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Re-charging your core

High voltage battery remanufacturing is electrification's next value stream

A quick look at the main insights

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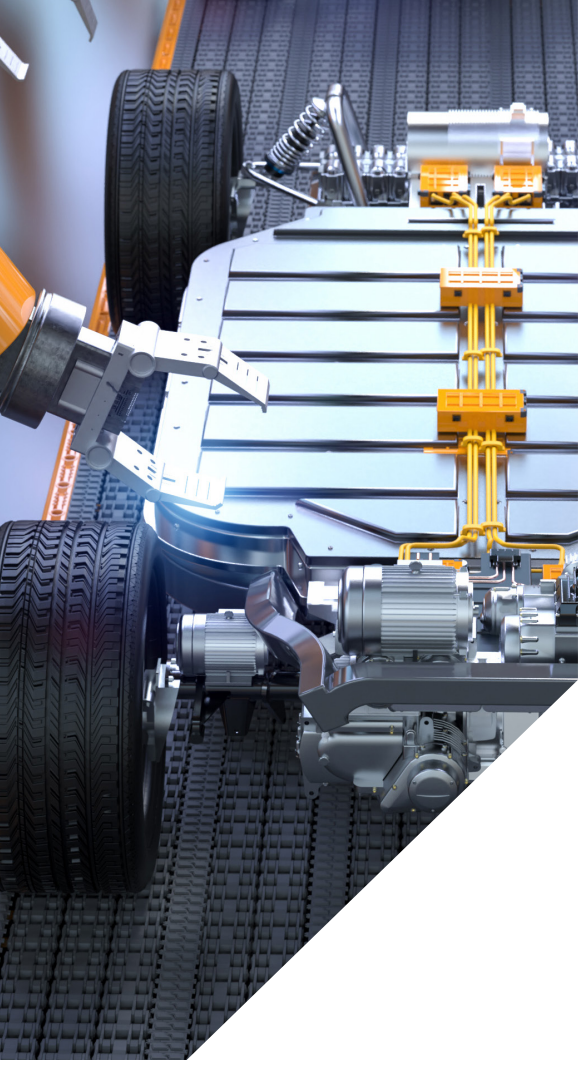


Executive Summary

Why read this?

High-voltage battery (HVB) remanufacturing is the next big profit pool across electrified mobility and energy storage lifecycles, yet many vehicle and industrial equipment makers and key suppliers lack a holistic battery remanufacturing strategy. The opportunity is to build strategic control over battery flows, protect residual values and unlock lifecycle margins, while enabling circularity and ESG compliance. Early movers will shape standards, secure access to used battery modules, and lock in customer trust.

Strategies for HVB remanufacturing are inevitably complex, and require trade-offs and partnerships:

- Companies need to **decide where to play** – battery pack, module, or cell – to identify their sweet spot for scale and economics.
- Companies need to **master the value chain,** from core sourcing to recycling broken battery parts, leveraging data for predictive insights, and building an operating model that balances centralization for scale with decentralization for speed.
- Companies need to **align inhouse activities and external partnerships,** clarifying who owns core inspection, exchange module certification, field service, and take back, and codify partner interfaces. This applies to OEMs, equipment manufacturers, dealers, fleet operators, and energy storage system (ESS) integrators.

Early movers in HVB remanufacturing can gain a competitive advantage in the long-term by:

1. **Keeping customers in the OEM's network throughout the asset's lifecycle.** Early movers can use remanufacturing to keep ageing vehicles, machines, and energy systems within the OEM service network. By offering cost effective, specification aligned module replacements, OEMs reduce customer leakage to independents in later life stages. This strengthens lifecycle revenue capture and brand loyalty across multiple ownership cycles.
2. **Smoothing the profit profile of EVs and ESS across market cycles.** A strong remanufacturing capability helps OEMs manage demand fluctuations and cost pressure. In weaker markets, it provides affordable repair options that maintain customer uptime; in stronger cycles, it reduces warranty expense through certified remanufactured replacements. Over time, this leads to more stable margins and a smoother profit profile across cycles.

We believe that HVB remanufacturing is a key emerging value stream in the maturing electric vehicle and energy storage economy. The window of opportunity is closing, and the time to act is now.

We recommend: Define your roadmap, footprint, partnerships and standards now, or risk being left behind.

1 | Why HVB remanufacturing matters

Remanufacturing preserves the asset value of batteries and extends the life of vehicles and machines

High-voltage batteries are now commonplace across a wide range of applications, from passenger vehicles, buses and other commercial vehicles to material-handling equipment, off-highway machinery, stationary energy storage systems (ESS) and back-up power. The high-voltage battery is not just another component among many: it is the economic heart of the vehicle, machine, or stationary system. With battery costs representing a large share of total asset value, battery pack failures can trigger financial shocks for owners and manufacturers alike.

