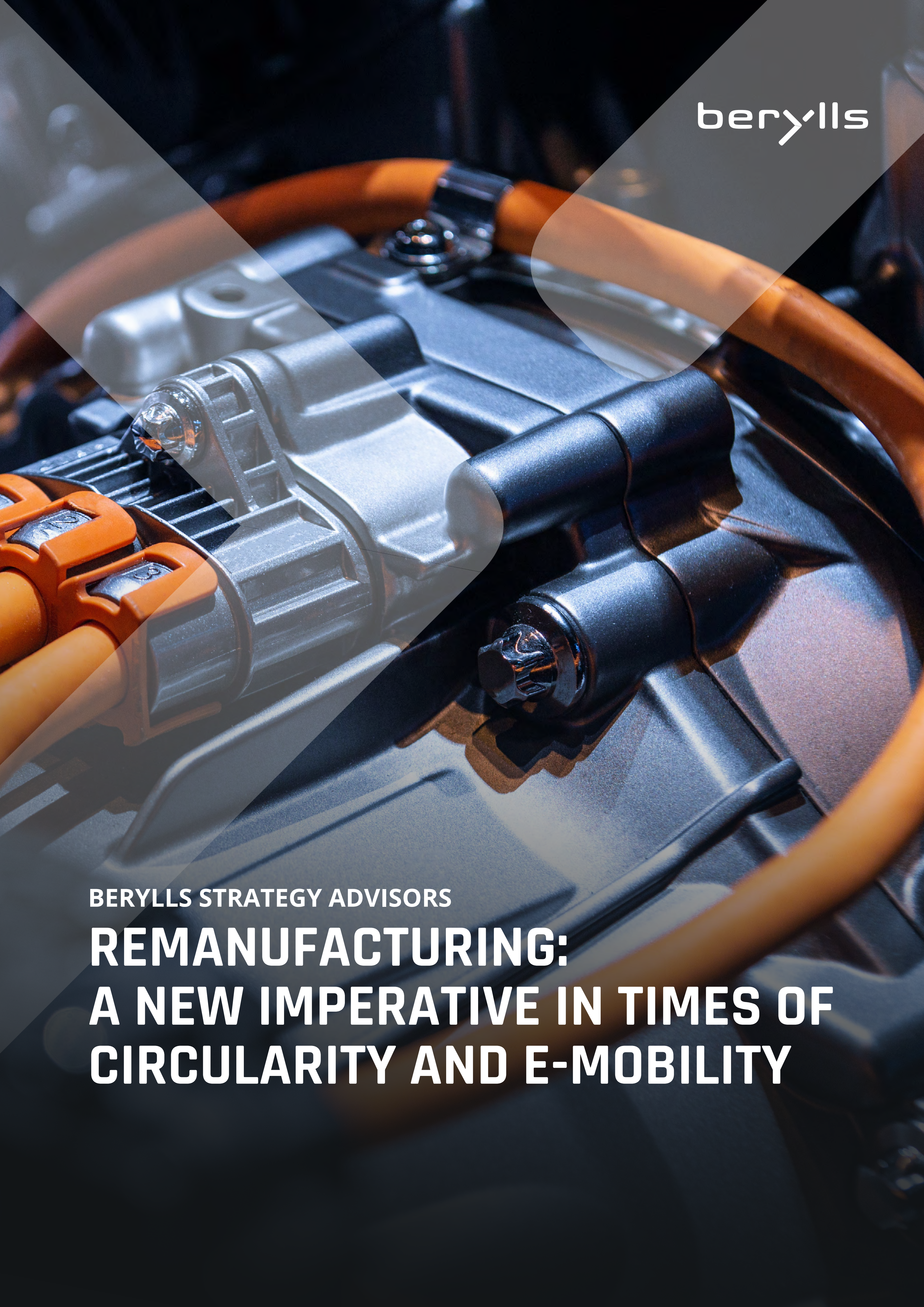
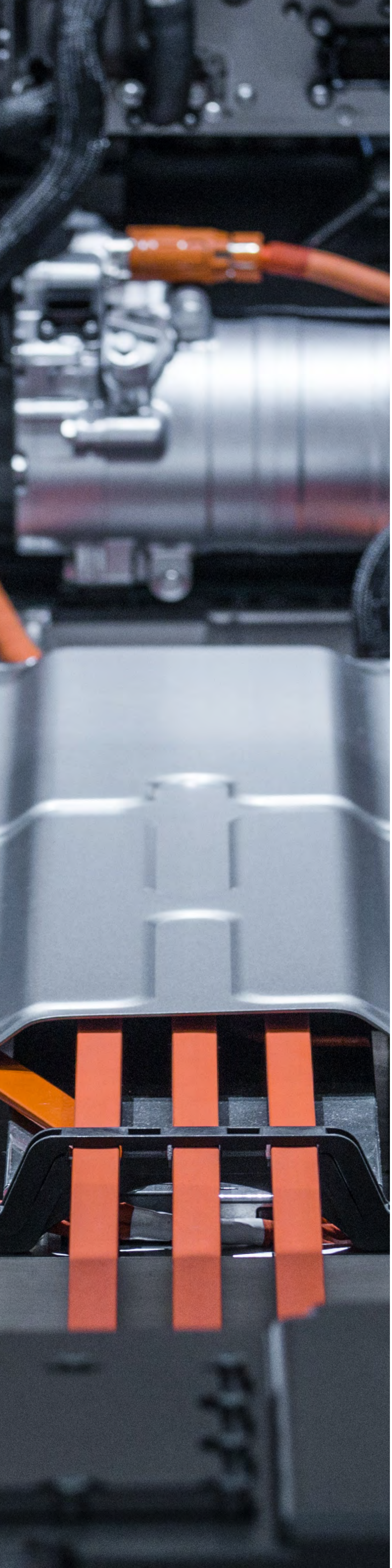


