BERYLLS BY ALIXPARTNERS INSIGHT

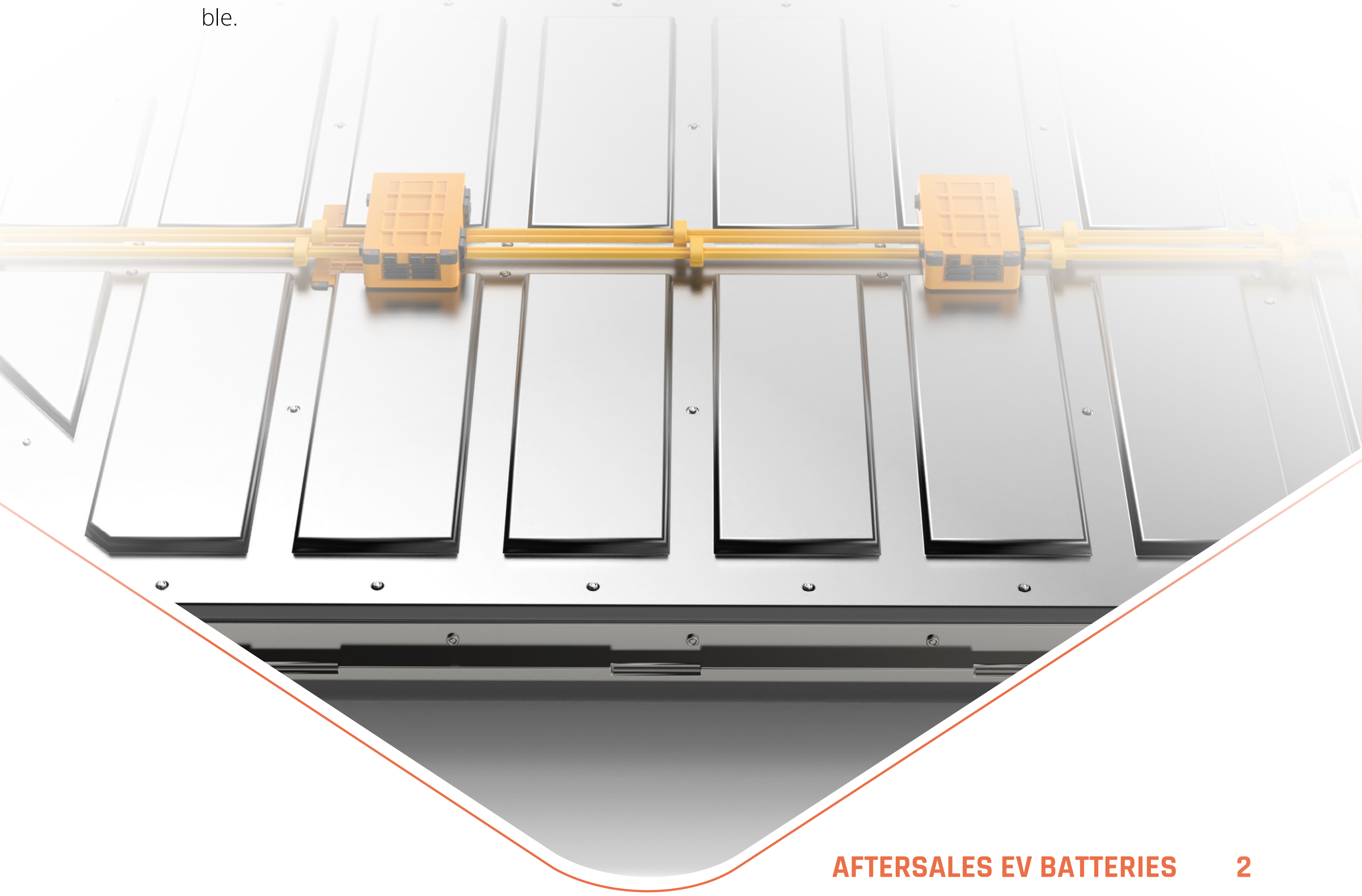
MANAGING AFTER-SALES EV BATTERIES – UNLIKE ANY OTHER SPARE PART IN THE TRADITIONAL AUTOMOTIVE ECOSYSTEM