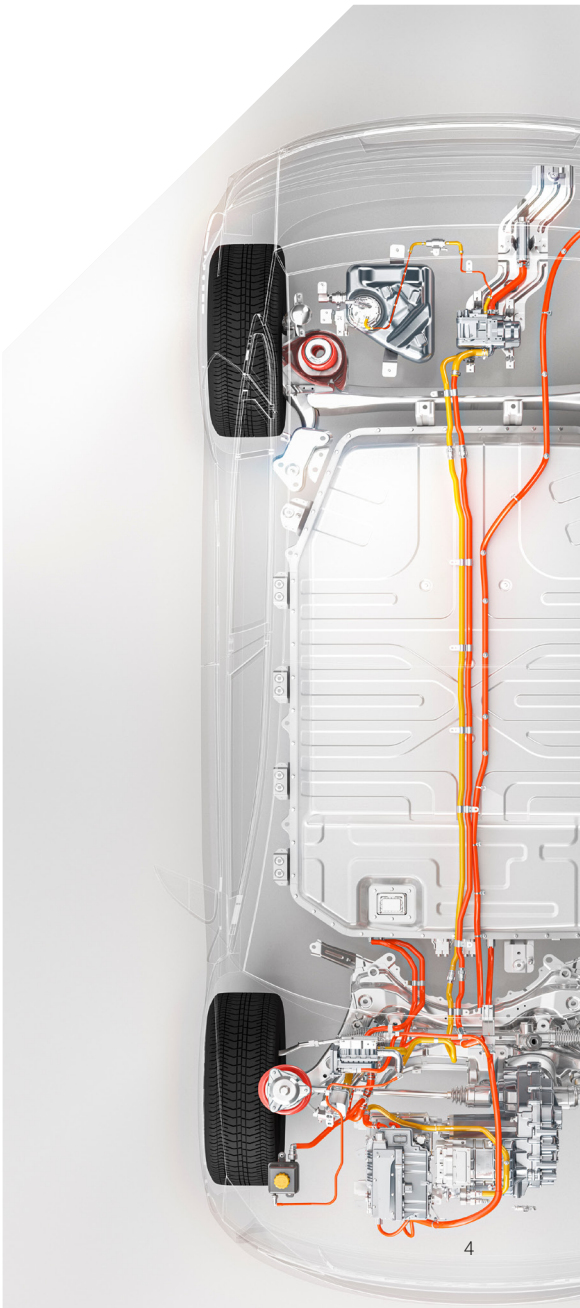
So, as many of the first- and second-generation vehicles and systems approach the end-of-life stage, businesses in these value chains face critical choices about how to best support customers over the asset's lifecycle.

Remanufacturing offers the smart path to managing the battery lifecycle. By replacing only defective modules within the battery pack rather than the whole pack, replacement costs can be reduced by up to 70%. This not only preserves asset value but also extends the life of vehicles and machines. The result is lower anxiety for end customers, higher customer retention, and stronger demand momentum.

For OEMs and equipment manufacturers, HVB remanufacturing unlocks **new aftersales revenue streams** at a time when traditional service income is eroding due to the relative lack of mechanical parts in an electric vehicle. It also **reduces warranty exposure:** by using certified used or remanufactured battery modules, manufacturers can significantly lower the cost of battery replacements during the warranty phase.

Demand growth from higher residual values and Certified Pre-Owned (CPO) units will more than offset the effects of first-generation owners delaying trade-ins and upgrades of a new vehicle or machine. Supporting higher asset value for the customer will also help keep them loyal to the brand and OEM family. For second or third generation customers, remanufacturing of HVBs offers the opportunity to extend the asset's life to customers who may not have otherwise owned or operated that brand's products.

Beyond the economics of HVB remanufacturing there is an environmental and sustainability impact. Remanufacturing reduces the CO_2 emissions associated with full-pack replacements and is a tangible step toward circularity – one that customers, communities, regulators, and investors increasingly expect.



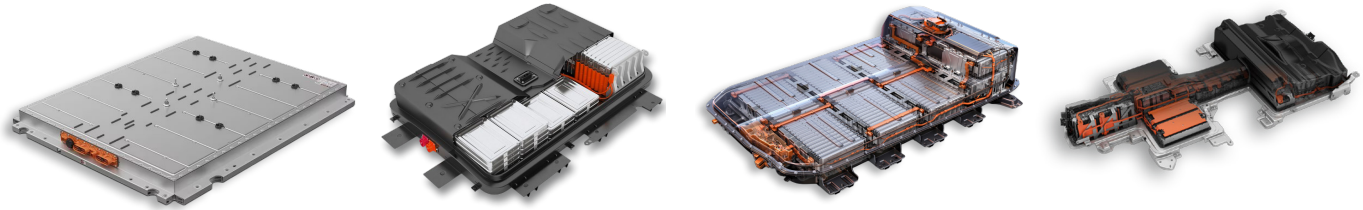
2 | The remanufacturing challenge

Product complexity makes standardized disassembly and processing extremely difficult

The commercial logic of battery remanufacturing may be compelling – but the practical challenge is significant, as setting up and scaling HVB remanufacturing is technically demanding and operationally complex. Batteries are typically composed of three distinct elements: the cell (which contains the battery chemistry and stored energy), the module (an assembly of cells), and the battery pack (combining modules into a fully functional power unit). The diversity of designs of cells, modules and packs, together with the use of multiple technologies and assembly methods across OEMs and equipment manufacturers (including ESS integrators), makes standardized disassembly and processing extremely difficult, especially when multiple brands are handled in one facility.

