WHITE PAPER

Circular economy & remanufacturing in electronics manufacturing

Strategic lever for TCO, materials management and European nearshoring

Author	Organisation	Version	Target audience
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Executive Summary

The circular economy in electronics manufacturing is not just about environmental protection – it is a direct answer to three problems that companies feel every day: rising material costs, dependence on Asian supply chains and growing legal requirements from Brussels.

Remanufacturing – the complete reconditioning of assemblies to new condition – and refurbishment – the marketable reprocessing – offer concrete advantages: lower total cost of ownership (TCO), less dependence on raw material markets, recovery of valuable materials, and a clear economic reason to relocate production closer to Europe. Circular economy systems simply cannot be operated economically across continents – logistics necessitates a decision in favor of Europe.

This white paper shows why this topic is a strategic priority for OEM companies today – and what concrete steps can be derived from it.

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1. Initial situation: More and more devices, less and less recovery

The electronics industry is growing – but recycling is not keeping pace. According to Eurostat, more than 14.4 million tonnes of electrical and electronic equipment were sold in the EU in 2023, an increase of over 89 percent since 2012. [1] Of this, only 5.2 million tonnes were collected and properly processed – that's a rate of 37.5 percent. [2]

Germany is particularly striking: despite a strong industrial base, only 29.5 percent of electronic waste was properly collected there in 2023. [3] The rest was lost due to lack of return, unreported disposal routes, or export as used goods – and with it, the raw material value it contains.

The 10.7 million tons of e-waste generated in the EU in 2022 contained approximately 1 million tons of critical raw materials – including 162,000 tons of copper, 208,000 tons of aluminum, and 2 tons of palladium. Only about 0.4 million tons of this was actually recovered. [4] The rest is lost.

Market potential Remanufacturing in Europe

In 2015, the European remanufacturing market for electrical and electronic equipment was estimated at €3.1 billion (source: ERN study 2015, cited in EIONET report 2021). The World Bank forecasts growth for the entire European remanufacturing market to €100 billion by 2030 – associated with CO_2 savings of 21 megatons (source: World Bank 2022, cited in arXiv 2512.03732).

2. Was bedeutet was: Repair, Refurbishment, Remanufacturing

The three terms are often confused. The difference lies in the depth of the intervention:

Repair / Reparatur	Fix a specific defect. No systematic inspection, no replacement of other parts. Minimal effort.
Refurbishment	Refurbishment to a saleable condition. Cleaning, testing, replacement of worn parts – but not a full manufacturing standard.
Remanufacturing	Complete refurbishment to like-new condition. Disassembly, inspection of all components, replacement of worn parts, reassembly according to original specifications. Maximum effort, maximum value retention. Technically, like-new condition is achievable – the crucial question is how the life cycle is redefined afterward. [1]
Recycling	Recovering raw materials through dismantling. Preserving value at the material level – the product itself is then gone.

1 The question of warranty is not unresolved. The international standard IEC 62309 addresses precisely this issue: It describes methods for assessing the remaining service life of reused components, specifies qualification tests, and defines documentation and warranty obligations for products with remanufactured components. Those who work according to this standard can assess and document the remaining service life of remanufactured components in a traceable manner and, based on this, provide a sound basis for warranty and guarantee decisions. For critical industrial assemblies, this is the crucial prerequisite – not whether remanufacturing is technically possible, but whether the remanufacturer can demonstrably recalculate and document the remaining service life. [14]

For OEM companies, remanufacturing is particularly interesting: it maintains the value at the assembly level, reduces new procurement and relieves the burden on logistics.

3. What remanufacturing really costs – and what it saves

3.1 Direct savings through reprocessing

Compared to manufacturing new parts, remanufacturing can reduce production costs by 40 to 64 percent, energy consumption by around 60 percent, and material usage by up to 70 percent. [5][6] These are not projections – these figures apply to industrial sectors such as drive technology, medical technology, and automotive supply, which have been using remanufacturing for years. Remanufacturing thus saves directly during production. But the real cost advantage only becomes apparent when considering the entire supply chain – and this is where the second, often underestimated, lever lies.

