Explainer

Financing Fleet Electrification: Battery-Electric Truck Component Resale Highlights Residual Value Upside

By Kabir Nadkarni
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Executive Summary

Battery-electric trucks (BETs) remain a relatively new asset class in the eyes of vehicle loan providers and financing companies. In the absence of truck-resale pricing data, vehicle financing companies often make the conservative assumption that a BET's residual value (RV) will fall to nearly zero early in its financing term. **Assuming a low RV for BETs makes their financing unaffordable, since borrowing fleets must finance most or all of the delivery price of a BET by making high periodic payments.**

While the secondary market for BETs matures and more resale transactions occur, a stopgap method is needed to benchmark the minimum RV of BETs and improve their financing outlook. **RV can be better estimated by valuating BETs' used components, including the battery pack, structural chassis, and various power electronics and devices that constitute the electric axle.** By benchmarking a BET's RV to the sum of the estimated resale value of these components, financing companies can be ensured that RV is at least as high as this sum, despite a lack of BET resale data for the time being.

CALSTART developed a financial model to evaluate the RV of BETs component by component, using reasonable degradation rates provided by industry partners. According to the model, **a substantial RV expectation is observed for a BET when component resale value is considered, especially in later years of the truck's life but also early in the typical financing term.** Specifically, the modeled BET's components together retain 15–25 percent of the truck's initial value by Year 5—a better outlook than those used by lenders in their current underwriting processes. This RV retention is close with diesel trucks', which is around 30 percent and likely to decrease in the future as BETs continue to become more cost-effective and favored by regulations. Furthermore, due to ongoing value in the battery during its second-life applications, BETs retain higher RV compared to diesel trucks after the Year 8 mark. This RV benchmark based on BET component resale is supported by innovative market activities of numerous battery second-life companies, like Zenobē and Connected Energy, who are capitalizing on the $2–$2.5 billion opportunity represented by the supply of used electric-vehicle batteries by 2030.

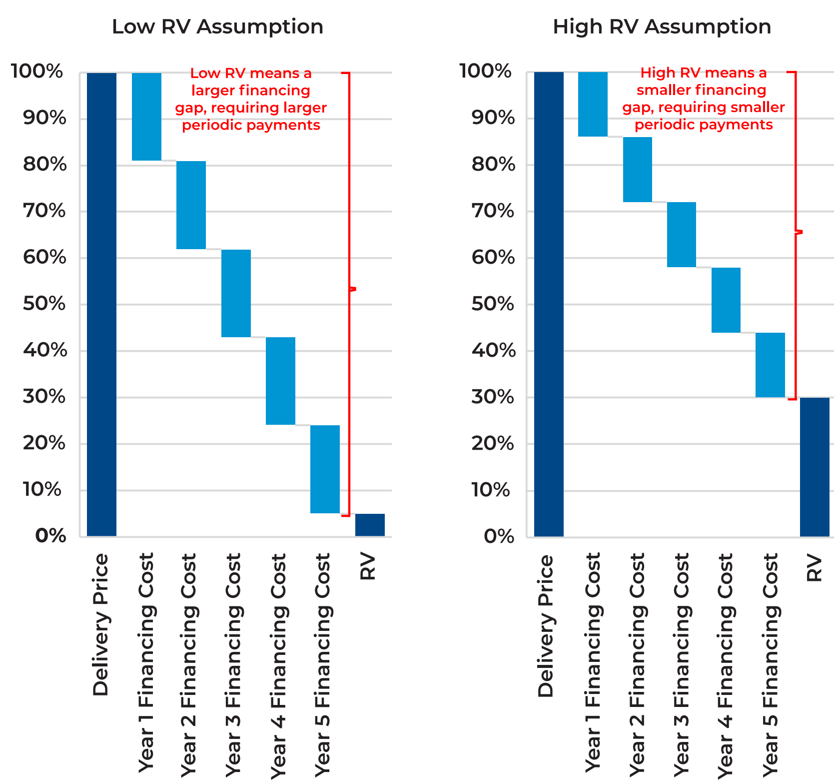
This component-based RV benchmark for BETs has major implications:

- **BET lease underwriters and equipment financing companies should attribute BETs with higher RV** throughout their financing term.
- From the perspective of policymakers and green banks, **RV guarantees or next-generation used BET voucher incentives should consider expected component resale value.** This would make the financing of BETs more affordable in their first life, while simultaneously helping develop a robust supply of used BETs for the secondary market.