BERYLLS STRATEGY ADVISORS

REMANUFACTURING: A NEW IMPERATIVE IN TIMES OF CIRCULARITY AND E-MOBILITY



Remanufacturing is a powerful lever to increase both economic and environmental sustainability. However, the establishment of a full remanufacturing ecosystem requires effort and stamina on the part of OEMs and suppliers. The effort is worthwhile. As the world's demand for more sustainable products and value chains becomes increasingly clear, remanufacturing is key to success.

AGENDA

1 Introduction: Circularity in the automotive industry

2 Remanufacturing in the circular economy

3 The module perspective: Assessing and designing “fit-for-reman”

4 Case example: Cost and benefit of remanufacturing an on-board charger

5 Conclusion: Imperatives to make reman work

1

INTRODUCTION: CIRCULARITY IN THE AUTOMOTIVE INDUSTRY

Rising cost for raw material, insecure supply chains and ever-increasing pressure on sustainability goals: The need and the upside for sustainability in the value chains are increasing drastically. Recalibrating the value chains and transforming towards a circular economy becomes a must for those who want to last.

Four pillars define the circular economy in the automotive industry: Refurbishment, Remanufacturing, Reuse and Recycling. These 4Rs differ according to the product level which they address (vehicle, module, or parts) and the respective activities: All allowing for a better utilization of resources. To make the different elements work two aspects are critical: A functioning ecosystem and suitable products.

While refurbishment is a powerful lever on the vehicle-level and recycling is the way to go when it comes to raw material on a part-level, remanufacturing and reuse are in scope when considering the module or component-level. While reuse is often applied to second-life applications and parts where a certain wear is acceptable, remanufacturing is a powerful approach when modules lose certain performance characteristics over time but can be reconditioned to return to their original purpose.