1 | EMERGING DEMAND FOR REPLACEMENT HVBS (HIGH-VOLTAGE BATTERIES)

After-sales demand for HVBs could become an unprecedented issue for the automotive industry

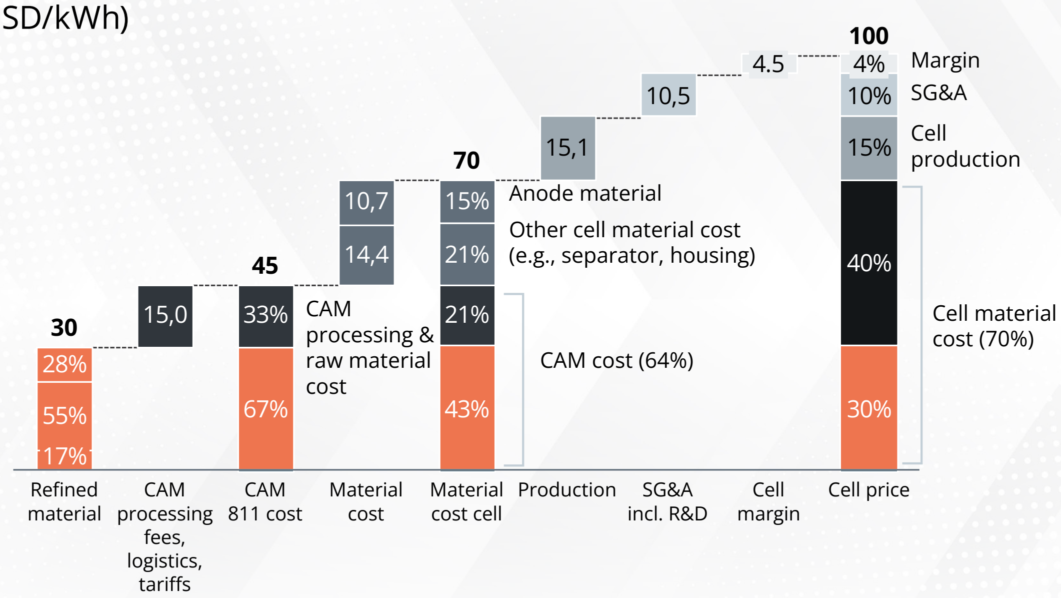
The EV battery is an auto part like any other and thus has a natural after-sales demand. Degradation over time below a certain level of SOH (state of health) – typically around 70% – would require replacements, on warranty or otherwise, depending on its mileage and the number of years driven. Recalls, accidents, and unexpected failures all add to the after-sales demand, similar to other parts in a vehicle.

However, the high prices of EV batteries and the massive investment required to produce them bring unprecedented challenges to the industry. These are further compounded by the rapid evolution of battery technology, which makes a battery outdated within a decade, as well as the difficulty in transporting and storing them, making conventional after-sales procedures unsuitable.



Managing the after-sales supply of EV batteries after vehicle EOP (end of production)

Cost Breakdown – Prismatic NMC-811
(USD/kWh)



COST INCREASE LEVERS

Due to the **small production volume** in post-EOP battery manufacturing, significant additional cost can arise from various cost increase levers

Material cost
Additional cost incurs from small raw material purchase and metal price fluctuation

Processing cost
Additional cost incurred from small-volume A/S-specific packaging

Inventory/logistics costs
Low volume leads to higher invt. mgmt. and logistics costs per unit

New prod. line set-up costs
Additional batch production incurs costs for tool changes and line setup

In the case of **strategic customers, suppliers often absorb the cost increases**, while for **non-strategic customers**, the increase is often **charged to the OEM.**