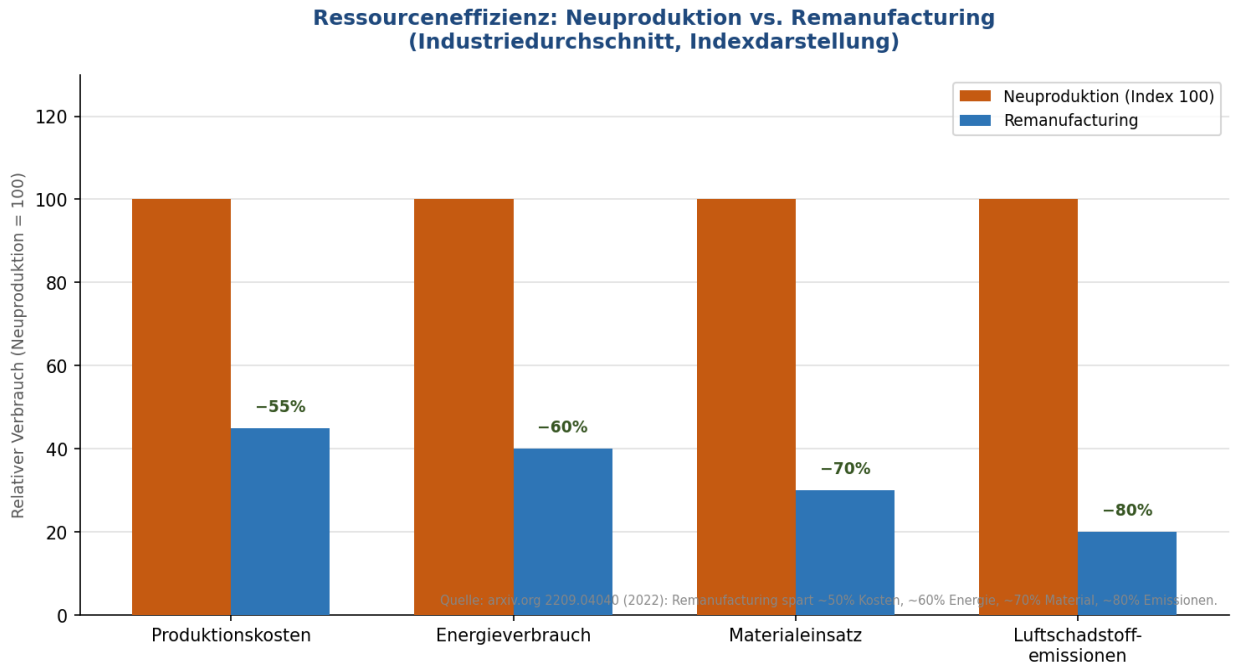

Fig. 1: Resource comparison – new production vs. remanufacturing (Source: arxiv.org 2209.04040, 2022)

New Production (Index 100) Remanufacturing

3.2 The hidden part of the invoice

Comparing only the purchase price provides an incomplete picture. Sourcing from Asia involves significant additional costs: freight and customs duties, warehousing for safety stock, incoming goods inspection, and the risk of delivery delays or failures. Experts estimate that these indirect costs can exceed the pure purchase price by 30 to 50 percent. [7]

The savings of 40 to 64 percent cited in the literature refer to the production costs of the remanufacturing process itself. The additional total cost of ownership (TCO) factors of sourcing new parts from Asia—particularly freight, customs duties, warehousing, and supply risks—can further increase the overall costs. Based on these two effects, an illustrative model calculation by the EMS Strategy Group yields a potential TCO saving of approximately 35 to 48 percent. These figures serve to illustrate typical scenarios and may vary depending on the product and supply chain.