I. Lenders' Residual Value Assumptions for Battery-Electric Trucks

CALSTART-led interviews have revealed that most of the major U.S. commercial banks and equipment financing companies rarely finance battery-electric truck (BET) fleets, citing residual value (RV) risk as one of the biggest barriers (CALSTART, 2022). RV is the estimated value of a vehicle at the end of its financing term. RV is an important consideration for both the financing provider as well as the fleet using the vehicle. From the financing provider's perspective, vehicle financing, equipment financing, and asset-backed general business loans are highly sensitive to RV, because the truck's RV serves as collateral. It is in the best interest of the financing provider to ensure that the RV of a truck is high. This derisks the truck financing, ensuring that in the event of borrower default, the recoverable collateral from reselling the truck can fully cover the principal repayment. From the perspective of the fleet, a high RV is beneficial because it decreases the financing gap and makes lease payments more affordable. This impact of RV on the affordability of financing terms is shown below in Figure 1.

Figure 1: Impact of RV on Affordability of Financing Terms in 5-Year Vehicle Financing Case



In the case of traditional diesel trucks, decades of financing have resulted in predictable RV estimates. (These estimates may decrease in the years to come, as diesel trucks may suffer from potential stranded-asset risk while the momentum toward fleet electrification grows.) An established history of diesel-truck resale pricing and low market volatility has historically supported lender confidence in RV, translating to ubiquitous capital access and affordable financing options.

BETs, a relatively new asset class, do not currently share similar confidence in RV. In the absence of empirical BET-resale pricing data, risk-averse commercial financing companies often assume the worst case that BETs will have low (sometimes even zero) RV. Financing providers have cited that this dramatic decline in RV could occur due to the following perceived risks: competitor price cuts, superior model rollout, product obsolescence of older BET models due to declining new battery costs and technology improvements, or rapid product wear and tear. Many financing companies have indicated to CALSTART that their internal lending policies require them to assign BETs with conservatively low RV outlooks during loan or lease assessments, translating to low/no collateral availability for asset-backed loans and leases. The low RV assumption from financing companies means that the full asset value of the vehicle needs to be financed during the lease term, resulting in high monthly lease payments to the fleet.

II. Component Resale Potential: An Intrinsic Minimum Benchmark for Battery-Electric Trucks' Residual Value

BETs are currently a new technology, and very few have been resold on the secondary market. Thus, the lack of documented RV for BETs cannot be benchmarked to used truck prices in the way that they are for diesel trucks. While the secondary market for BETs matures and more resale transactions occur, a stopgap method is needed to benchmark the minimum RV of BETs and improve their financing outlook.

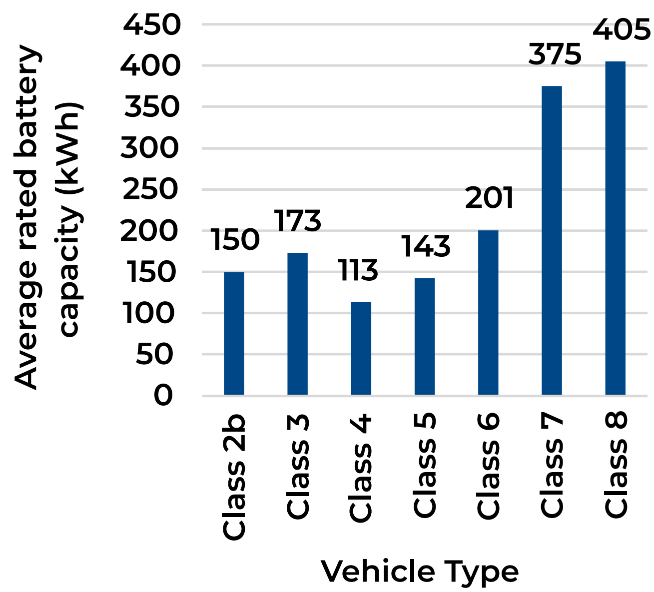
CALSTART interviews with industry-leading BE trucking companies show there is a strong secondary market for the various components of a BET after the truck has reached the end of its financing term. By benchmarking a BET's RV to the sum of the estimated resale value of each of its components, financing companies can be ensured that RV is at least as high as this sum, despite a lack of BET resale data.

Battery Packs

At roughly 50–60 percent of the initial purchase price, the battery pack is the most valuable component of a BET (CALSTART, 2022). An individual battery cell—the fundamental unit of the battery pack—stores electrical energy and is typically a lithium-ion cell, though other chemistries like lithium-iron-phosphate (LiFePO4) or nickel-cobalt-manganese (NCM) may also be used by various manufacturers. Each cell consists of an anode, cathode, and electrolyte. Cells are grouped together into modules, connected in a specific configuration (usually in series and/or parallel) to achieve the desired voltage and capacity. A series of modules, combined with protection systems, are then organized in a shape that will be installed in a specific BE vehicle, forming the battery pack (ACC Automotive Cells, 2022).

