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ZENOBĒ + North America -

Smart fleet electrification starts with battery management

The fleet operator's guide to reducing risk through battery-as-a-service

Whether you're just beginning your fleet electrification journey or it's well underway, this guide will help you achieve the best outcomes from your fleet's batteries.

Learn:

- ✓ What battery degradation is
- ✓ How it affects fleet batteries
- ✓ How you can reduce your battery risk
- ✓ How to benefit from your batteries' second lives
- ✓ How battery-as-a-service works

ZENOBĒ

Trusted electrification partner

With over 120 depots electrified and more than 2,000 electric fleet vehicles supported to date, we know what fleet owners and operators are looking for. We have learned how to design depots and manage EV batteries to meet performance expectations while reducing risk and improving ROI.

The fleet operator's guide to reducing risk through battery-as-a-service

Batteries are critical to the success of a fleet electrification project. They must perform consistently to ensure your vehicles have the charge they need to complete their daily routes. And the longer they perform reliably for your fleet, the better the return on your investment.

Batteries are a significant piece of any fleet electrification budget accounting for 40-50%[1] of the purchase price of each electric vehicle (EV). While the asset cost is typically higher than gas and diesel-powered vehicles, fuel costs for electric are lower per mile than for internal combustion engines (ICE) as are the expected maintenance costs. Lifetime costs for electric can be further lowered if batteries are carefully managed during their driving lives. Battery management maximises the battery life, ensures reliable performance and enhances residual value. Just like your favorite pro athlete, eventually, your EV battery will have to hang up its shirt. You can delay that day by adopting the right behaviors now.

That's why battery management belongs at the core of successful fleet electrification programs. And, while it may sound counterintuitive, good battery management starts with an end-of-life plan.

Why put a battery's end-of-life plan first?

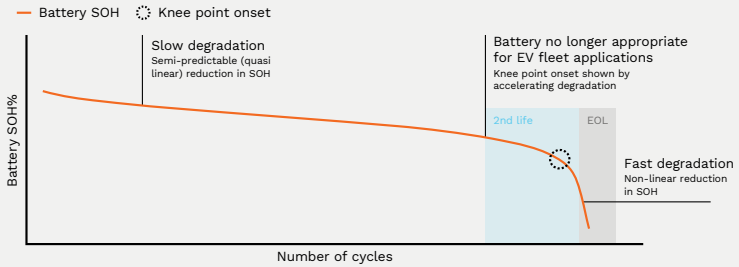
Charging and discharging a battery is a chemical process that causes physical changes to the battery. Over time and with use, the total amount of energy that the battery can store will decrease, a phenomenon known as degradation.

The most used measure of degradation is state of health (SOH) – the amount of energy stored by a battery compared to its day one capacity. Sometime after degrading past 70% SOH, battery replacement is usually required in fleet vehicles like buses as the rate of degradation begins to accelerate.

Watching for the 'knee point'

Battery degradation eventually reaches the 'knee point' where there is a marked acceleration in the degradation rate, as shown in Figure 1. As the battery degrades faster, the vehicle range drops rapidly as well and the battery will not be usable for its initial purpose – ultimately a vehicle battery will be replaced before it reaches this point.

Figure 1: Once a battery reaches around 70% SOH it needs replacement as its degradation accelerates beyond point of use for bus operations



Ultimately, under expected degradation rates, heavy-duty fleet batteries will need to be replaced at least once in a fleet vehicle's life.

That's why smart EV battery management starts with the battery's end-of-life in mind. It applies strategies to maximize each battery's useful driving life while closely monitoring for degradation signs so that batteries never degrade past the point of utility.

You may be wondering what happens to batteries once they are retired from EV fleets.

Second-life batteries have value today.

If you're thinking, *"70% SOH means these batteries still have a lot to give,"* you're right.

Good battery management also accounts for the residual value of the fleet battery in its next life – commonly referred to as its second life – where its remaining capacity is sufficient to deliver years of reliable stationary or portable energy storage.

Second-life battery systems have many use cases. They are excellent substitutes for portable diesel generators, especially where a quiet power source is valued like a concert stage or a residential film location.

Portable second-life battery systems can be used alone or paired with a diesel generator at remote construction or industrial sites to reduce emissions. They also work well in larger containorized storage systems to boost power at electric fleet charging depots.