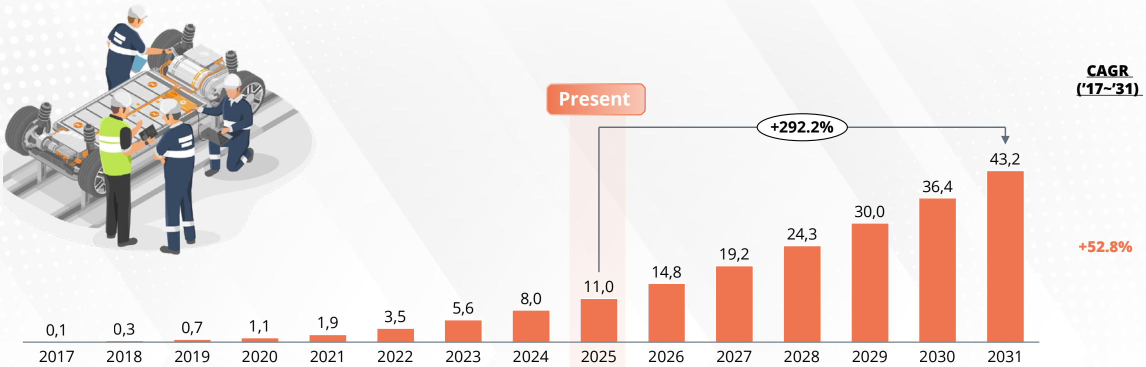
After-sales batteries can incur significant costs and create supply chain challenges for OEMs, as it is expensive to produce EV batteries on a small scale for after-sales use only after EOP. Although cell production accounts for only 15% of battery costs, manufacturing small batches after mass production ends can drive prices up by 2–3 times, or even over 5 times if a new production line setup is needed.

Another way to meet the after-sales demand is to produce all the HVBs expected to be required for the lifetime of the vehicle during the production period. However, this strategy is also expensive due to the high level of capital investment and storage costs as well as the risk of leading to a supply shortage if after-sales demand is underestimated.

Indeed, when grappling with battery supply issues for the early EV models that reached EOP in the early 2010s, some OEMs have had to resort to buyback programs as expensive as the original purchase price, scavenge scrapyards for the same models to remanufacture EV batteries, or even retrofit new versions of batteries despite additional development and approval costs.