Seeing as different classes of BETs have varying duty-cycle requirements, battery packs for each class are manufactured to have a different maximum capacity. Figure 2 shows the average battery capacity for each class of BET.

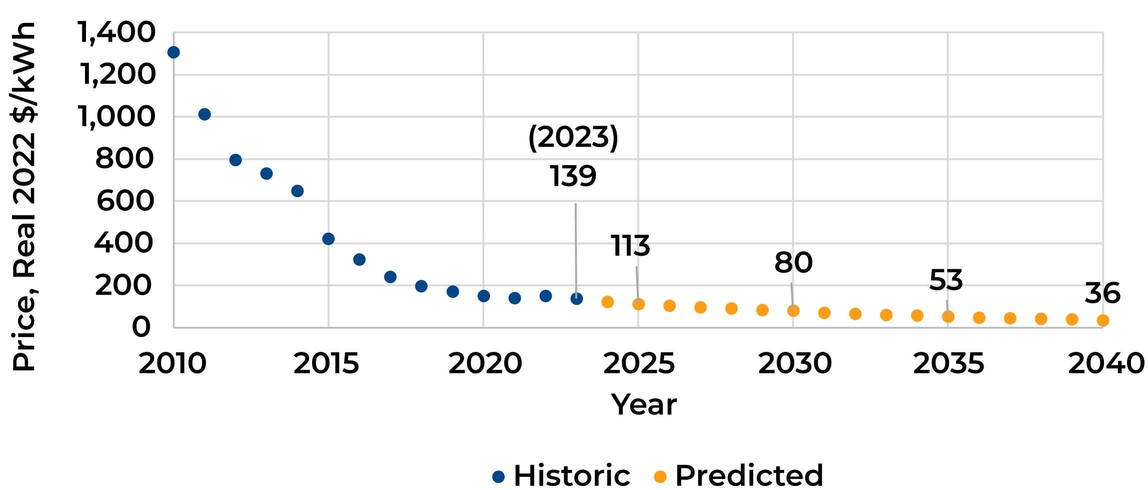
Figure 2: Average Battery Capacity of BET by Vehicle Class



Data Source: California HVIP 2024

As battery manufacturing technology continues to mature and advance along the learning curve, battery costs have rapidly declined over the past decade, and this trend is expected to continue. Figure 3 shows historic volume-weighted average lithium-ion pack prices and forecasted prices.

Figure 3: Volume-Weighted Average Lithium-Ion Pack Price



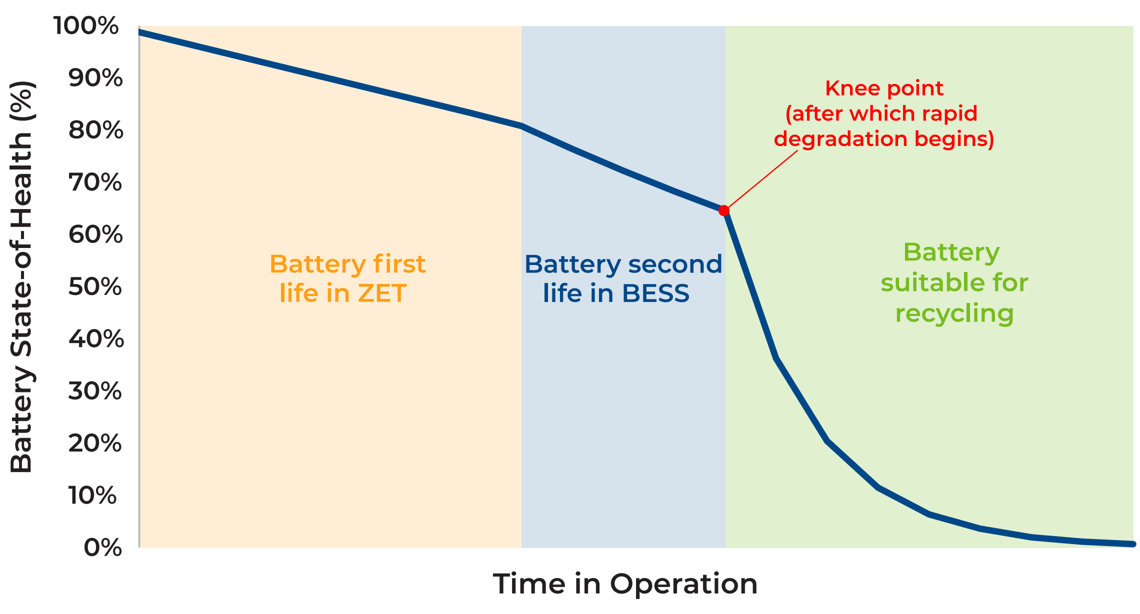
Historic Data: BloombergNEF's Electric Vehicle Outlook Report 2023