Cost index	New purchase Asia	Remanufacturing Europa
Underlying value	100	100
Production costs	100	60–70
Logistics / Customs / Risk	+35 to +45	+15 to +18
Total TCO	135–145	75–88
Ersparnis	–	35–48 %

Table 1: Derivation of TCO savings – Calculation example from EMS Strategy Group

Those who refurbish component groups regionally do not incur these additional costs – or at least not significantly. The following graphic illustrates the cost structure from Table 1:

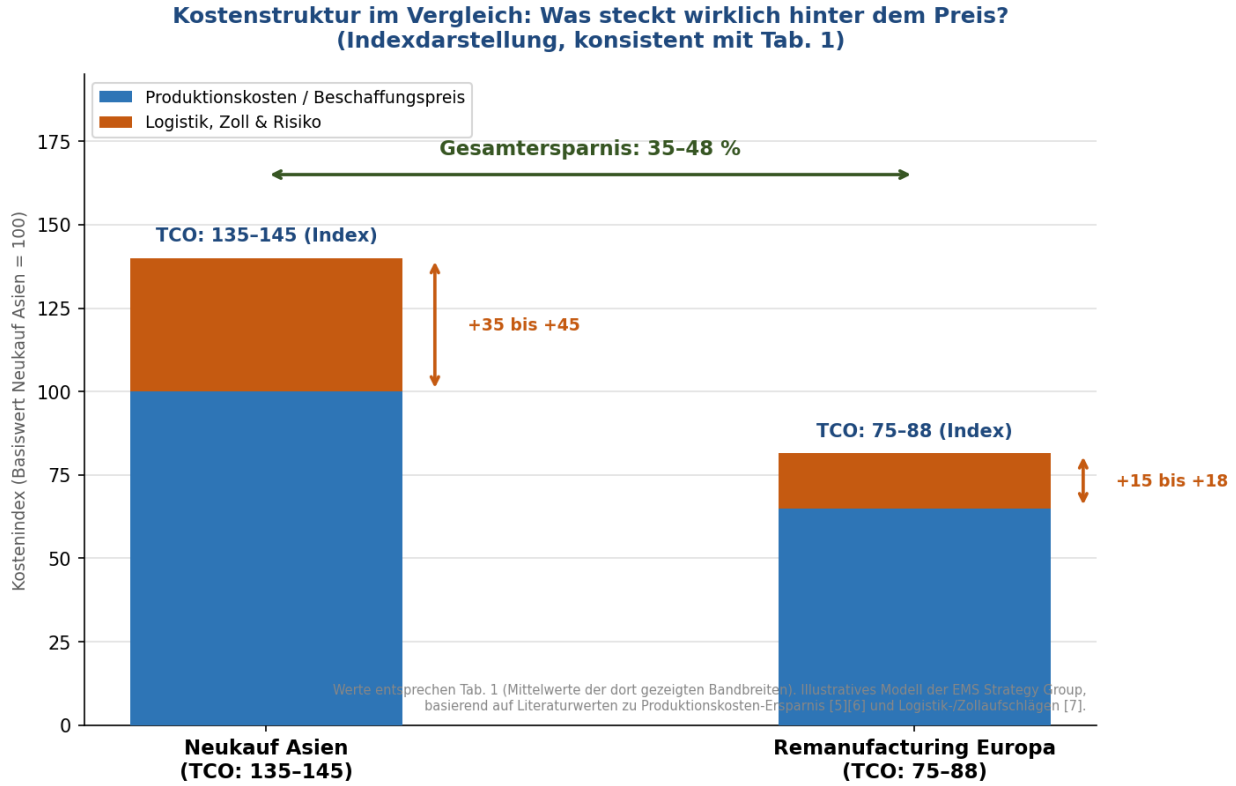

Fig. 2: Cost structure comparison – new purchase Asia vs. remanufacturing Europe (index representation, consistent with Table 1)

● Logistics, Customs & Supply Chain Risk ● Production Costs / Purchase Price

The graphic illustrates how the total savings of 35 to 48 percent are composed: When purchasing new parts from Asia, significant surcharges for freight, customs duties, warehousing, and risk are added to the procurement price. These surcharges are considerably lower when remanufacturing in Europe.