Figure 1: Pillars of circularity: Refurbish, Remanufacture, Reuse, Recycle (4Rs)

	1R	2R	3R	4R
Step	REFURBISH	REMANUFACTURE	REUSE	RECYCLE
Level	Vehicles	Modules		Parts
Activity	**Overhaul used vehicles** to bring them to the required quality level for their next use cycle	**Repair or recondition used or broken modules and components** so they perform as well as new ones	**Put a used, still-working module** into another vehicle or use for second-life application	**Dismantle cars and parts** down to their **raw materials** and reintroduce into production
Examples (Battery EV)	**Repair and polish up a used vehicle for a new customer** (e.g., fix dents and scratches or retrofit new components like head-up displays)	Replace **defective elements of an on-board charger** with a remanufactured one to make it fully functional	Reuse a battery in a **new vehicle** or as a form of **stationary energy storage**	Extract **cobalt, lithium, rare earths** and other valuable materials from the battery pack

2 REMANUFACTURING IN THE CIRCULAR ECONOMY

The goal of remanufacturing is to return a product to its original performance quality with a warranty that is comparable to a new one. Thereby, the remanufacturing process creates a closed circular value chain where only a fraction of new material and emission is required, e.g., when replacing defect or low-performing components. Overall, we see three process steps that close the “reman” value chain:

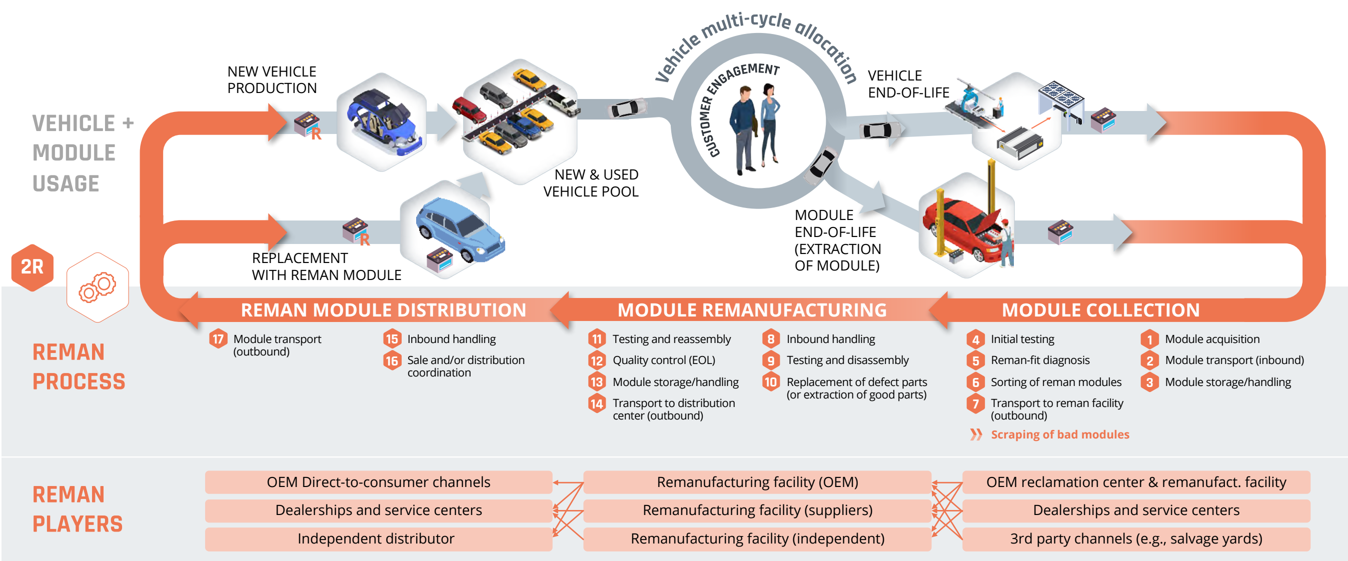
» **Module collection** starts with the identification and extraction of products for remanufacturing from the vehicle. Further testing confirms whether or not a module or component is “reman-fit”. If it is, the product is transported to either the OEM’s “reman” facility, or a dealership or service center. If it is not, the product is scrapped.

» **Module remanufacturing** can only begin after further testing and where necessary, disassembly to separate defective from functioning parts. The “good” parts are then submitted to further testing, reassembly, and rigorous end-of-line (EOL) quality control.

» **Module distribution** involves the sale or distribution of the remanufactured part to one of the OEM’s direct-to-consumer channels, a dealership service center, an independent distributor or to the plant of an OEM.