Battery-pack capacity degrades over thousands of charge cycles due to internal resistance building up, resulting in lower kilowatt-hour (kWh) energy storage capacity in the battery and range for a BET. The rate of degradation can be influenced by several variables including operational causes (e.g., frequency of deep discharge and, for many battery pack types historically, frequency of high-voltage fast charging), environmental factors (e.g., extreme temperature fluctuations) and time (e.g., calendar degradation over time even without use). Importantly, industry experts have cited that battery packs do not degrade evenly, with higher degradation occurring in concentrated zones of cells. Overall, degradation of a battery pack can be measured by a loss in state-of-health (SOH). Industry research has revealed that historically, battery-pack capacity has degraded at roughly 5–10 percent on average per 1,000 full charge cycles. As battery technology matures, this statistic is expected to improve.

Even though industry norms dictate that a battery pack may not be suitable for continued use in a BET after it has reached 80 percent SOH—a phenomenon that typically occurs around five to seven years into the battery's useful life depending on the number of full charge cycles that the battery has performed or mileage of the BET—the pack may still be usable for secondary applications such as stationary battery energy storage systems (BESS). Note that this unsuitability for vehicle application is not only due to the battery's maximum capacity decreasing and therefore the vehicle's range being reduced, but also due to qualitative degradation in the battery pack's performance. By reselling a BET's battery for use in a second-life application before giving it the necessary end-of-life treatment, more value can be gained from it and therefore enhances the truck's RV.

Figure 4 depicts the suitability of a BET's battery in various applications based on SOH, demonstrating that the battery pack has potential second-life applications following its use in a truck.

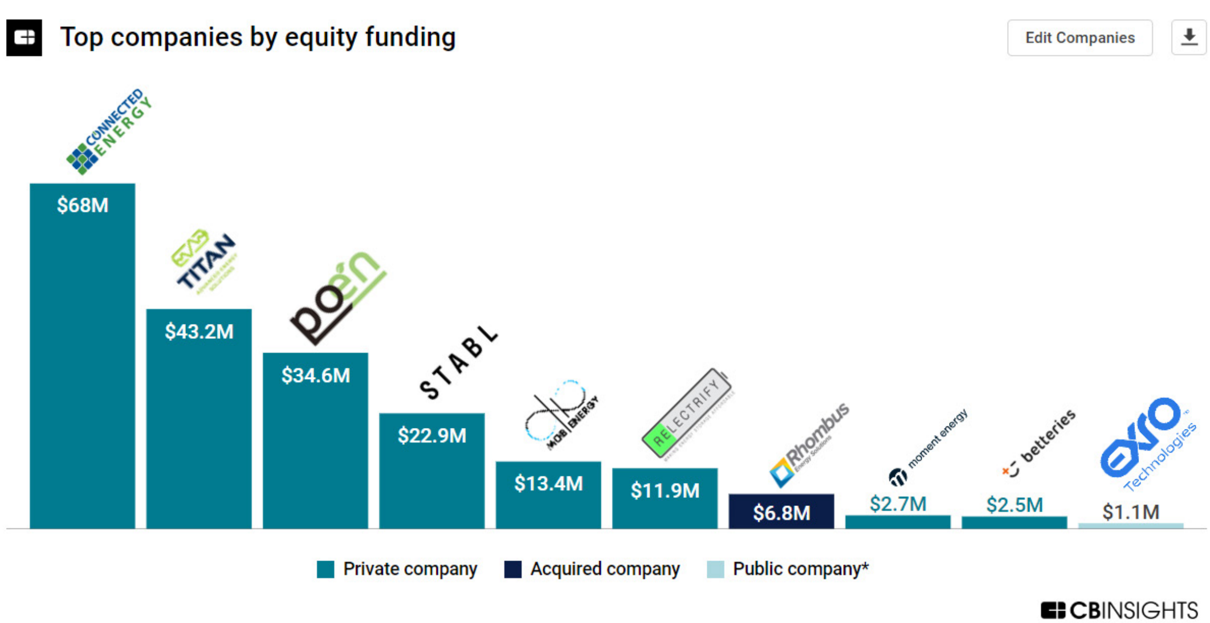
Figure 4: Typical Battery Degradation Schematic Showcases Suitability in Various Applications