3.3 Total Cost Comparison

The following figure applies the calculation example from Table 1 to three typical assembly classes – from simple to complex. It compares list price, total cost of ownership (TCO) for new purchases from Asia, and TCO for remanufacturing in Europe:

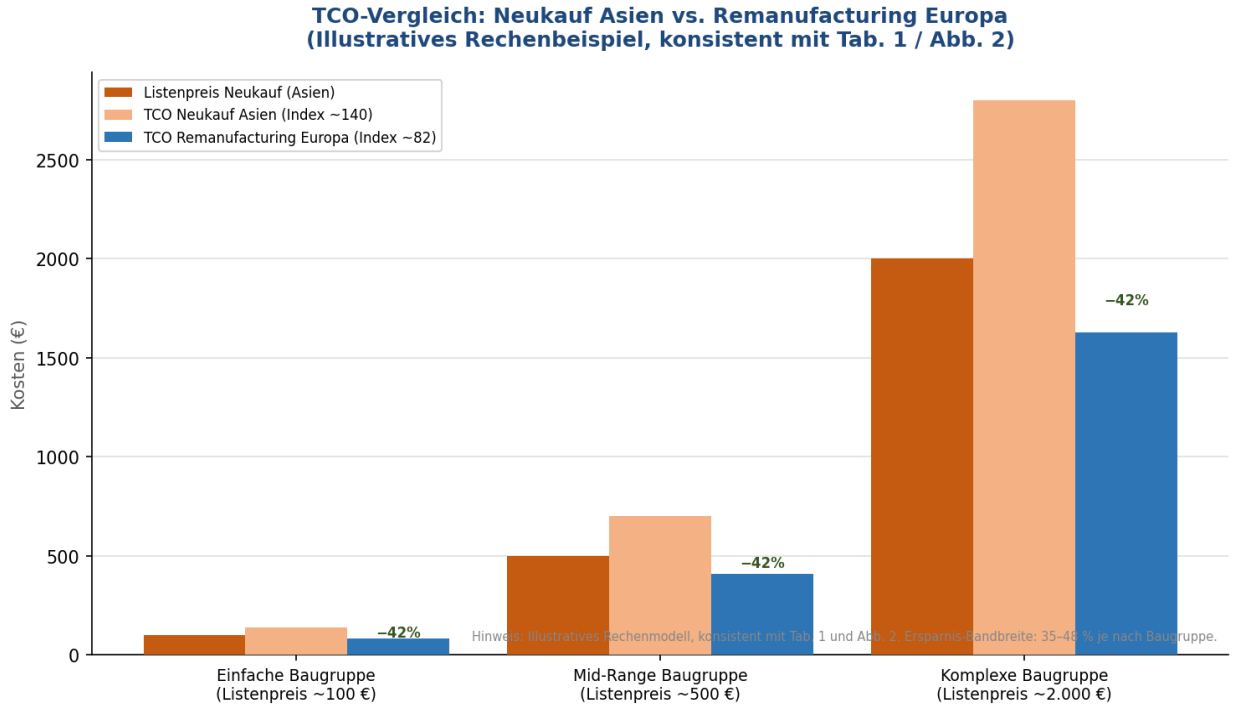

Fig. 3: TCO comparison of new purchase in Asia vs. remanufacturing in Europe by component class (Illustrative calculation model, consistent with Table 1 and Fig. 2)

New Purchase Price (Asia) **Remanufacturing TCO (Europe) – Index 82**

New Procurement TCO (Asia) – Index 140

assessment

Those who only compare the purchase price when procuring electronic assemblies are getting a distorted picture. Once freight, customs duties, storage costs and delivery risks are fully factored in, remanufacturing from Europe is often the more cost-effective choice – and not just the more sustainable one.