Second-life energy storage systems

- Lower carbon compared to first-life battery*
- Lower cost
- Quieter
- Average 150 kWh capacity

Uses:

- On-grid: extra power to your depot
- Off-grid: temporary/portable power or on-site renewables storage
- Diesel off-grid: fuel efficiency, CO_2 reduction and more

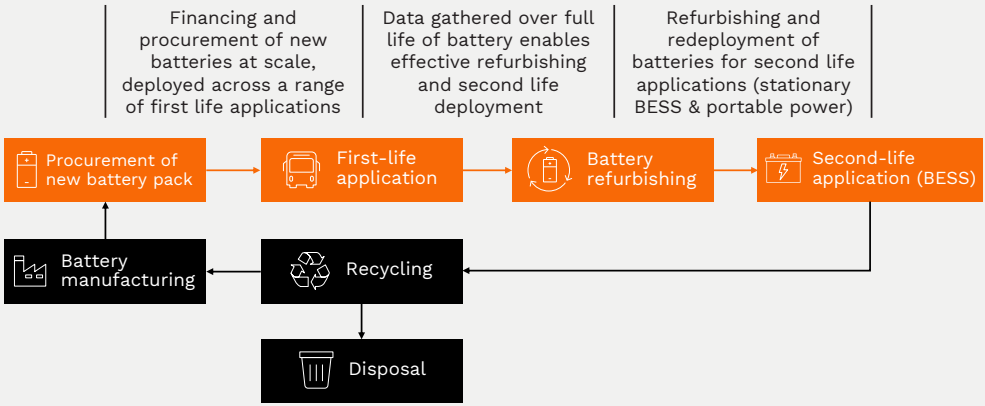
+ Learn more

These second-life scenarios form an additional step in what is called a circular economy for EV batteries, prolonging their usable life (see Figure 2).

Zenobē refurbishes retired EV batteries into second-life storage systems. We have years of real-world experience doing this from bus to warehouse depots – see our case studies on page 8. By having commercial uses for these second-life batteries we can assign a residual value to the batteries in their first life, passing these savings on to our customers to reduce the upfront costs of fleet electrification.

However, there's one more step. To ensure that a fleet's batteries live up to their second-life projections, they must be monitored closely throughout their first life. That's where a battery-as-a-service model comes in.

Figure 2: A circular economy keeps batteries and their materials in use for longer



Reducing costs and risks with battery-as-a-service

The battery-as-a-service model benefits fleet owners and operators by fully realizing the second-life value of their fleet batteries during their first life.

Under this model, Zenobē leases batteries to fleet operators. We are responsible for the batteries and assume the risks associated with battery performance, degradation and replacement, repurposing them at the end of their driving lives and sending any underperforming modules for recycling.

Not only does the battery-as-a-service model reduce the upfront cost of electrification for operators, it removes the risk and uncertainty about battery replacement and disposal as this is all accounted for in the monthly fee.

EV batteries are classified as a hazardous waste for shipping which means that they require onerous and costly handling. It's estimated that the end-of-life burden can add an incremental $3,000 per battery.[3] Zenobē already has a second-life market for the batteries it leases to fleets, so operators need not worry.

Zenobē maximizes its batteries' residual value in a number of ways:

01. Extending battery life through our battery management best practices (see "Everyday tips" on page 9).

02. Monitoring the data from the battery's first life allows us to better estimate its second-life value by developing a view on its SOH

03. Aggregating large numbers of batteries across different customers means we can achieve economies of scale in repurposing that individual operators may not be able to do.

Benefits of battery management + planning for a second life

Lowers Total Cost of Ownership (TCO)	TCO looks at the costs over the lifetime of your fleet and is a useful lens for comparing diesel or gas powered vehicles to electric. Managing batteries in a manner that minimizes the need for and costs associated with battery replacement lowers TCO. When the battery's residual value in a second-life storage application is factored in, this is further reduced.
Lower operational risk	Fleet operators are guaranteed that batteries will be managed to perform against operational requirements, giving them peace of mind that their electric fleet can fulfill its routes.
Covers replacement batteries	Similarly, if a battery shows signs of early degradation or a defect, battery-as-a-service covers its replacement which also removes exposure to battery market price fluctuations.
Frees your focus	Fleet and transportation management are a big responsibility. Battery-as-a-service allows you to keep your focus on completing your routes on time and safely.
Avoids battery end of life (EOL) costs	On top of the cost of a replacement battery, finding a second-life buyer or a recycler for a retired battery can cost around $3,000 plus the time.[2] All this is avoided.
Best practices leadership	Battery life cycle management is a best practice in fleet electrification today. Policymakers and policy advocates are encouraging regulation that requires EOL plans for EV batteries. This approach keeps you a step ahead.
Sustainable practices leadership	Not only does fleet electrification bring immediate environmental benefits over diesel or gas, a second-life plan for your fleet's batteries: • Extends the usable life of your batteries keeping their materials and CO_2 reducing abilities in use • Is lower carbon when compared to a first-life battery for the same purpose* • Avoids the resource consumption to manufacture more new batteries

Second-life storage for onsite solar

We helped a large construction company store clean energy from 5,500 solar panels at its headquarters using a 1.4 MW second-life storage solution.

+ Read more

Battery-as-a-service for depot electrification

We delivered an end-to-end solution for global transport operator National Express (Mobico) including financing, batteries, chargers, and management software with onsite storage provided by second-life bus batteries.