Global HV replacement battery capacity demand forecast

Unit: GWh

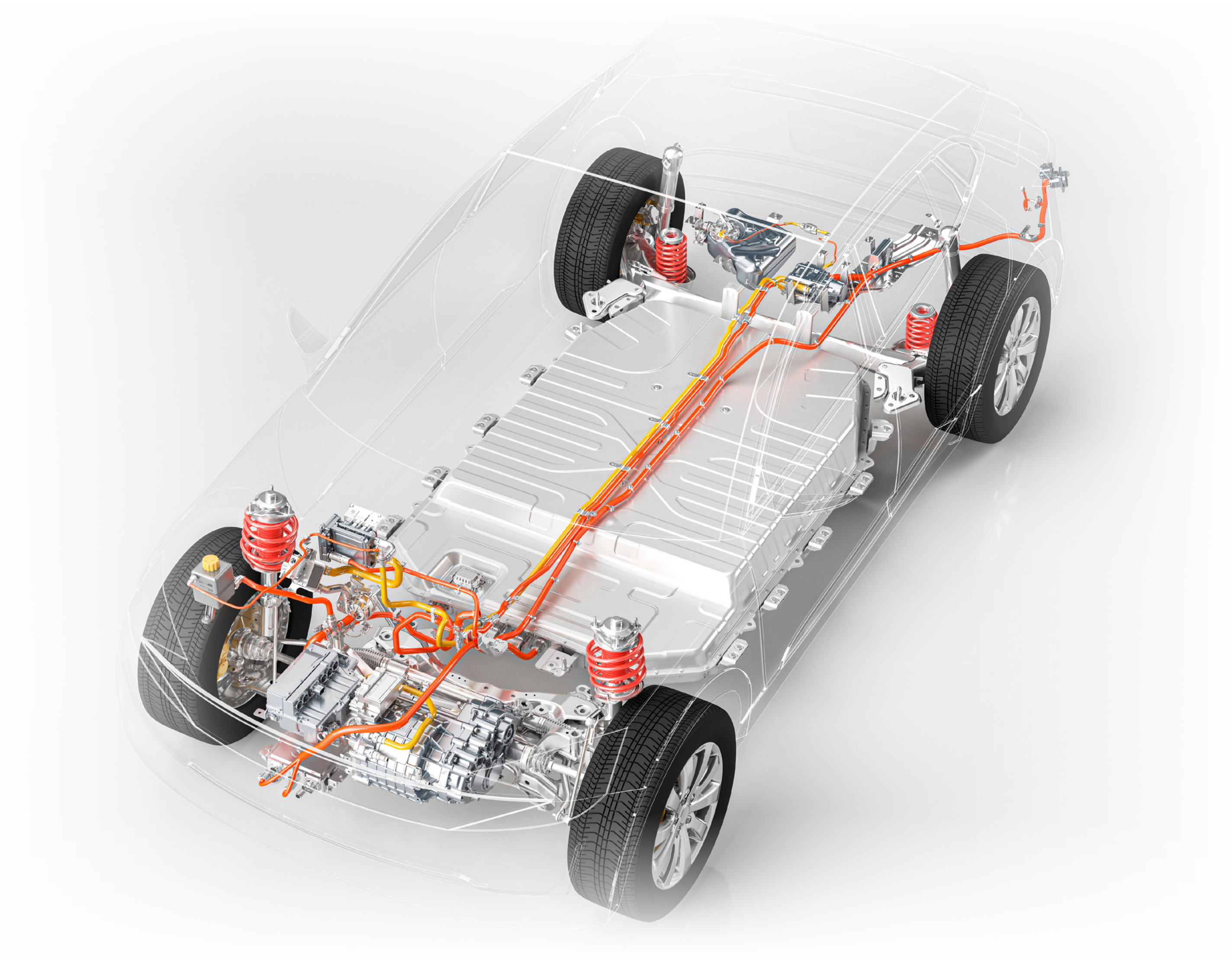


	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	CAGR ('17~'31)
Global EV UIO (M units)	2.3	3.8	5.5	7.6	12.1	20.0	30.7	42.6	57.1	75.1	96.2	119.9	146.1	174.6	205.0	**+37.7%**
HV replacement battery demand (K units)	2.9	7.9	13.7	20.8	36.1	62.9	98.7	137.9	186.3	246.8	317.3	396.4	484.0	578.9	680.2	**+47.6%**
Average battery capacity per unit (kWh)	39.5	47.1	54.0	55.0	54.9	57.7	60.6	61.1	61.3	61.7	62.7	63.7	65.0	66.2	66.9	**+3.8%**

Assumptions: Yearly remaining EV count estimated, considering the production volume based on production year and applying scrap rate (domestic scrap rate applied for 2015-2023, scrap rate estimated through geometric average of the previous 7 years for 2024 and beyond). Annual battery replacement rate assumed as 5%. Vehicle lifespan assumed as 15 years

Note: UIO Unit in Operation

Source: S&P Global, KADRA, Berylls Strategy Advisors



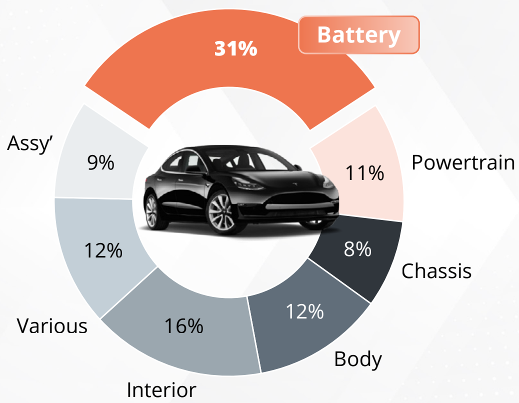
A short supply of after-sales batteries might even worsen as more EV models reach the EOP stage. EV batteries that are now in mass production cannot be fitted to these models. Considering that OEMs generally anticipate a 3–5% battery replacement rate across their EV fleet, our analysis expects global demand for replacement batteries to reach 45 GWh by 2031, which is equivalent to approximately 600,000 medium-sized EVs.

As a result, OEMs might be exposed to unexpected financial and operational burdens if they are not ready to tackle this issue. The entire automotive industry has yet to find viable solutions.

2 | WHY AFTER-SALES DEMAND FOR HVBS WILL BECOME A CHALLENGE FOR OEMS

Unlike traditional internal combustion engine components that can be easily stocked and replaced, batteries are expensive, complex, and degrade over time, even in storage. EV battery replacements may create challenges for OEMs with a combination of four factors: the high post-EOP battery price, OEMs' limited leverage over batteries, difficulties in demand forecasting, and a lack of guidelines for after-sales batteries.