While OEMs and suppliers play a vital role in the remanufacturing process the ecosystem is not limited to these players. A network of partners that span from car service stations, waste collection services, to dedicated remanufacturing service providers may enter the ecosystem. Looking at the value chain, critical success factors include access to the used modules in the market, distribution capabilities, technical competencies and capacities to remanufacture the respective modules.

Figure 2: Remanufacturing process and circular value chain for automotive



Source: European Remanufacturing Network, Berylls Strategy Advisors Analysis

After the remanufacturing process, the remanufactured modules are reintroduced into the lifecycle – for this, we see two major applications:

» The first one is the usage of remanufactured components as aftermarket parts to replace broken parts in existing vehicles. This application is already well established for certain components, e.g., transmissions for combustion engines.

» The second application may be the usage of the remanufactured parts in the "new" vehicle production. This usage is not yet established. In this context, product compliance, liability and homologation are of particular importance. Thus, a clear remanufacturing strategy per module should be pursued to also provide the legislative foundation for a later roll-out.

Ideally, everyone wins from remanufacturing – the OEM, suppliers, dealers, customers and society at large. Well-designed and implemented remanufacturing most obviously helps the environment by reducing waste and cutting carbon emissions, as suppliers no longer need to build complete modules. Remanufacturing also creates cost efficiencies and increases productivity through the resale of used parts and the lowering of shipping and lead times. The overall saving in time, money and resources increases profits, while the OEM gains a better reputation by demonstrating its commitment to sustainability.

To sum it up, establishing an ecosystem around remanufacturing and involving other participants are key for a successful execution of remanufacturing. However, besides bringing structures, processes and capabilities in place, the module to be remanufactured and its applicability to remanufacturing – or "remanufacturability" – may be even more relevant for success.

3

THE MODULE PERSPECTIVE: ASSESSING AND DESIGNING “FIT-FOR-REMAN”

The most important question for OEMs and suppliers to answer before building up a remanufacturing ecosystem is which modules should be remanufactured. The first decision criterion should be the value of a module. As remanufacturing is a complex and costly process, it is very likely that it can only be executed profitably for modules with a certain value. Therefore, sorting the bill-of-material (BOM) along price is a good start in determining components that are fit for remanufacturing. However, the module’s value or economic relevance must not only be determined by the actual price the OEM pays for the module when purchasing it from the supplier but can also be a “strategic value”, e.g., with very scarce material or a volatile supply chain.

Taking economic relevance (and expected profitability) into account, a successful “reman” outcome depends on how far the identified part or module meets the following four criteria:

» **Component design: How well does the product design allow for remanufacturing?**
Focus areas: Smooth disassembly and the degree to which the product’s performance relies on a few key parts or modules that fit easily together

» **Process capability: How efficient is the remanufacturing process?**
Focus areas: Additional expertise to ensure that production and remanufacturing processes are similar, with the same level of flexibility and automation

» **Wear characteristics: How well does the component’s durability support remanufacturing?**
Focus areas: Wear-and-tear of modules and parts compared with other components, and checking that returned products are free of contaminants such as dirt and oil

» **Ecological benefit: How much better is the remanufactured part’s environmental footprint?**
Focus areas: Avoidance or reduction of waste, lower CO_2 emissions, and compliance with relevant environmental laws and regulations, such as remanufacturing quotas

These dimensions not only function as assessment criteria for existing products but also as guidelines for product design of new modules and components. Particularly for the long-term optimization of remanufacturing a holistic consideration throughout the product creation process (and standardization/multi-usage of modules across models) is a key driver for scale and economic benefit.

The results when applying this logic to a current BOM of a mid-size electric vehicle are shown in figure 3. While the battery module has the highest economic relevance as a share of the BOM, product design, processability and wear characteristics make it less appealing for remanufacturing. The assessment shows, that of the 15 modules with the highest share, electronic modules and the on-board charger in particular appear to be promising candidates for remanufacturing.