Graphic 1

Battery packs: One function, multiple formats



Volkswagen ID.3 Battery | Nissan Leaf Battery | Ford Mustang Mach-E Battery | VW E-Golf Battery

- **Multiple designs**
  Battery packs differ widely in size, architecture, and materials. Variations between battery electric and hybrid electric systems add further complexity. OEMs and equipment manufacturers follow distinct design philosophies, often prioritizing performance over serviceability. While a move to platforming may reduce variance over time, today's landscape remains fragmented, challenging scalable remanufacturing efforts.
- **Multiple technologies**
  Cooling systems, cell formats, and integration methods vary significantly. For instance, bottom cooling versus hose cooling requires different handling and safety protocols. These differences hinder standardized tooling and processes, driving up cost and turnaround time.
- **Multiple assembly processes**
  Many battery packs use non-detachable joints, such as welding or adhesives. These make disassembly complicated, often requiring specialized or destructive methods. This slows operations and increases the risk of damaging viable modules.

It is likely that design-for-remanufacturing standards will eventually become the norm for HVBs but that is some way into the future. For now, the high degree of variability in cross-sector HVB design – driven by application needs and OEM and other manufacturer-specific strategies – makes industrial remanufacturing a challenge. Overcoming this challenge demands investment in flexible tooling, mixed-portfolio facilities, modular jigs, and adaptable safety protocols including segment-specific personal protection equipment.

3 | Assessing HVB remanufacturing options

Module level remanufacturing offers the best value trade-off

High-voltage battery (HVB) remanufacturing refers to the restoration of a battery pack or one of its subsystems by replacing the defective component with a like-for-like module of equivalent quality, performance, and safety to reinstate the system to a condition that meets the original specifications.

A core requirement of HVB remanufacturing is ensuring that the replacement component matches the technical characteristics and ageing profile of the remaining battery. This includes chemistry, configuration, State-of-Health (SoH) and performance parameters. Only when the newly installed component is aligned with the overall pack's condition can the HVB operate safely and reliably, meeting the manufacturer's intended performance standard.

For these reasons, remanufacturing is not a simple repair, but a controlled, specification-driven process that restores the battery to a certified functional state.

Given the complexity of the battery sector described above, defining the optimal HVB remanufacturing process becomes a critical decision. Remanufacturing must be based on which level of the battery system is targeted – pack, module, or cell. Each approach comes with distinct technical, economic, and operational implications.