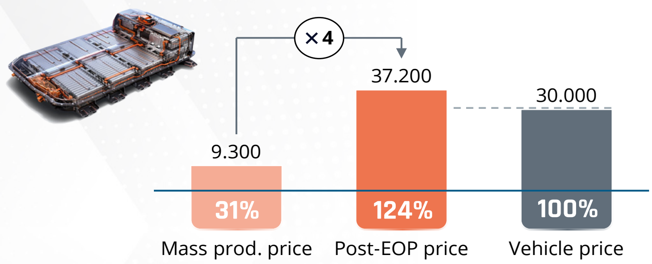
Vehicle cost breakdown



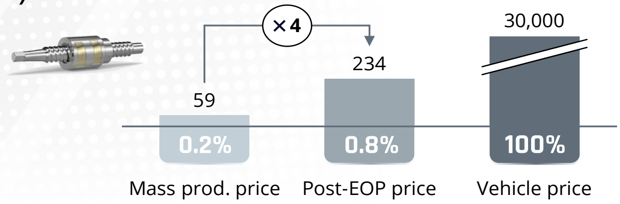
[1] 140 USD/KWh, based on 66.5kWh
2 R-EPS Rack Bar Nut Assembly

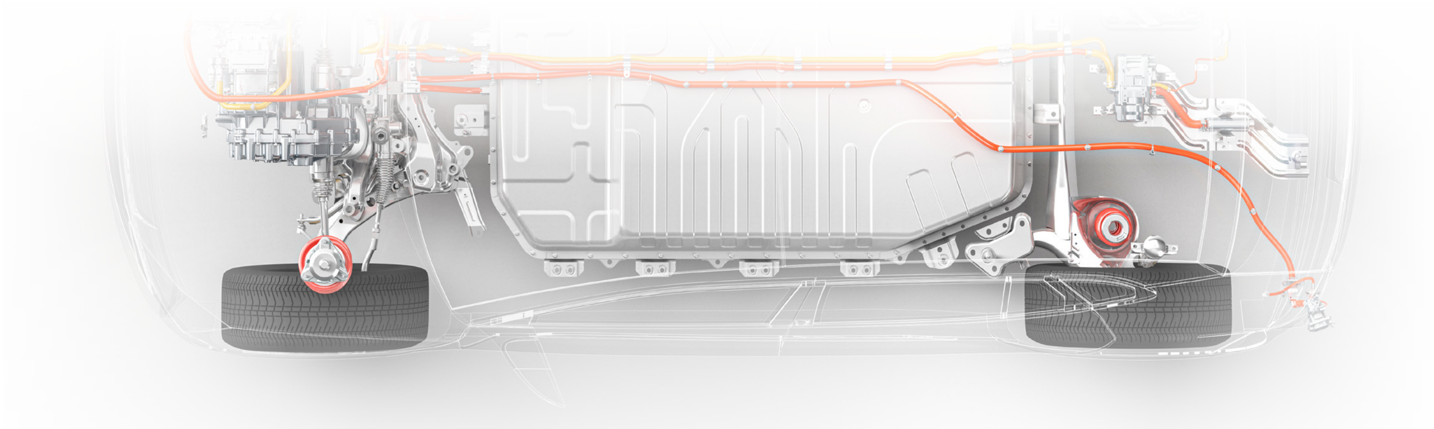
Source: Berylls Strategy Advisors

Battery[1] cost comparison
(USD)



Steering system component cost comparison
(USD)





High post-EOP battery costs

Batteries typically account for 30% of an EV's total price, but post-EOP battery costs can surpass the vehicle's entire value. Variations in cell type, chemistry, and size – even within the same vehicle model – can result in incompatibility issues, forcing small-batch production that drives up costs. Lower production volumes lead to a higher proportion of fixed costs and additional investment for tooling adjustments or new production line setups. In some cases, the price can exceed five times the original supply price, making it impossible to transfer to customers under the standard after-sales policies. After all, no customer would agree to pay $40,000 to replace a battery in a car that is only worth $10,000.

OEMs' limited leverage over batteries

As battery production requires large-scale manufacturing and close collaboration with suppliers, OEMs need to ensure long-term supply stability. While battery contracts are based on OEM-specific standard agreements, post-EOP supply conditions such as quantity, price, and supply period are often either unclear or not guaranteed. Automakers that do not maintain strategic partnerships with battery suppliers may have limits on their flexibility in terms of pricing and sourcing strategies. This reliance on suppliers puts OEMs in a vulnerable position, making it difficult to meet customer service needs in a timely and cost-effective manner.