Figure 3: Assessment of 15 modules with the highest economic relevance for remanufacturing

NO.	ITEM	ECONOMIC RELEVANCE (AS % OF BOM)	COMPONENT DESIGN	PROCESS CAPABILITY	WEAR CHAR-ACTERISTICS	ECOLOGICAL BENEFIT	OVERALL RATING
		rank order	weight: 30%	weight: 30%	weight: 30%	weight: 30%	100%
1	Battery unit	**35% – 40%**	●●○	●○○	●○○	●●●	●◐○
2	Body and doors	**5% – 6%**	●○○	●○○	●●○	●○○	●◔○
3	E-drive (excl. OBC)	**3% – 4%**	●●●	●●○	●●○	●●○	●●◔
4	Cockpit display panel	**2% – 3%**	●●○	●○○	●●●	●●○	●●○
5	Seat assembly	**2% – 3%**	●○○	●●○	●●○	●○○	●◐○
6	Network connector	**1.5% – 2%**	●○○	●○○	●●○	●●○	●◐○
7	Cockpit domain controller	**1.5% – 2%**	●○○	●●○	●●●	●●○	●●○
8	Wheel system	**1.5% – 2%**	●●○	●○○	●○○	●○○	●◔○
9	Brake system	**1.5% – 2%**	●●○	●●○	●○○	●○○	●◐○
10	Front combination light	**1% – 1.5%**	●○○	●●○	●●○	●○○	●◐○
11	On-board charging system	**1% – 1.5%**	●●●	●●●	●●●	●●○	●●◕
12	Motor controller HV wiring	**1% – 1.5%**	●○○	●○○	●○○	●○○	●○○
13	In-Car monitoring system	**1% – 1.5%**	●○○	●●○	●●○	●○○	●◐○
14	Electric power steering assembly	**<1.0%**	●●●	●●○	●○○	●○○	●◕○
15	Electronic booster/brake master pump	**<1.0%**	●●●	●●○	●●○	●●○	●●◔

●●●: High remanufacturability ●●○: Medium remanufacturability ●○○: Low remanufacturability

Source: Berylls Strategy Advisors Analysis

4

CASE EXAMPLE: COST AND BENEFIT OF REMANUFACTURING AN ON-BOARD CHARGER (OBC)

Considering the assessment of the 15 modules with the highest share in the BOM, we applied the remanufacturing ecosystem introduced under section 1 to an OBC and sketched a cost break-down assuming a remanufacturing facility with a capacity of approximately 9,500 units per year.

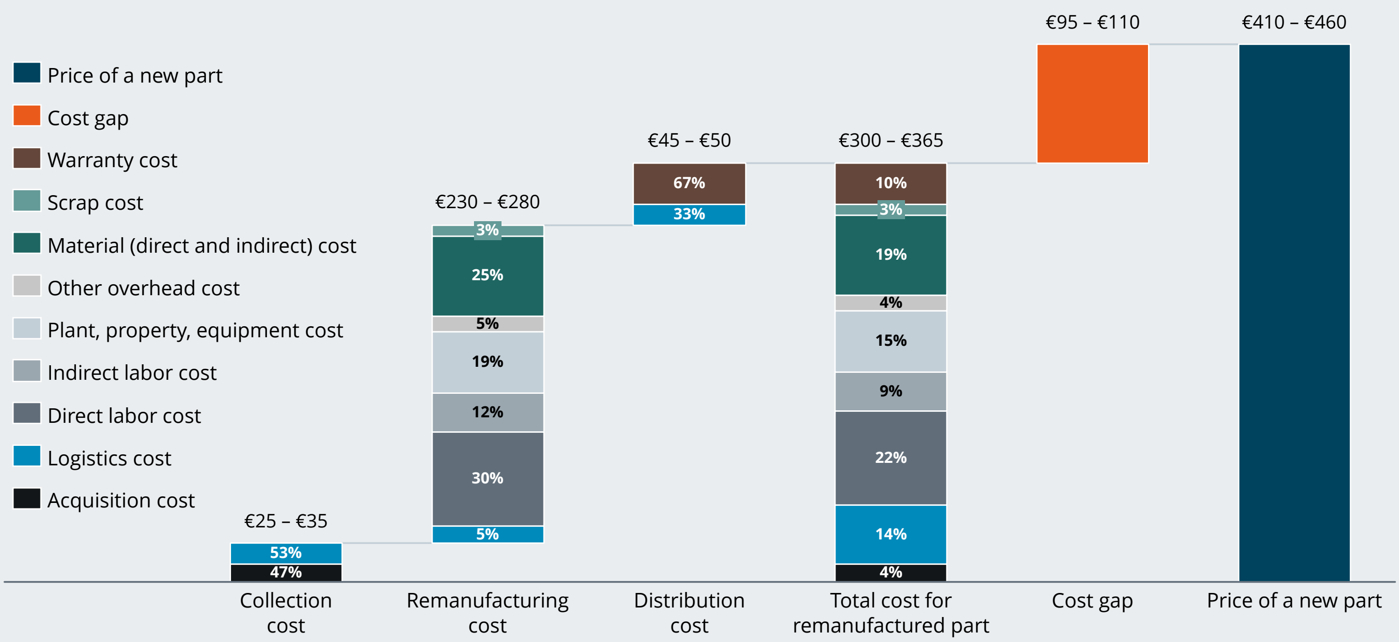
Looking into the cost structure for the remanufacturing cost of an OBC, three key observations can be made:

» **Labor and material cost are the largest drivers:** As we consider a rather decentralized and less automated approach for remanufacturing, labor cost is with approx. 20% relatively high, especially when contrasted to automated series production. In addition, material cost also accounts for a certain cost, mostly because we expect several components and even entire segments (e.g., printed circuit boards) to be replaced within an OBC in order to achieve performance characteristics that are comparable to new ones.

» **The majority of cost incur in the actual remanufacturing process:** While logistics and coordination of modules within the market appear to be very complex the share of cost is rather low. Nevertheless, players active in these areas are demanding a share of the margin either way.

» **There is money in it:** Assuming an average price range for OBCs between €410 and €460 a potential margin of €95 to €110 (>20%) can be achieved.

Figure 4: Indicative bottom-up cost calculation for a remanufactured on-board charger



Source: Berylls Strategy Advisors Analysis, International Council on Clean Transportation (ICCT)

So, what is the market potential for remanufactured OBCs? Looking at the usage of remanufactured components as potential aftermarket parts, the market size is largely driven by the size of the electric vehicle (EV) fleet. Forecast scenarios for the EV stock in 2030 range from 200mn units to 350mn units[1]. Assuming that 10% of cars need to have its OBC replaced and 25% of those parts can be covered by remanufactured components a volume of 5.0mn to 8.8mn units results. With a potential margin of €100 per OBC[2], remanufacturing of OBCs may save €500mn to €875mn p.a. by 2030.

As illustrated above, the application of remanufactured components in the production of "new" vehicles may be another use-case – neglecting legislative challenges for now. Forecast scenarios for EV sales in 2030 range from 30mn to 65mn[1]. Assuming every car needs to have an OBC (or similar) and 15% will be covered by remanufactured components an additional volume of 4.5mn to 9.8mn units results.With a potential margin of €100 per OBC[2], remanufacturing of OBCs may save another €450mn to €975mn p.a. by 2030.

Combining both outlooks, remanufacturing of OBCs has the potential to save the automotive industry €1bn to €2bn p.a. by 2030.

[1] Source: Global EV Outlook 2022, International Energy Agency (IEA)
[2] Note: Not accounting for changes in price and inflation for OBCs until 2030

5 CONCLUSION: IMPERATIVES TO MAKE REMAN WORK

Eventually, remanufacturing is a powerful lever to reduce new material and energy consumption as well as material cost and allows to leverage existing capacities (e.g. personnel and infrastructure).

Thereby, remanufacturing improves both environmental sustainability and profitability.

When designing vehicles and corresponding value creation processes five imperatives for OEMs, suppliers, and regulators result:

» **Build an ecosystem:** OEMs and suppliers should identify and team up with the right "reman" partners

» **Develop design and process capabilities:** Components and modules should be made as far as possible with a view to being remanufactured

» **Prioritize and plan the product portfolio:** Identify products with the most "reman" potential and aim for a portfolio which is remanufacturable

» **Push for a "reman-friendly" regulatory environment:** Remanufacturing is a volume game, so OEMs and suppliers must ensure that regulators are playing on the same side as well

» **Hang in there:** Remanufacturing is also a long game, where only the most determined players will reap the full reward. But the prize is worth the effort – stay the course!