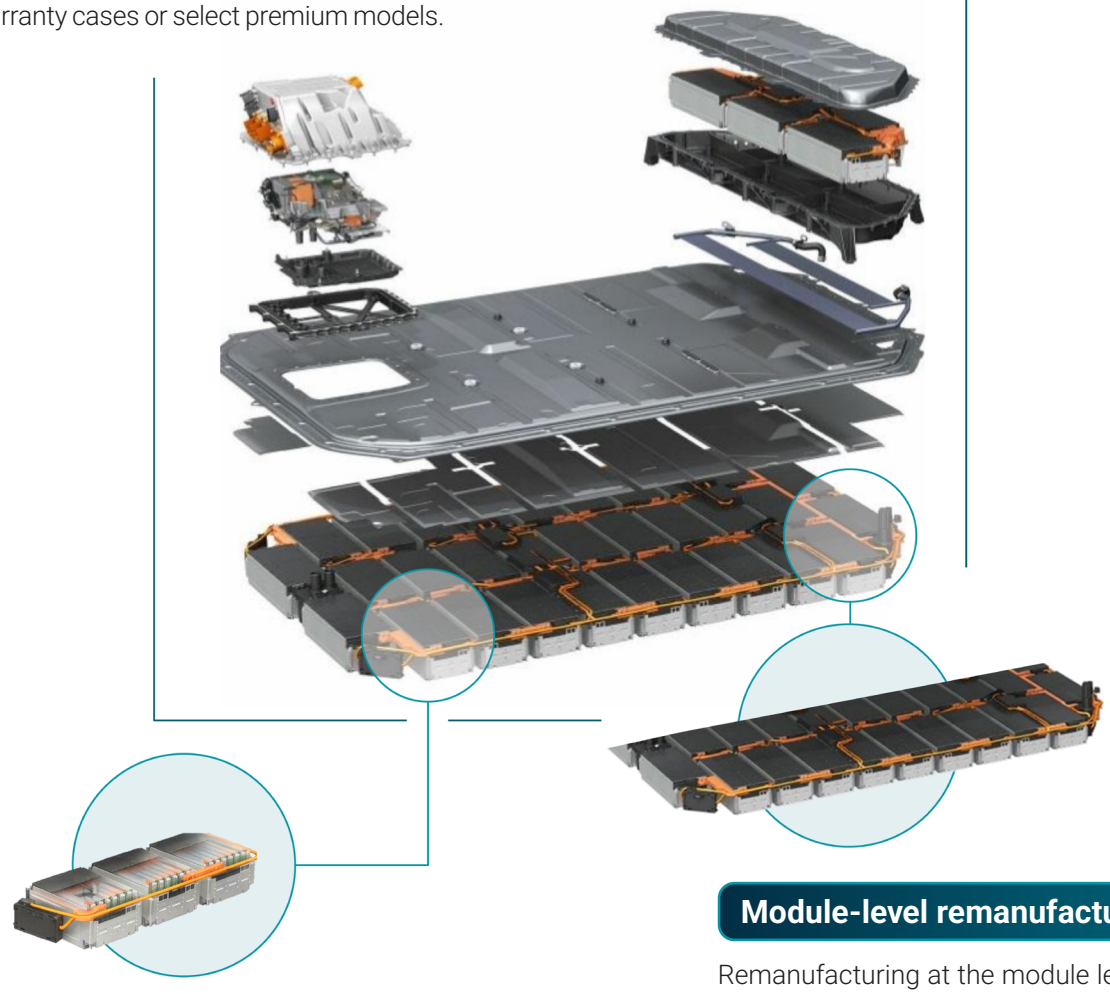
Graphic 2

Overview of HVB remanufacturing options

Example based on a passenger car HVB but the same argument is transferable to other battery types.

Full HVB pack replacement

Replacing the entire high-voltage battery pack is rarely viable. Costs often exceed the asset's residual value, making it uneconomical. System diversity – across chemistries, architectures, and generations – further complicates compatibility. This approach is not scalable and should be limited to warranty cases or select premium models.



Module-level remanufacturing

Remanufacturing at the module level offers the best balance of feasibility and value. Modules restore performance without the complexity of full-pack handling. Challenges include limited BMS data access, the need for compatible replacement modules, and post-installation recalibration. Still, with the right setup, module-level reman is scalable & commercially attractive.

Cell-level replacement

Repairing individual cells is highly complex and risky. Even minor damage during reassembly can trigger thermal failure. Matching cells by chemistry and ageing is nearly impossible at scale, and liability remains unresolved. Given the high risk and low scalability, cell-level repair is not a recommended strategy.

As a result, we expect module-level remanufacturing to deliver the best trade-off between cost, complexity, safety and turnaround time across passenger cars, buses and commercial vehicles, material-handling fleets, off-highway equipment, and ESS. Full-pack replacement is expected to remain a niche path for select warranty or safety cases, while cell-level repair is almost impossible to scale and liability-intensive, as described above.

4 | Segmenting the HVB remanufacturing value chain

Logistics and remanufacturing design are critical strategic considerations

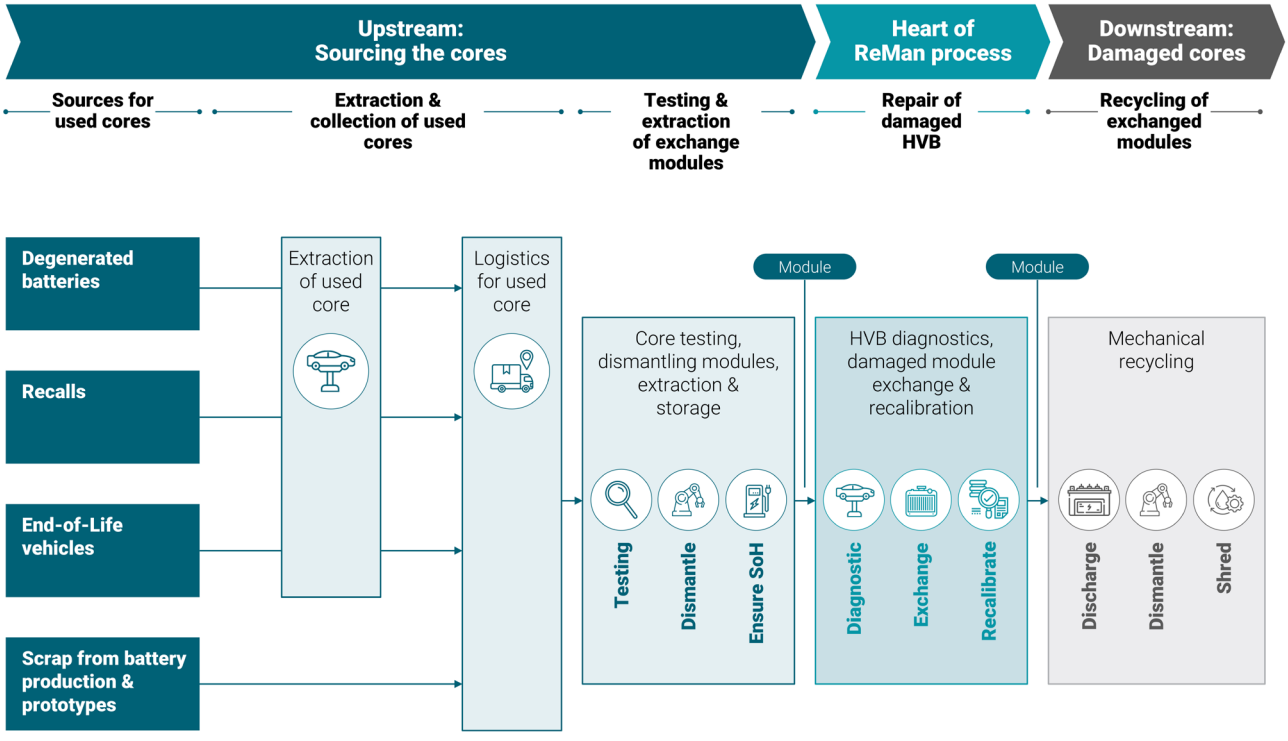
For companies that choose to enter the HVB remanufacturing sector, it is important to recognize that remanufacturing is a multi-stage value chain that must balance safety, cost, and turnaround time.