3.4 Valuable raw materials are contained in every component assembly

Electronic assemblies contain precious metals and critical raw materials with significant market value. Palladium—a standard material in multilayer capacitors—trades for $25,000 to $30,000 per kilogram. Even small improvements in recovery can yield millions of dollars on an industrial scale. [4]

The EU has enshrined this in law: The Critical Raw Materials Act (2024) sets the goal of covering at least 25 percent of the EU's annual demand for critical raw materials from domestic recycling by 2030. [8] Companies that are building circular systems today are well prepared for this.

4. What the EU prescribes – and what's to come

4.1 Ecodesign Regulation (ESPR)

The ESPR (Regulation EU 2024/1781) has been in force since 18 July 2024. [9] It significantly expands the previous ecodesign requirements: In the future, rules will apply to almost all products sold in the EU – no longer just to energy-related devices. For electronics manufacturing, this means specifically:

- Binding requirements for repairability, durability and recyclability
- Introduction of a digital product passport (DPP) for all regulated product groups
- Prohibition of the destruction of unsold consumer goods
- Planned requirements for the repairability of consumer electronics from 2027 onwards

The digital product passport is particularly important in this context: it obliges manufacturers to systematically document material composition and life cycle information. This is precisely the data basis needed for economically scalable remanufacturing. [10]

4.2 WEEE Directive: Revision is in preparation

The EU Commission has evaluated the WEEE Directive and announced a revision under the Circular Economy Act. [11] The aim is to give greater weight to reuse and refurbishment than to mere recycling. Companies that treat this as a mere obligation are missing out on the strategic added value.

5. Why the circular economy is attracting manufacturing to Europe

5.1 Cross-continental processing does not work

Closed-loop systems require that used devices and components be returned to the refurbisher. This return flow is time-critical and costly – and not profitable over intercontinental distances for three reasons:

- Legally: The new EU Waste Shipment Regulation (in force since May 2024) severely restricts returns and significantly increases the burden of proof. [11]
- Ecologically: Long sea freight routes contradict the ESG reporting obligation and will become more expensive in the future due to the carbon border adjustment mechanism (CBAM).
- Economic:Transportation costs, customs procedures and longer lead times can significantly reduce or, in many cases, completely eliminate the potential cost advantage of remanufacturing in the Far East..

5.2 Eastern Europe and DACH are the logical locations

The best locations for refurbishment centers are where used equipment is generated, skilled workers are available, and there is high demand for refurbished products. [12] Eastern European countries such as Poland, the Czech Republic and Hungary already offer favourable conditions for remanufacturing activities. They combine established industrial capabilities, comparatively competitive labour costs within the EU and shorter transport distances to Western European end markets. These characteristics make them well suited for supporting regional circular value chains. [13]

assessment

Recycling systems only work close to the end market. Those who send assemblies to Asia for remanufacturing end up paying more – through freight, customs, and waiting times. The cost advantage disappears before the assembly even returns. Those who establish remanufacturing capacities in Europe today will have a clear logistical and regulatory advantage tomorrow.

6. What OEM companies should address now

6.1 Establish take-back and inspection processes

The first step is internal: Companies need clear processes for the return of field-returned parts, end-of-life assemblies, and production rejects. This includes standardized testing protocols, a classification according to the level of refurbishment required, and a clear decision rule: refurbishment, remanufacturing, or material recovery?

6.2 Demand reprocessing expertise from the EMS partner

When selecting European EMS partners, it should be checked in the future whether they can remanufacture assemblies – or are willing to develop this capability. Relevant questions: Are there processes for component testing and classification? Can the partner disassemble assemblies and reassemble them according to the original specifications?Is the quality management system designed to release refurbished products according to defined quality criteria and to provide verifiable proof of their performance??

6.3 Prepare the digital product passport early

The digital product passport (DPP) will become mandatory for electronics and ICT products between 2028 and 2030. [10] Those who build the necessary data structure today – that is, systematically record material composition, life cycle information and repairability data – will save themselves an expensive retrofit process later and at the same time have the basis for a functioning remanufacturing system.

Specifically, this means: supplementing bills of materials with material data, requesting substance information from suppliers, and choosing a system that supports DPP requirements. Those who start now will not be under time pressure in 2028.