+ Learn how

Everyday tips for longer battery life

Here are three practical steps fleet operators can use to minimize battery degradation now and plan for future operations:

1. Route allocation

By cycling vehicles across different routes of varying service lengths and topographies, operators can ensure vehicle batteries degrade evenly across the fleet.

Route allocation can ensure individual vehicles are not repeatedly charged at an ultra-fast rate which can speed degradation but is often a necessity.

Zenobē's in-house modeling has looked at the impact of repeatedly running vehicles on the same routes each day, against cycling the vehicles to ensure they all complete a similar number of miles. The careful management of route allocation can provide the highest likelihood of requiring only a single battery replacement during the vehicle's useful economic life.

2. Depth of discharge

By operating a battery outside of its nominal voltage range – the target voltage the battery should be used at – the degradation of the battery will increase. The nominal voltage range of a battery can simply be thought of in terms of the battery's state of charge (SOC), with batteries degrading less when operated between 10-90% SOC.[4]

To help operators remain in this range, many OEMs place limits on the available battery capacity under their warranty terms. In practice, this means that operators cannot access the full capacity of their battery, only the usable capacity.

Operating batteries in their most efficient voltage range will mean energy losses and so electricity bills should be lower. Something for fleet operators to keep in mind when they're tempted to charge to 100%.

3. Minimize throughput

Electric vehicle drivers themselves can both positively and negatively influence degradation of the battery. Harsh acceleration and braking reduce the vehicle's efficiency when driving, increasing energy throughput and depth of discharge of the battery and thus its degradation.

Key to managing energy throughout is a software platform that reports performance data. Zenobē's software has shown that driver training and performance tracking can lead to a 20% improvement in vehicle efficiency through improved driving styles. Over a year, this can reduce throughput significantly, both slowing down degradation and saving on energy costs.

No fleet is alike, neither are their battery needs

Fleet electrification and battery management solutions do not come in one-size-fits-all packages. Therefore, a modular approach is often best to align all of the electrification puzzle pieces wherever you and your fleet are in your electrification journey. Understanding the important milestones in a battery's life cycle and how to best manage them is crucial.

Battery management is essential to sound fleet planning and ensuring that your operational requirements will continue to be met well into the future. And, a battery-as-a-service model with a second-life plan for fleet batteries produces a long-term, collaborative relationship that benefits all program stakeholders as well as the environment.

It's important that fleet owners and operators be supported by professionals who combine deep technical skills and experience with a knowledge of their real-world and day-to-day management.

Want to learn more?

Battery-as-a-service allows you to focus on your core mission – completing your routes and all pickups and deliveries on time and safely. With more than 2,000 fleet EVs supported and 120 depots electrified, how can we put our expertise to work for you?

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About Zenobē North America

Zenobē North America is on a mission to make clean power accessible in the U.S., Canada and Mexico. Zenobē has set the bar in battery management and performance for electric fleets, transmission-scale storage projects and second-life battery solutions across the globe. With well over $2 billion raised since its founding in 2017, Zenobē is now identifying partners and projects in North America. Zenobē is based in New York, with Fleet Electrification offices in Chicago. Learn more at zenobe.com/north-america.

Footnotes

[1] BBC, "How China's buses shaped the world's EV revolution," Dec. 6, 2023

[2] National Renewable Energy Laboratory, "Electrifying Transit: A Guidebook for Implementing Battery Electric Buses," April 2021.

[3] Alliance for Electric School Buses, "Driving Change: A State Playbook for Equitable Electric School Bus Policy"

[4] Energies, "Second-Order Discrete-Time Sliding Mode Observer for State of Charge Determination Based on a Dynamic Resistance Li-Ion Battery Model," Oct. 22, 2013

* How did we work out second-life batteries are lower carbon?
We began by working out the carbon emissions of buying a new battery and then using it to offset a diesel generator over a 7 year asset life. We then compared this to the emissions of a second-life battery which is run in an electric vehicle charged with power at the standard intensity of the UK grid - where we're headquartered - before being repurposed to replace a diesel generator for 5 years. We found that the carbon avoided by the first life of the battery outewighs the initial emissions of its production, meaning it comes into a second life as a 'carbon negative' asset.

Our assumptions:
- An average of 95kg CO2/kWh for battery production emissions based on McKinsey & Company's 'The race to decarbonize electric-vehicle batteries' 23 Feb. 2023 and IVL Swedish Environmental Research Institute's 2019 report, as referenced in Forbes
- An average grid intensity of 163g/kWh based on National Grid ESO's Carbon Intensity API
- A 7 year life for a first-life battery asset, based on the typical depreciation period for this asset type
- A 5 year life for a second-life battery asset, derived from EV battery degradation curves and industry literature

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