The short-term reality is investment heavy – at least until enough used batteries reach the relevant age to unlock scale. So, it is very important for companies to decide on when to enter to realize a viable business model, but also on how to enter. We expect some providers to cover the whole remanufacturing value chain inhouse, while others will outsource certain areas to third party service providers. Specializing in certain steps, to become a service provider for others, is another feasible approach to participating in this emerging market.

As the chart below shows, the value chain consists of three main stages, which can be broken down into further steps. The heart of the value chain is the actual repair of the damaged HVB of an electric vehicle or energy storage system, and this is made possible by an upstream process of sourcing of the core to be used for the repair, and a downstream process for recycling the damaged module extracted from the HVB.

Graphic 3

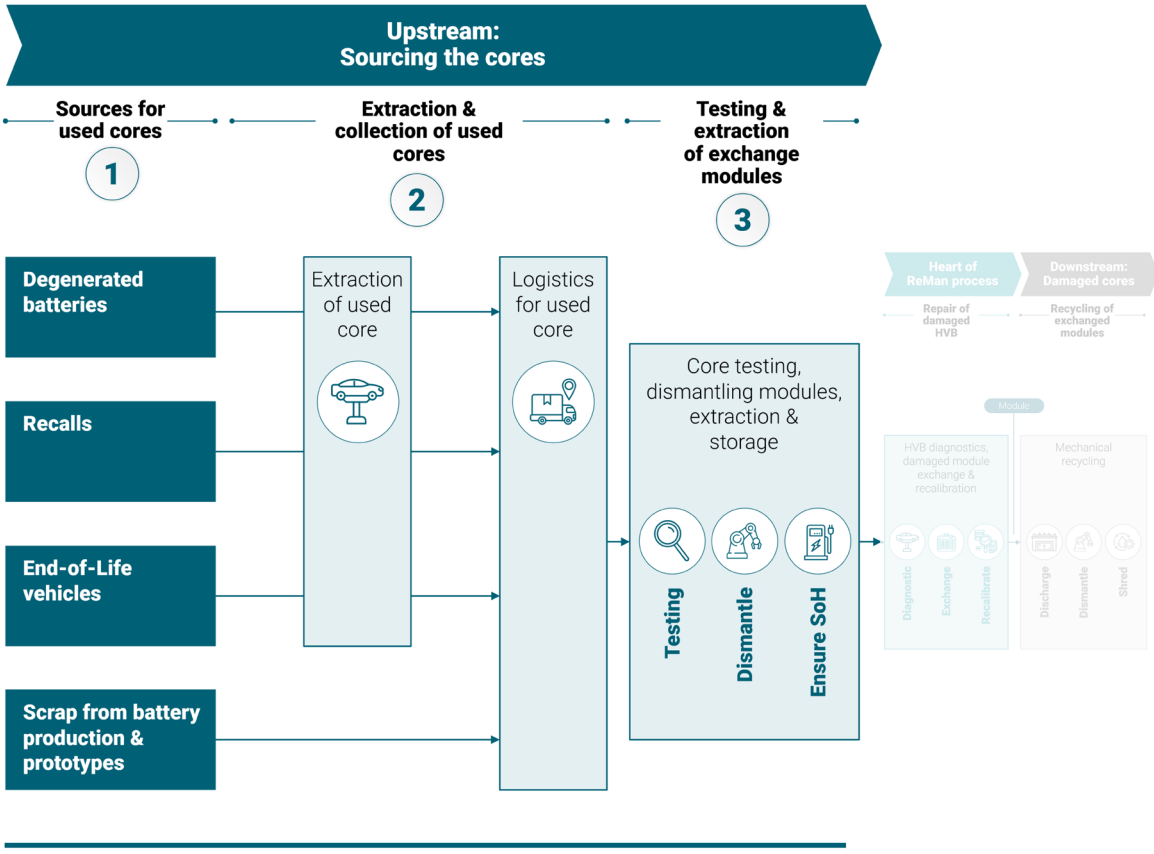
HVB remanufacturing value chain for modules