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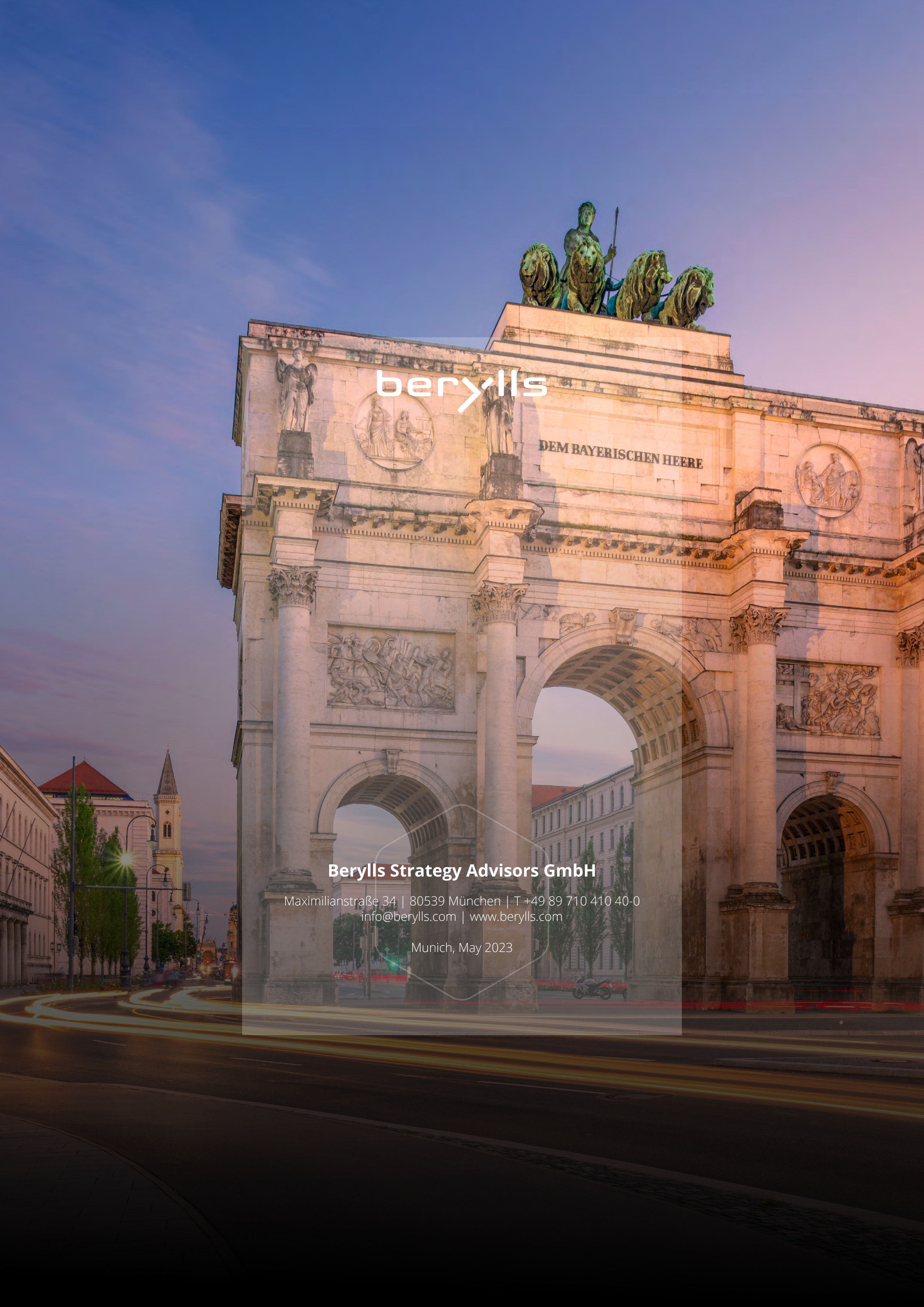

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Munich, May 2023