Difficulties in demand forecasting

Due to the nature of batteries and lack of historical data, it is difficult to forecast battery demand accurately. Battery degradation is affected by multiple factors such as driving habits, charging patterns, and climatic conditions, but EV battery replacement patterns are still not fully understood. The conventional forecast model relies on vehicle sales data, accident rates, battery failure rates, and recall data, combined with degradation modeling. Some leading EV OEMs are using real-time big data analysis, considering additional parameters such as charging behavior and SOH. Global OEMs generally estimate EV battery replacement rates at around 3–5% of the UIO (units in operation). However, it has been observed that the demand forecasts commonly have low accuracy, prompting OEMs to maintain a safety stock based on their internal policies.

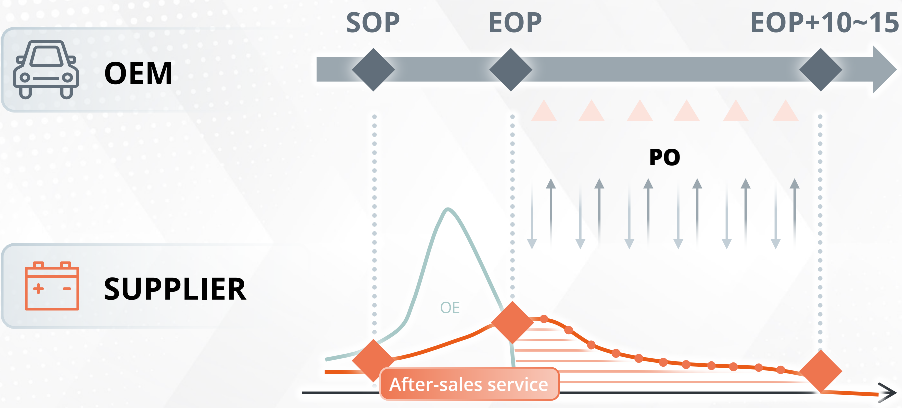
Lack of guidelines for after-sales batteries

Guidelines for after-sales battery specifications, storage, and transportation have yet to be addressed through industry-wide regulations. As a result, each OEM is left to establish its own battery management protocols, including a safety management system, temperature and humidity control, and SOC (state of charge) monitoring. Some OEMs have established dedicated containers and specific temperature/humidity standards for battery transportation – such as maintaining a dew point of –40°C – while others simply use wooden containers without setting out detailed requirements. Without clear guidelines, OEMs will have to bear the responsibility for ensuring the reliability, performance, and longevity of after-sales batteries.

3 | HOW OEMS ARE PLANNING TO HANDLE EV REPLACEMENT BATTERY SUPPLY

How are EV OEMs navigating this challenge today? To ensure battery availability long after a vehicle model reaches its EOP, OEMs have adopted a range of battery sourcing strategies – each with distinct advantages and limitations. While various approaches are being explored, a truly satisfactory solution that ensures cost-efficiency and supply stability has yet to be found, leaving the industry in a state of flux.

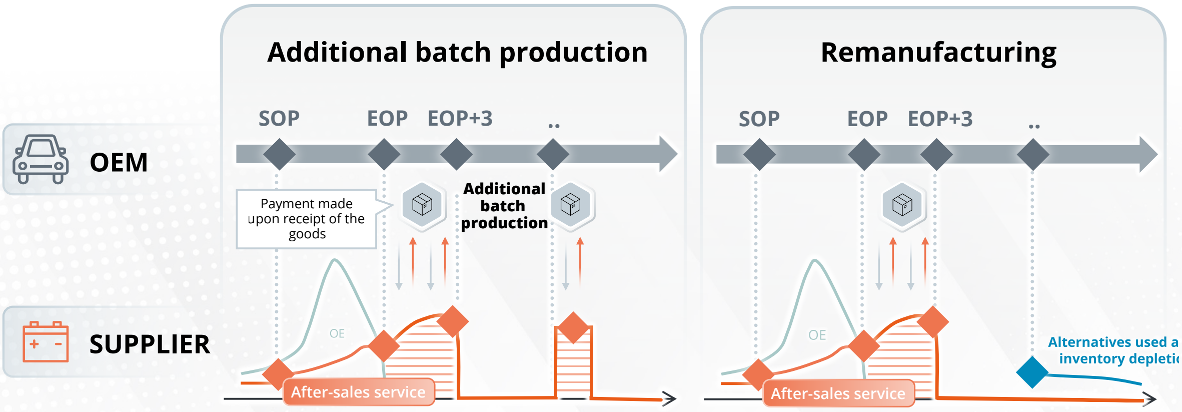
Low-volume orders over an extended period