Here, we look at each of the three stages in greater detail:

GRAPHIC 3.1

Upstream elements of the remanufacturing value chain



1 Sourcing of used cores

The remanufacturing value chain starts with securing access to used battery packs (called 'cores'). Sources include degenerated batteries, warranty replacements, recalled units, end-of-life vehicles and machines, production scrap and prototype batteries. Today volumes are fragmented, and ownership is often unclear. Strategic access to these flows is critical for building a viable remanufacturing footprint.

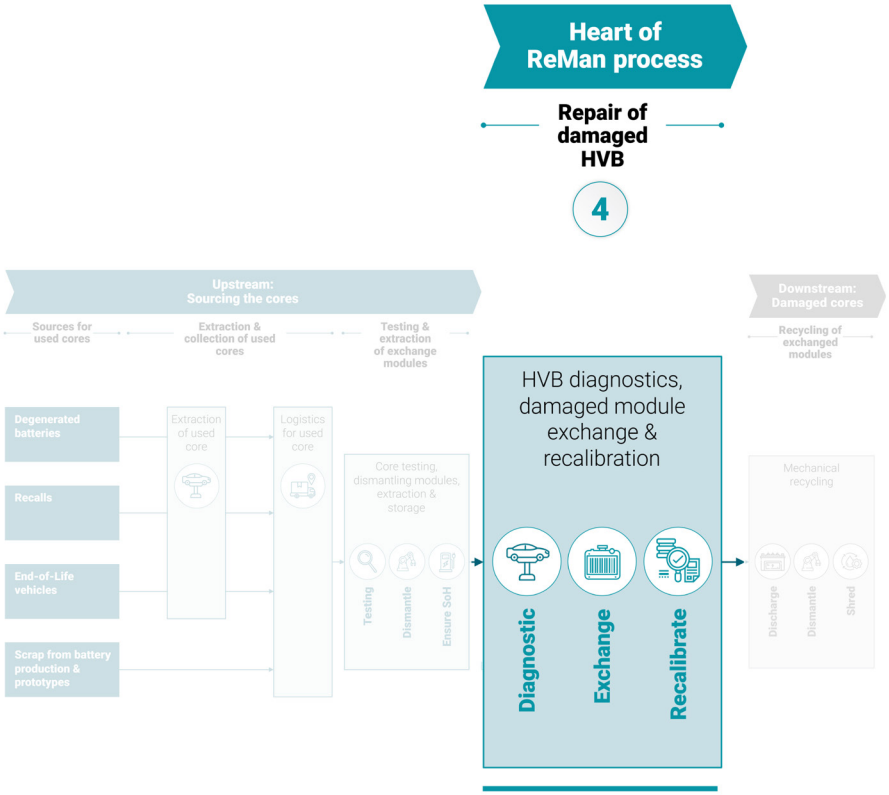
2 Extraction & collection of used cores

Extraction involves isolating the high-voltage system, discharging it under controlled conditions, and removing the used high voltage battery pack. We expect this to be done mostly decentralized in specialized dealerships and repair networks. In cases where a 'totaled' or end-of-life vehicle or piece of equipment will be recycled, it may instead go to a centralized dismantling facility where the HVB is extracted along with other potentially re-usable modules or components. Collection and logistics processes must comply with dangerous goods regulations, and traceability is essential to ensure safety and warranty integrity.

