods within range of three to five years. Results from this study suggest that there is a strong economic incentive for Class 2b and 3 vehicle owners to transition to electric in the next decade.

Total cost of ownership parity for battery-electric vans and pickup trucks with a range of up to 400 miles is achieved by 2035. Driven by significant reductions in maintenance costs, the TCO of all BEV vehicles in the study reaches parity with conventional vehicles by 2035, based on a five-year duration for the first owner. A significant number of fleet operators and consumers will have an attractive financial incentive to invest in battery-electric technologies within the next decade.

PHEVs are not cost competitive in the Class 2b and 3 vehicle segments. Due to the reliance on dual powertrains, the initial purchase price of a PHEV creates a significant challenge for PHEVs to compete against either fully electric or ICE powertrains.

It is important to note that a multitude of factors affect the adoption of non-conventional technologies, and significant technology shifts cannot be determined by purchase price and/or TCO parity. Consumer risk aversion and range anxiety, a lack of comprehensive recharging networks in many locations, and limited electric vehicle model availability all contribute towards slowing the trend toward BEVs. Policies encouraging a wider variety of vehicle models to enter the market and ensuring the availability of a reliable charging network can help mitigate these barriers and accelerate electric vehicle deployment.

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Appendix: Announced electric Class 2b and 3 vehicles

Vehicle name	Battery size (kWh)	Electric drive range (miles)	Efifciency (kWh/ mile)	Vehicle type	MSRP	Confirmed for the U.S.	Source
Rivian R1T	151	314	0.48	Pickup	$67,500	Yes	EPA & DOE (2021); Rivian, 2021)
Lordstown Endurance	109	250	0.44	Pickup	$52,500	Yes	InsideEVs (2021); Lordstown Motors (2021)
Bollinger B2	142	200	0.71	Pickup	$125,000	Yes	Bollinger Motors (2021)
Tesla Cybertruck - Single Motor	na	250	na	Pickup	$39,900	Yes	Tesla (2021)
Tesla Cybertruck - Dual Motor	na	300	na	Pickup	$49,900	Yes	Tesla (2021)
Tesla Cybertruck - Tri Motor	na	500	na	Pickup	$69,900	Yes	Tesla (2021)
Lightning F-150 115 kWh	na	230	na	Pickup	$39,974	Yes	Ford (2021a)
Lightning F-150 155 kWh	na	300	na	Pickup	$52,974	Yes	Ford (2021a)
GMC Hummer EV	na	300	na	Pickup	$112,595	Yes	GMC (2021)
GMC Hummer EV3x	na	350	na	Pickup	$99,995	Yes	GMC (2021)
GMC Hummer EV2x	na	300	na	Pickup	$89,995	Yes	GMC (2021)
GMC Hummer EV2	na	250	na	Pickup	$79,995	Yes	GMC (2021)
Canoo MPDV1	40	130	0.3077	Van	$33,000	Yes	Canoo (2021)
Canoo MPDV1	60	190	0.3158	Van	na	Yes	Canoo (2021)
Canoo MPDV1	80	230	0.3478	Van	na	Yes	Canoo (2021)
Fiat E-Ducato	47	146	0.3219	Van	$64,264	No	Fiat (2021)
Fiat E-Ducato	79	230	0.3435	Van	$84,264	No	Fiat (2021)
Ford E-Transit - Low Roof/Regular	67	126	0.5317	Van	$47,185	Yes	Ford (2021b)
Ford E-Transit - Low Roof/Long	67	126	0.5317	Van	$48,395	Yes	Ford (2021b)
Mercedes eSprinter	47	95	0.4947	Van	$52,726	No	Mercedes-Benz (2021a)
Mercedes eVito L2	35	92	0.3804	Van	$55,617	No	Mercedes-Benz (2021b)
Mercedes eVito L3	35	92	0.3804	Van	$56,338	No	Mercedes-Benz (2021b)
Nissan e-NV200 Visia	40	124	0.3226	Van	$35,774	No	Nissan (2021)
Nissan e-NV200 Acenta	40	124	0.3226	Van	$38,494	No	Nissan (2021)
Nissan e-NV200 Tekna	40	124	0.3226	Van	$40,534	No	Nissan (2021)
ABT e-Transporter 6.1 panel van	37	82	0.4549	Van	$69,663	No	Volkswagen (2021a)
ABT e-Transporter 6.1 kombi	38	80	0.4694	Van	$76,819	No	Volkswagen (2021a)
VW ID Buzz Cargo	111	340	0.3265	Van	na	Yes	Volkswagen (2021b)