This BET battery lifecycle schematic is the backbone of the proliferating second-life battery technology market, consisting of numerous companies that focus on reusing used electric-vehicle (EV) batteries, often for stationary energy storage applications. This market is meeting the rising demand for sustainable energy storage by providing a cost-effective alternative to new batteries. Companies specializing in this sector develop battery management systems that carefully monitor the battery health of repurposed battery packs, ensuring their reliability in off-grid power systems and renewable energy projects. Second-life batteries are versatile, making them well-suited for supplying energy solutions in remote areas, promoting electronic waste reduction, and supporting circular economy initiatives within the EV industry. This market is fueled by the increasing availability of end-of-first-life EV batteries and the demand for affordable, high-quality energy storage solutions.

Another critical tailwind for the emerging used EV battery market is the fact that many EV charging developers see stationary battery storage as a behind-the-meter solution to overcome demand charges and high utility upgrade costs; these developers are often well connected to EV fleets who can supply used EV batteries. Second-life battery technology represents a promising avenue for enhancing energy storage infrastructure while reducing environmental impact. A summary of top companies by equity funding in the second-life battery technology market is shown in Figure 5. Recent analysis shows that the supply for second-life truck, bus, and vehicle batteries suitable for stationary applications could exceed 30 gigawatt-hours per year by 2030 in the United States alone, translating to a market opportunity of roughly $2–$2.5 billion (McKinsey & Company, 2019).

Figure 5: Summary of Top Companies by Equity Funding in Second-Life Battery Technology Market (CB Insights, 2024)



*Source: CB Insights *Funding data as of 9/10/2024*

Zenobē Integrates Battery Second-Life Business Line to Lower Cost of Fleet Electrification

Zenobē, a U.K.-based CALSTART member company, specializes in battery storage and electrification solutions within the energy and transport sectors. The company offers services for fleet electrification, including charging infrastructure and battery systems, as well as large-scale battery storage connected to the electricity grid to provide power. Additionally, Zenobē refurbishes batteries for second-life applications, offering portable and static power solutions for the use of clean energy.

One of Zenobē's products is called the Powerskid (Figure 6), a self-contained system with second-life batteries worth 160 kWh, inverter, and distribution built into a robust, transportable container. The Powerskid operates in both on- and off-grid applications. In on-grid applications, the device charges when site load is low and adds power at high-demand periods, either to sell electricity or to shave load. In off-grid applications, the device replaces a temporary or permanent diesel generator in combination with renewable generation. The Powerskid meets the Low Voltage Directive 2014/35/EU EMC 2014/30/EU standards, as well as other industry standards for energy storage devices including IEC 60364, NEN 3140, and CE/UKCA (Zenobē, 2024).

In one example of the Powerskid's deployment, Zenobē installed a series of Powerskids to help Belgian construction giant Aertssen secure their supply of renewable power from its 5,500 solar panel installation at its main office and manage energy price volatility. Zenobē deployed 1.4 megawatt-hours (MWh) of second-life electric bus batteries, roughly equal to 10 buses. This resulted in Aertssen being able to store surplus renewable energy generated by their solar panels and manage energy price volatility. The stored energy can now be released to power Aertssen's business operations, including its fleet of electric forklifts. Thanks to the Powerskid, their BE forklifts can run on renewable power at night without the need to buy energy at expensive periods of the day. Zenobē's Powerskid deployment with Aertssen marks the first time a second-life bus battery was deployed in Belgium. Zenobē sourced these second-life bus batteries via auction from a third-party fleet, but following this pilot it plans on reusing all of its own electric fleet batteries in similar second-life applications, thereby boosting their BETs' RV outlook (Zenobē, n.d.).

Figure 6: Powerskid, Zenobe's Stationary Energy Storage Product Made With Used Vehicle Batteries

Photo credit: Zenobē

Connected Energy Redeploys Used Battery Packs in Energy Storage Projects

Connected Energy is a leading second-life battery technology company that is redeploying batteries from Volvo (an investor in the company), Renault, and Nissan vehicles into second-life stationary energy storage applications. Its 360-kWh E-STOR system, which uses 24 second-life Renault EV batteries reconfigured into a 20-ft. container, has been deployed in the U.K. and Europe to support EV charging, optimize renewable energy generation and enable efficient microgrids. Similarly, Connected Energy is currently working with a range of partners to develop its first utility-scale energy storage site ranging from 10 megawatts (MW) up to 100 MW+ called M-STOR, which is expected to reuse up to 300 second-life batteries each (Connected Energy, 2024).