3 Testing & extraction of exchange modules

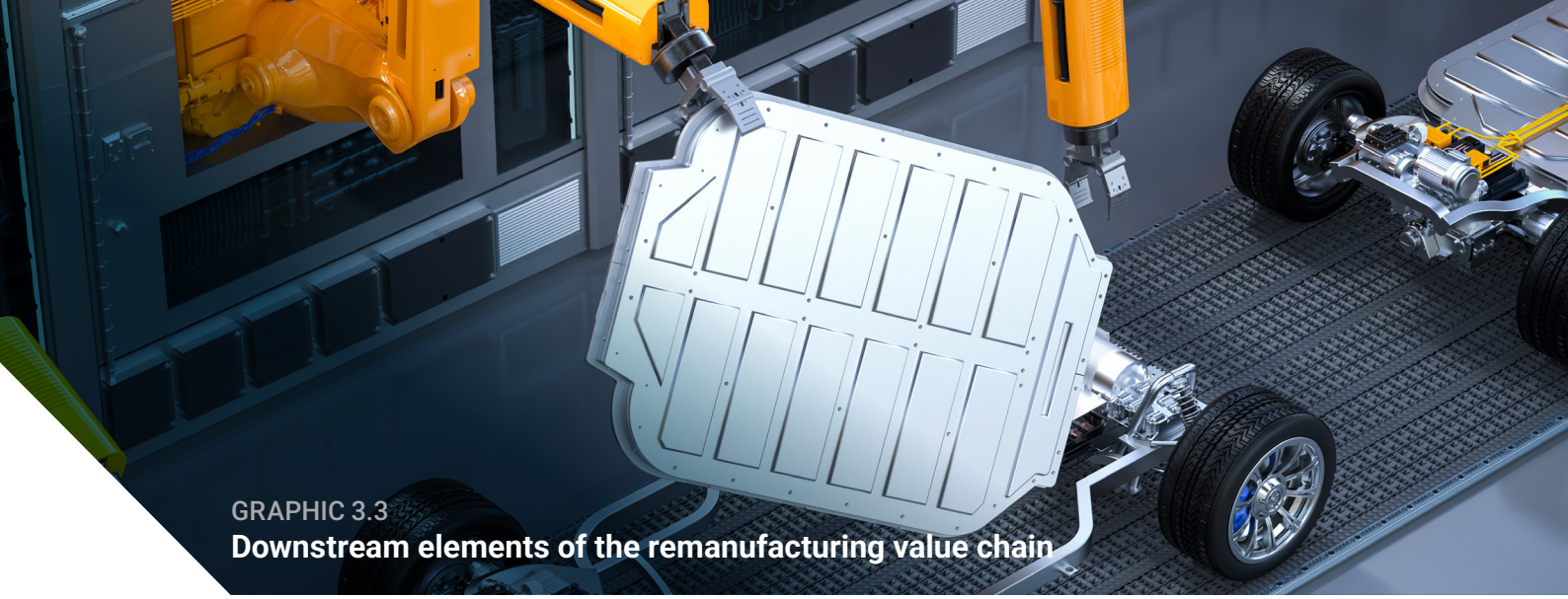
At specialized hubs, HVBs collected from the different sources undergo non-destructive testing to assess their state of health. High voltage battery systems are opened, and the individual modules extracted and tested. Modules which qualify to be used as exchange/swap modules in the remanufacturing value chain (i.e. those which are technically sound and show sufficient remaining state-of-health) are certified and stored with sufficient state-of-charge. This step is the technical heart of remanufacturing, and the most capital-intensive. Battery modules are still relatively expensive and a large number of replacement modules will need to be stored so that remanufacturers and repair centers have an appropriate module at hand for all the different technical specifications. For ESS assets, module traceability and certificate management across cell suppliers are paramount to maintain system warranties and grid-compliance documentation.