One strategy some OEMs take is placing low-volume battery orders over an extended period, typically spanning 10 to 15 years. This approach enables them to procure batteries as needed, thereby reducing the burden associated with inventory management.

However, this method is not being widely adopted, largely due to supply-side constraints. Battery manufacturers are generally reluctant to maintain small-volume production lines for obsolete battery models, as it is not financially viable. Without long-term strategic partnerships between OEMs and suppliers, sustaining small-scale supply over such a prolonged period is highly challenging. Consequently, only a select few OEMs – those with robust, well-established supplier relationships – have been able to implement this approach. While battery suppliers could charge more than twice the original price when OEMs urgently request discontinued batteries – such as in the case of recalls – they are generally cautious about excessive pricing, taking long-term partnerships into consideration.

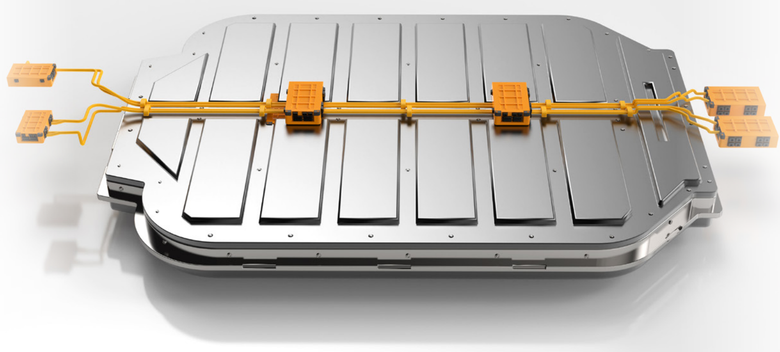
"All-time buy" strategy



Faced with these limitations, most OEMs instead rely on the "all-time buy" strategy. This approach continues battery mass production with reduced production lines for an additional two to three years beyond a vehicle's EOP, giving OEMs time to refine their lifetime demand forecasts and stockpile after-sales inventories.

Yet, this approach requires significant capital expenditure to procure and store large volumes of batteries. Moreover, the financial burden can increase due to higher working capital requirements, as well as the logistics and storage management costs associated with long-term inventory holding. Furthermore, demand forecasting remains imprecise, increasing the risks of over- or under-stocking. Long-term storage also poses battery degradation challenges, requiring specialized conditions to maintain a stable SOH.

Does the "all-time buy" strategy mean that OEMs need to stockpile a decade's worth of demand within just a few years? Not necessarily. While a stockpiled inventory serves as the primary solution, OEMs reassess demand based on updated data, and then, when necessary, they resort to batch production, reliable but costly, or remanufacturing, which is affordable yet unpredictable. Batch production after a production line shutdown incurs steep costs while remanufacturing, though more cost-effective, raises concerns over quality and supply chain volatility.



Global OEM in-house battery production (plan)

		STELLANTIS	TESLA
In-house battery production (plan)	Owns a battery subsidiary **PowerCo** Plans to build **6 cell plants** in Europe totaling **240 GWh** capacity by 2030	Invested €40 m in **Battery Technology Center** in Turin, Italy, enabling in-house testing and development of EV battery packs	**In-house production of 4680 battery cells** at Gigafactory Texas Ongoing expansion of internal battery R&D and manufacturing capabilities
Global EV production volume planned in 2031 (M units)	3.6	2.8	2.8