As one project example, Connected Energy has been using its second-life battery technology to support its electrification partnership with Volvo Truck & Bus in the U.K. As a market leader in BETs, Volvo needed to provide high-powered charging at three key locations within their dealer network. Like many fleet depots, the sites were not designed with EV charging in mind and a capacity upgrade was not feasible. To redistribute energy during periods of peak demand, Connected Energy deployed a 300-kW E-STOR system, consisting of 360 kWh worth of second-life EV battery capacity, at each site. The E-STOR systems were able to effectively address grid capacity limitations by storing excess power during off-peak periods, and provided Volvo with a second-life use case for its vehicle batteries at their own charging facilities (Connected Energy, 2024).

Structural Chassis

A BET's structural chassis refers to the framework or backbone of the vehicle that supports and integrates various components necessary for its operation. This consists of a steel or aluminum alloy frame, suspension system, axles, braking system, mounting points for cab, cargo bed, or towing attachments. Given its large volume of material, especially including aluminum and steel, the structural chassis is considered the second most valuable component of a BET's initial cost.

In the case of certain original equipment manufacturers (OEMs), the chassis is the same between a BET versus a diesel truck. For other OEMs, diesel and BETs have distinctly different chassis designs due to their unique powertrains. This is often because diesel trucks require robust chassis support for their heavy internal combustion engines, complex drivetrains, and associated vibrations, resulting in a front-heavy design with reinforced structures for durability. Conversely, a BET's chassis often needs to support heavy battery packs that are placed low for improved stability and a more balanced weight distribution.

The structural chassis of a BET might experience wear and tear over time due to heavy loads, road vibrations, exposure to environmental elements, and potential corrosion, impacting its integrity and performance. Importantly, due to 30–40 percent fewer moving parts and less frequent maintenance for BETs compared to diesel trucks, such as fewer fluid changes and greasing needs, a BET's structural chassis tends to degrade slower (Trucking News, 2021).

Electric Axle Components

A BET's e-axle, or electric axle, is the unit that serves as the primary drivetrain component responsible for powering the vehicle's wheels using power provided from the battery pack. It makes up the remaining initial cost of a BET and typically consists of:

- Electric motors: One or more electric motors are included to deliver high torque suitable for heavy-duty applications.
- Power electronics, including:
    - Inverters and DC-DC converters: These devices manage the flow of electricity from the battery pack to the motors. These power electronics also tend to include intelligent functionality and rectification for returning power back to the battery during regenerative braking.
    - Battery Management System (BMS): This electronic system manages the state of the battery to keep it within safe operating parameters, controlling factors such as voltage and charge of each cell.
    - Battery Thermal Management System (BTMS): This system regulates temperature level and distribution across a battery pack to keep it within the optimal range for performance and longevity. It typically uses cooling, heating, insulation, and ventilation.
    - Integrated control and management electronics: These devices support in governing motor speed, torque output, regenerative braking, and other vehicle dynamics, ensuring smooth and efficient operation.
    - Transmission system: Some e-axles include transmission systems, including a reduction gearbox or a single-speed gear ratio, to optimize torque delivery to the wheels.

E-axle components degrade for a variety of reasons. Motor components degrade over time due to operating stress. For example, electrical insulation weakens with exposure to voltage imbalances, over and undervoltage, voltage disturbances, and temperature. Contact between moving surfaces can also cause wear. Power electronics including inverters, DC-DC converters, and BMS are subject to electro-mechanical wear and temperature fluctuation stresses that occur due to frequent charging, poor operating or charging conditions, high depth of discharge, and overall usage patterns. Depending on the type, these electronic components can last up to 25 years. Others can fail after only a few years. Degradation of an electric truck's BTMS over time can be attributed to a combination of thermal stress, cycle fatigue, chemical exposure, environmental factors, and the quality of design and maintenance.