GRAPHIC 3.2
Core element of the remanufacturing value chain

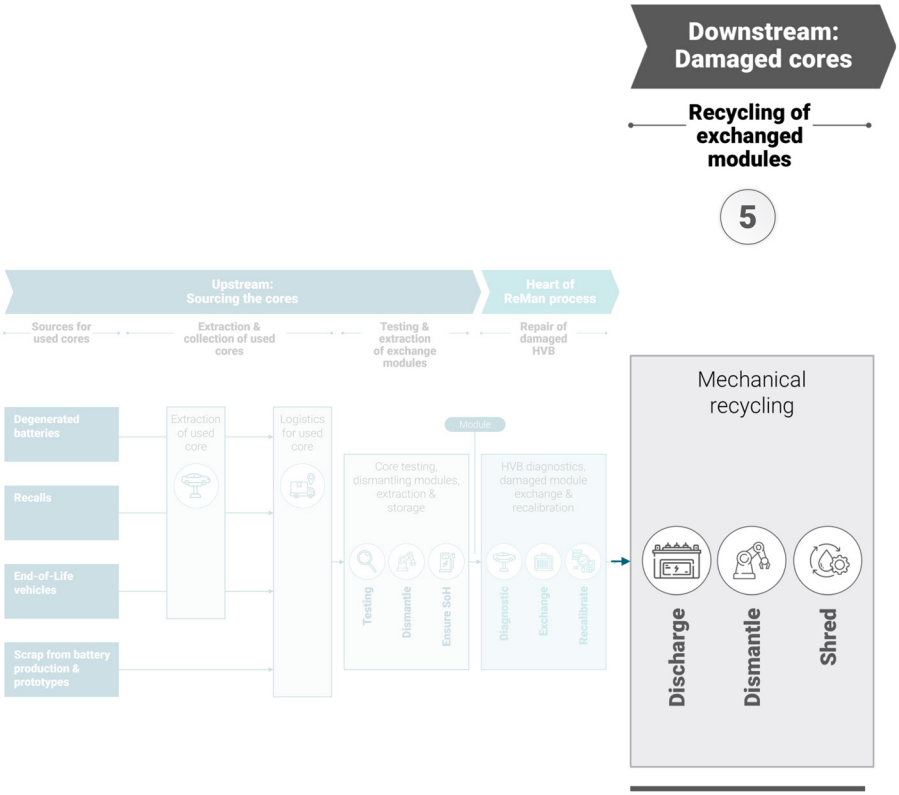


4 Asset-level repair

Vehicles and stationary systems will undergo diagnostics in workshops, depots, or on customer sites to identify faulty modules, if the state of health (SoH) of the HVB drops below certain thresholds ahead of the typical aging curve. Typically, when this happens, not all the modules of the HVB are damaged, just one or two, which still reduces the average SoH of the whole HVB considerably. Damaged modules are removed and replaced with compatible certified remanufactured units (where available). The battery management system (BMS) of the repaired HVB is then rebalanced and recalibrated to ensure performance and safety. This decentralized step is key to minimizing downtime and protecting customer experience, as the repair can happen in a range of workshops/ customer sites.



GRAPHIC 3.3
Downstream elements of the remanufacturing value chain



5 Exchanged/ damaged module recycling

Returned modules that fail testing in the workshop or are damaged are discharged, dismantled, and shredded. The resulting “black mass” is then fed into established recycling streams and ultimately will go back upstream into battery cell manufacturing, supporting circularity and broader ESG goals. Ensuring efficient and effective routing between remanufacturing and recycling is essential to prevent bottlenecks and maximize value recovery.

5 | Success factors in HVB remanufacturing

Module level remanufacturing offers the best value trade-off

Our extensive experience working with OEMs, equipment manufacturers (including ESS integrators), suppliers, and downstream players has taught us that winning in HVB remanufacturing requires more than technical capability. It demands strategic clarity and operational discipline across the entire value chain.

Players must focus on **three imperatives:**

1 Design for remanufacturing

As we described in Section 2, HVB remanufacturing is technically demanding and operationally complex, and one of the key reasons is the variety of design across battery cells, modules and packs and the different technologies and assembly methods used. So, building a successful HVB remanufacturing business starts at the design and assembly stage. OEMs and battery makers will need to prioritize product design that enables easier disassembly and module recovery, so that HVBs can be taken apart in a straightforward and standardized way for inspection and repair, and then reassembled in an equally standardized way.

2 Secure supply and demand intelligence

Access to and the condition of used modules (cores) will define the economics of remanufacturing. Leaders must build privileged sourcing channels, inspection processes, and anticipate localized supply and central demand through advanced core collection and forecasting systems. Pricing strategies should then influence customer behavior and stabilize volumes. Without predictable flows, scale remains elusive.

3 Set and scale the operating model

The right remanufacturing footprint is a balancing act: centralization delivers economies of scale, while decentralization ensures speed and customer proximity at acceptable logistics costs. Providers must decide which steps to own, outsource, or partner for (including collection, inspection, operations, testing, and logistics) and set inspection, quality and other standards that work globally while allowing for local operational flexibility.

HVB Remanufacturing

These strategic elements are not optional. They are each made up of sets of critical decisions that work together to deliver or destroy value: OEMs and suppliers must get them all right.

6 | The time to act is now

High-voltage battery remanufacturing is no longer a distant concept – it is the next large profit pool across electrified mobility and energy storage. OEMs, equipment manufacturers, ESS integrators, suppliers, and the independent aftermarket all share the same starting point: a window of opportunity to build a scalable, defendable, lucrative business. But that window is closing fast. Early movers will shape standards, secure core access, optimize workflows, and lock in customer trust across segments. That leaves late entrants at risk of being locked out and losing customer access later in the asset's lifecycle.

HVB remanufacturing is not just about operational efficiency and technical capability. Companies also need to decide today: which steps of the value chain will you own, and which elements of the battery will you focus on? Where will you partner and how will you choose partners that are the right fit? How will you balance centralization for scale with decentralization for speed and cost?

WHEN IT REALLY MATTERS, TALK TO THE EXPERTS.

If you have questions about building, scaling, or defending your HVB remanufacturing business, our global team at AlixPartners and Berylls by AlixPartners is ready to help you design the roadmap and capture the value, before someone else does.

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ABOUT US

For more than forty years, AlixPartners has helped businesses around the world respond quickly and decisively to their most critical challenges—circumstances as diverse as urgent performance improvement, accelerated transformation, complex restructuring and risk mitigation.

These are the moments when everything is on the line—a sudden shift in the market, an unexpected performance decline, a time-sensitive deal, a fork-in-the-road decision. But it's not what we do that makes a difference, it's how we do it.

Tackling situations when time is of the essence is part of our DNA—so we adopt an action-oriented approach at all times. We work in small, highly qualified teams with specific industry and functional expertise, and we operate at pace, moving quickly from analysis to implementation. We stand shoulder to shoulder with our clients until the job is done, and only measure our success in terms of the results we deliver.

Our approach enables us to help our clients confront and overcome truly future-defining challenges. We partner with you to make the right decisions and take the right actions. And we are right by your side. When it really matters.

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