6.4 Full cost accounting instead of offer price

Decisions for or against remanufacturing should be based on a complete cost analysis – not just the lowest bid price. This analysis should include: freight and customs costs, capital tied up in safety stock, incoming inspection costs, the risk of delivery delays and failures, and the value of critical raw materials in the assemblies. Only with these figures can a realistic comparison be made.

6.5 Dual-sourcing strategy with reprocessing component

A useful addition to the classic dual-sourcing strategy is a second supply route via refurbished assemblies. This reduces dependence on a single new supplier and creates flexibility in case of bottlenecks – without lowering quality requirements, provided the refurbishment system operates according to defined standards.

7. Conclusions

The main conclusions of this white paper can be summarized as follows:

- Remanufacturing is not only a sustainability measure, but can also offer significant economic advantages under suitable conditions.
- Taking a complete view of the Total Cost of Ownership often changes the valuation compared to a purely price-based approach.
- European regulatory developments are increasing the importance of closed material and product cycles.
- The digital product passport and standardized procedures for lifetime assessment create important prerequisites for scalable remanufacturing.
- For many OEMs, the question in the future will likely not be,**at**remanufacturing is used, but**where**, **for which assemblies** and **under which economic conditions**

8. Conclusion

Circular economy in electronics manufacturing isn't just a matter for the sustainability department; it's an operational decision with direct implications for costs, supply security, and location strategy. Anyone seriously considering remanufacturing will inevitably encounter objections that are valid in practice and shouldn't be dismissed: At the beginning of a product lifecycle, returns are simply lacking; returning assemblies is logistically more complex than a well-planned container shipment; labor costs in Europe are higher than in Asia; and a remanufactured component is never physically exactly the same as a newly produced one. These points are real and shouldn't be downplayed by anyone seriously advocating for this approach.

That's precisely why this approach only convinces me when considered in its entirety. Remanufacturing doesn't replace initial production, but rather addresses the initial maintenance cycles and field returns that occur anyway – as a strategy for the entire lifecycle, not just for day one. European regulations, especially the new Waste Shipment Regulation, create strong incentives for companies to organize their return flows within Europe; those who consolidate this through existing service hubs transform a legal obligation into a logistical advantage instead of a cost driver. The higher labor costs in Europe are offset once the saved material value is factored in – this leverage is considerable for precious metals and critical raw materials. And the question of reliability can be resolved methodically: IEC 62309 is a standard developed specifically for this purpose. It doesn't replace new physical goods, but it provides a methodological framework for transparently assessing and documenting the remaining service life of reused components and, based on this, making informed decisions about their further use. In conjunction with the preventive replacement of known aging components – for example, electrolytic capacitors – the reliability of refurbished assemblies can be specifically increased.

My assessment is therefore that remanufacturing is not a replacement for new production, but rather its economic complement throughout the entire product life cycle. Those who are aware of the aforementioned objections and systematically address them, instead of ignoring them, build a security of supply that is not easily shaken by fluctuations in raw material prices or geopolitical supply disruptions.

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About the author

Dirk Kaussen is Founder and Managing Director of EMS Strategy Group. With around 40 years of experience in the electronics industry — including founding and managing his own electronics manufacturing company in Germany — he brings deep expertise in manufacturing processes, EMS partner selection, supply chain stability, relocation projects, and risk management. His approach combines practical solutions with a direct connection to industrial reality.

About the EMS Strategy Group

EMS Strategy Group supports industrial enterprises in the strategic advancement and optimization of their electronics manufacturing operations – from high-level planning to operational execution. Our core expertise lies in the strategic relocation of manufacturing volumes to European EMS providers, the establishment of new production capacities, and the expansion of existing manufacturing structures.

Furthermore, we design resilient supply chain frameworks, conduct comprehensive risk assessments, and guide dual-sourcing strategies to secure and fortify supply chains. Upon request, we manage projects closely until a successful serial production ramp-up is achieved.

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