III. Component Degradation and Resale Model

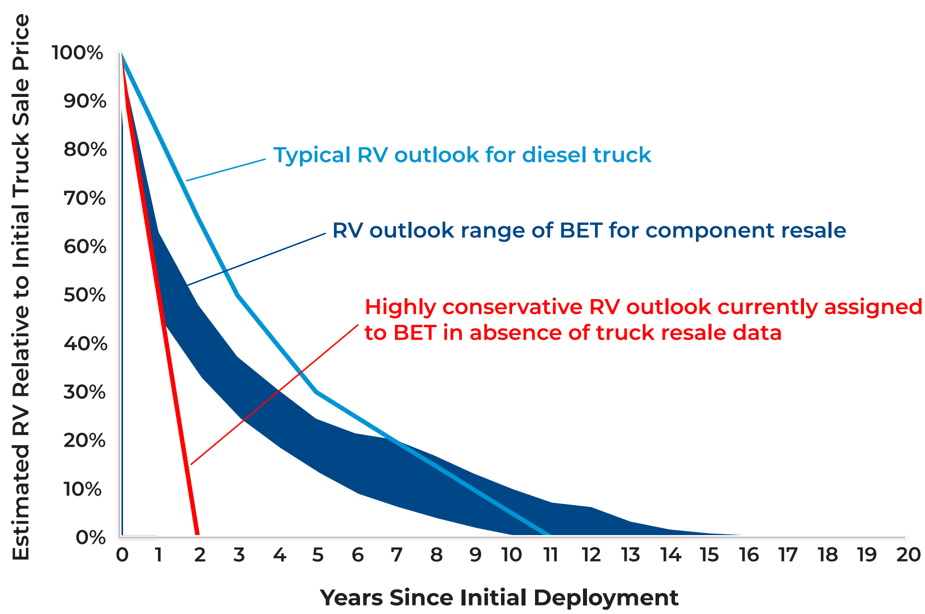
CALSTART developed a financial model to evaluate the RV of BETs component by component. The model begins by disaggregating the initial purchase price of a BET into its constituent parts. Each component undergoes a degradation assessment tailored to its specific characteristics.

Primarily, the battery component is analyzed using industry-validated data on battery-capacity degradation and market trends in battery pricing. Factors such as battery degradation rate per 1,000 full charge cycles, annual vehicle miles traveled, starting range (185 miles in the case of a Class 8 freight BET), and the threshold beyond which the battery range becomes inadequate for fleet operations (150 miles in the case of a Class 8 freight example) are considered. Multiple scenarios of battery-pack pricing are factored in, based on BloombergNEF's 2023 EV Outlook Report plus a conservative discount of 20–30 percent (BloombergNEF, 2023). These parameters allow for an assessment of the battery's resale potential, were it to be resold for non-truck second-life applications like in stationary energy storage. Secondly, the structural chassis and e-axle components of a BET are benchmarked against a degradation curve typically associated with that of diesel trucks plus another conservative discount of 20–30 percent.

The model aggregates the resale value of the components in future years and compares this sum to the initial purchase price to determine the overall asset RV in percentage terms. In the absence of BET-resale pricing data, this approach enables lenders and fleet operators to have insight into an initial benchmark for the RV of BETs comprehensively, facilitating informed decisions in BET financing.

When this model is applied to a Class 8 tractor, the result is a strong RV benchmark (Figure 7). Even in a worst-case scenario where the truck's used battery and other components have been discounted by 30 percent compared to market prices, and where a conservatively higher battery SOH degradation rate is assumed, substantial RV is expected for a BET, especially in later years of the truck's life.

Figure 7: Benchmarking BET RV to Component Resale Value Makes BET RV Competitive with Diesel