	BYD	TOYOTA	KIA
In-house battery production (Plan)	**Vertical integration** of battery and vehicle development and production, with full in house capabilities	» Fully acquired PEVE[1], a former JV with Panasonic » In-house production of NiMH and Li-ion batteries for EVs » Building a **$14 bn battery plant** in North Carolina, USA	» Launched **'B Taskforce** in 2025 to enhance internal battery capabilities » Plans to build **battery R&D center** in Anseong by 2027, with an annual capacity of **1-2 GWh**
Global EV production volume planned in 2031 (M units)	2.8	2.4	2.3

[1] Primearth EV Energy, renamed to Toyota Battery Co., Ltd.
Source: S&P Global, Press Releases, Berylls Strategy Advisors

In-house battery production

These ongoing supply chain challenges – though not the sole reason – have led some OEMs such as Tesla and Toyota to pursue in-house battery production as a strategic alternative. By internalizing battery production, OEMs can gain greater control over supply chains and enhance long-term stability. However, this approach necessitates massive capital investment and careful consideration. Moreover, it is not a viable option for many, particularly for smaller OEMs lacking scale or financial resources.

4 | STRATEGIC OPTIONS

After years of overlooking the issue and multiple unsuccessful ad-hoc attempts to address it, OEMs are now facing a critical crossroads. The problem is unlikely to resolve itself, especially as battery manufacturers' leverage is expected to grow even further. OEMs have two primary choices: optimize conventional practices to manage the rising costs of after-sales service batteries, or develop innovative strategies to address customer service needs and supply chain costs. Alternatively, they may explore new business opportunities that arise from these challenges.

After-sales supply contract consolidation

In the past, having separate contracts for mass production and after-sales parts supply were favorable to OEMs for the majority of parts. However, when it comes to batteries, this approach is becoming one of the biggest issues in maintaining EV business. Both OEMs and battery manufacturers need to plan and negotiate after-sales supply at the mass production contract stage in order to manage the rising costs incurred towards the end of the production and life cycle of the vehicles. A stronger strategic partnership between OEMs and battery manufacturers will be necessary as well as adjusting detailed supply terms to manage the cost of small-volume production and delivery.

Compatibility strategy

OEMs need to develop battery compatibility strategies at the cell/module level across models, platforms, and generations, starting from the planning and design phase. While using dedicated batteries for each model offers advantages in terms of design flexibility and cost efficiency during mass production, it can lead to a large number of SKUs, which become increasingly expensive to manage. By improving compatibility at the cell/module level, OEMs can increase unit production, reduce manufacturing costs, and potentially eliminate their reliance on suppliers for service parts procurement. Additionally, battery swapping can also be integrated into the compatibility strategy, further streamlining after-sales services and cutting costs.

Optimized batch production

Although ad-hoc small-volume batch production is the most expensive option, the costs can be mitigated by increasing the batch size. The optimal batch size should be determined by balancing production and inventory costs.

Small-volume specialists

Some OEMs are experimenting with small-volume start-ups and subcontracting specialized battery manufacturers capable of low-volume production with reduced overheads, given the right specifications and tooling. These small-scale operators can also be alternative suppliers for small-volume productions, not only for after-sales parts, but also for conducting experiments and development-stage prototypes.

Remanufacturing ecosystem

Some OEMs are already covering 15–20% of their replacement battery needs through remanufactured batteries, which not only helps reduce costs but also contributes to building a sustainable circular economy. To rely on remanufacturing as the primary solution for obsolete battery supplies, OEMs must develop remanufacturing ecosystems either in-house or through strategic partnerships. This includes establishing scrap battery sourcing schemes, engineering for mass production, and systems for recycling unusable materials. Since a mismatch between vehicle scrappage rates and replacement demand could undermine supply stability, remanufacturing should be complemented by other measures, such as inventory buffering or limited new production.

Leverage ESS (energy storage system) biz model

Another approach aimed at mitigating battery stockpiling costs is to develop a business model that leverages stored batteries. Long-term battery storage requires health monitoring and regular charging/discharging cycles, which are also required for ESS system management. An automated long-term battery storage system is essentially equivalent to an ESS system. If battery SOH can be managed over ESS usage, the profits from the energy trade could offset storage costs and potentially even cover the cost of the batteries themselves.

After-sales EV batteries are an example of the unexpected challenges the automotive industry is faced with in the course of electrification. Holistic solutions in terms of cost, SCM, and ESG can create an attractive business opportunity.

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