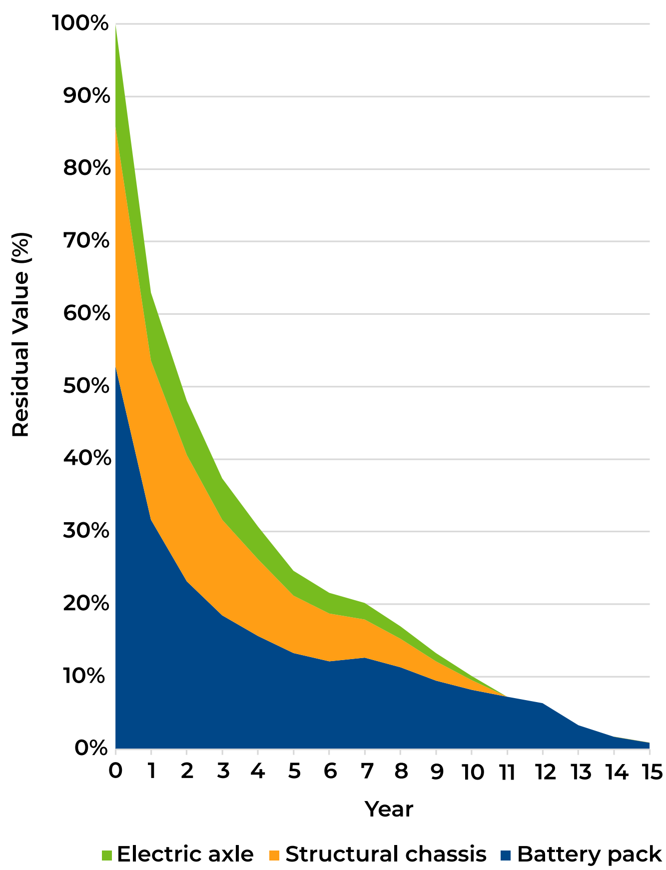


Specifically, the modeled BET's components together retain 15–25 percent of the truck's initial value after Year 5—a better outlook than those used by lenders in their current underwriting processes, which assume much faster depreciation. This RV retention is also more competitive with diesel trucks' current RV, which is around 30 percent in the same timeframe. Importantly, diesel truck RVs should be expected to underperform in future years as cost competitiveness of BETs improves and the newer asset class is favored by regulations like Advanced Clean Trucks (ACT), Advanced Clean Fleets (ACF), and the U.S. Environmental Protection Agency's Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles – Phase 3.

Furthermore, due to ongoing value in the battery during its second-life applications, the asset retains higher RV compared to diesel trucks after the Year 8 mark.

In the best-case scenario modeled for the Class 8 BET, Figure 8 shows the zoomed-in, component-specific RV. Comparing each of the components' RVs shows that the battery pack not only starts off as the most valuable component, but its long-term retained capacity also continues to support the component-based RV of a BET well past the Year 7 mark, at which point a comparable Class 8 diesel tractor's RV typically goes to zero.

Figure 8: Component-by-Component Breakdown of RV Compared to Original Delivery Price of Modeled Class 8 BET



IV. Conclusion: Component Resale Critical for Boosting Residual Value Outlook

In the temporary absence of BET-resale pricing data, component resale pricing offers a strong RV benchmark for these assets. The resale of BET battery packs for second-life stationary energy storage applications as being demonstrated by Connected Energy, Zenobē, and numerous other innovative energy storage companies is a strong market signal that BET batteries have an extended life past their vehicle application. Furthermore, the structural chassis and electric axle, when designed to be interoperable, can be given a second life in other applications as well. CALSTART's RV benchmarking model shows that BET components, when resold, together provide a strong RV benchmark to both lenders and fleets interested in deploying

BETs. By contracting the second life of these components using a combination of component resale auctions and RV guarantees, lenders and fleets can narrow the gap between the RV outlook of BETs and diesel trucks.

This RV benchmark estimate has major implications for the financing of BETs. If OEMs, fleets, and financing providers are able to coalesce upon resale terms of individual BET components at the end of a lease, such as through agreed-upon pricing for battery resale to distributed energy storage developers, then the overall financing amount for a BET is lower and lease payments for BETs can be made much more affordable to fleets. The findings of the above model could serve as the benchmark for an RV guarantee concept, which OEMs or third-party financing bodies provide as an incentive for making BET financing affordable.

This RV benchmark is also an important consideration for designing next-generation voucher incentive programs. For example, instead of providing upfront vouchers to reduce the sticker price of BETs, incentive-providing government agencies can instead look to guarantee the RV of leased BETs, thereby making lease payments affordable for small fleets while also stimulating the used component market.

There are some important limitations to bear in mind with this analysis. First, despite the fact that the benchmarking method reveals the potential resale value of a BET's components, RV will still be determined by the highest price that the repurchaser is willing to pay during a used truck auction. The noteworthy implication from this model is that, instead of simply looking to resell BETs on the used vehicle market (which might generate low resale prices due to the availability of new models), resellers of BETs should consider options for reselling individual components, as this may accrue a higher value. One such arrangement could be OEMs, or a third party such as a green bank or voucher incentive provider, offering an RV guarantee on their financed BETs and establishing relationships with stationary energy storage developers to resell used BET batteries in bulk at an agreed-upon price point. This way, the OEM and third-party funding provider can realize the RV potential of the BET by reselling components, while having the overall effect of making BET leasing and financing more affordable.

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About the Author

Kabir Nadkarni is the Industry Assessment Specialist at CALSTART. In this role, he leads research and analysis of industry trends across zero-emission transportation with a focus on financing solutions and related policy efforts at the state and national level.

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About CALSTART

A mission-driven industry organization focused on transportation decarbonization and clean air for all, CALSTART has offices in California, Colorado, Florida, Michigan, New York, and Europe. CALSTART is uniquely positioned to build the national clean transportation industry by working closely with its 285 member companies and building on the lessons learned from the major programs it manages for the State of California. CALSTART manages more than $500 million in vehicle incentive and technical assistance programs in the United States and is leading a global effort to build the zero-emission commercial vehicle market.

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