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Why batteries are too valuable to recycle

A multi-life approach to battery use

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Key Takeaways

Battery recycling isn't the most sustainable strategy when it comes to disposing of used electric batteries – not by a long shot. We still don't have sufficient industrial-scale recycling facilities in place, and those we do have cannot provide the efficiency or the capacity we need to handle the sheer volume of used batteries coming down the line. However, by championing the right multi-life approach, we could make battery reuse and repurposing a lot more attractive.

The multi-life model has the potential to reduce **car battery costs by up to €3,000** based on the calculations in our multi-life battery model. With a modified design and a full lifecycle approach, costs are likely to go down and revenue go up at various intervals in the product lifecycle.

Lower costs will **make car prices more competitive** in the entry-level and mid-price segment, closing the gap to Chinese competitors and securing market share.[1]

If the strategy works as intended, it could increase the overall share of EVs on our roads and help us meet our net-zero targets for personal mobility much faster.

European automobile manufacturers could become less dependent on third-party suppliers with the right multi-life strategy. And even if there is some business risk in this approach, OEMs should do everything in their power to secure a **strategic advantage** until they can achieve the efficiency gains they need to catch up with their competitors.

It is up to both manufacturers and politicians to advocate for clear-cut **regulatory policies** and support the industry during the transition.

[1] See also our study "The Key Role of Battery Costs", Deloitte, 2023.

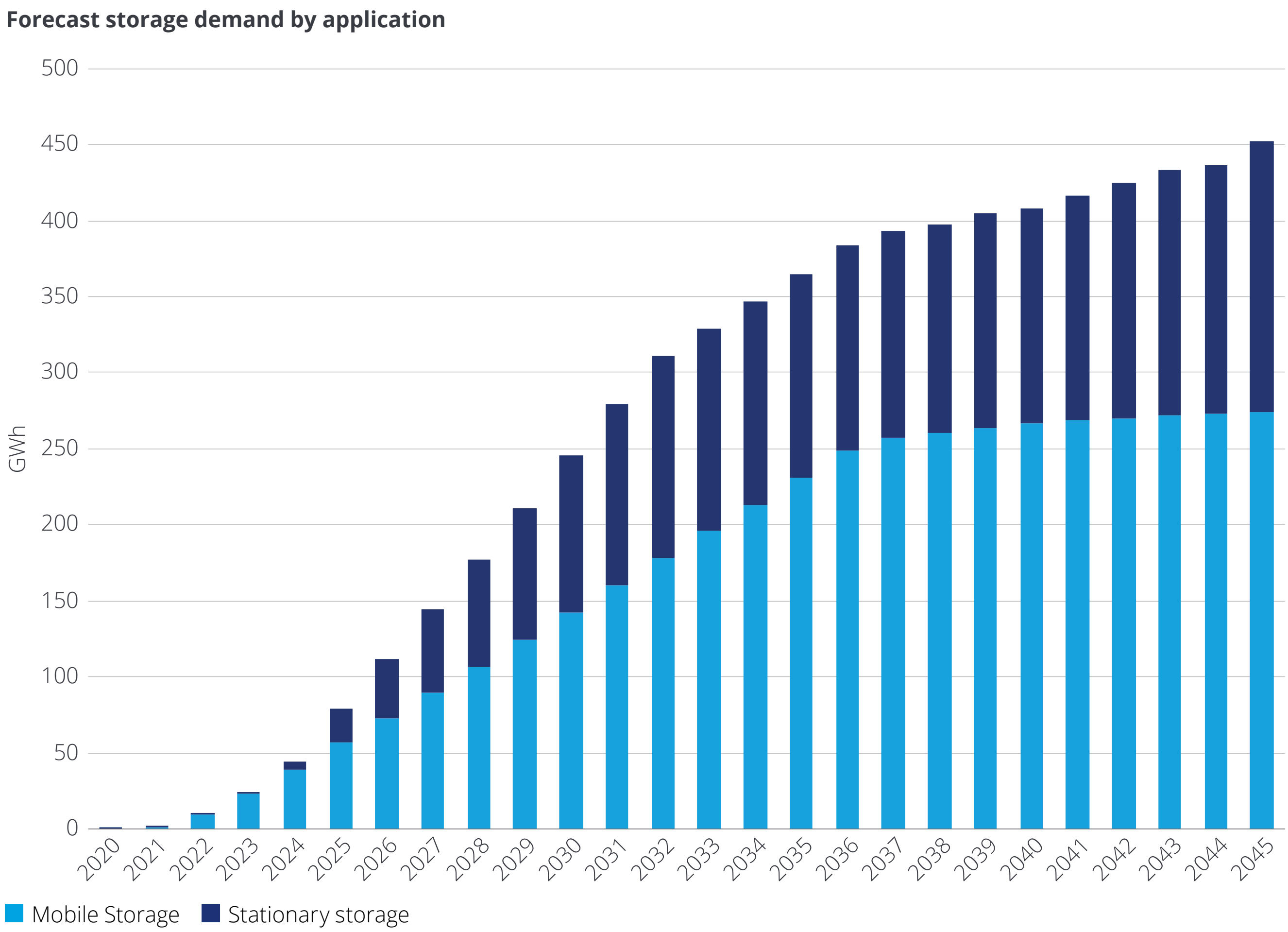
Introduction

To produce the batteries driving the energy transition in personal mobility, we need a variety of raw materials that are not available on the European continent. Germany and the EU are heavily dependent on sourcing these materials from non-European countries, a situation we urgently need to rectify. In the past, European companies managed to solve similar challenges and reduce dependencies as well as costs by introducing closed-loop systems and recycling initiatives. That will not be enough to solve our current battery conundrum – we need to embrace novel solutions, and the time to act is now.

The battery recycling conundrum

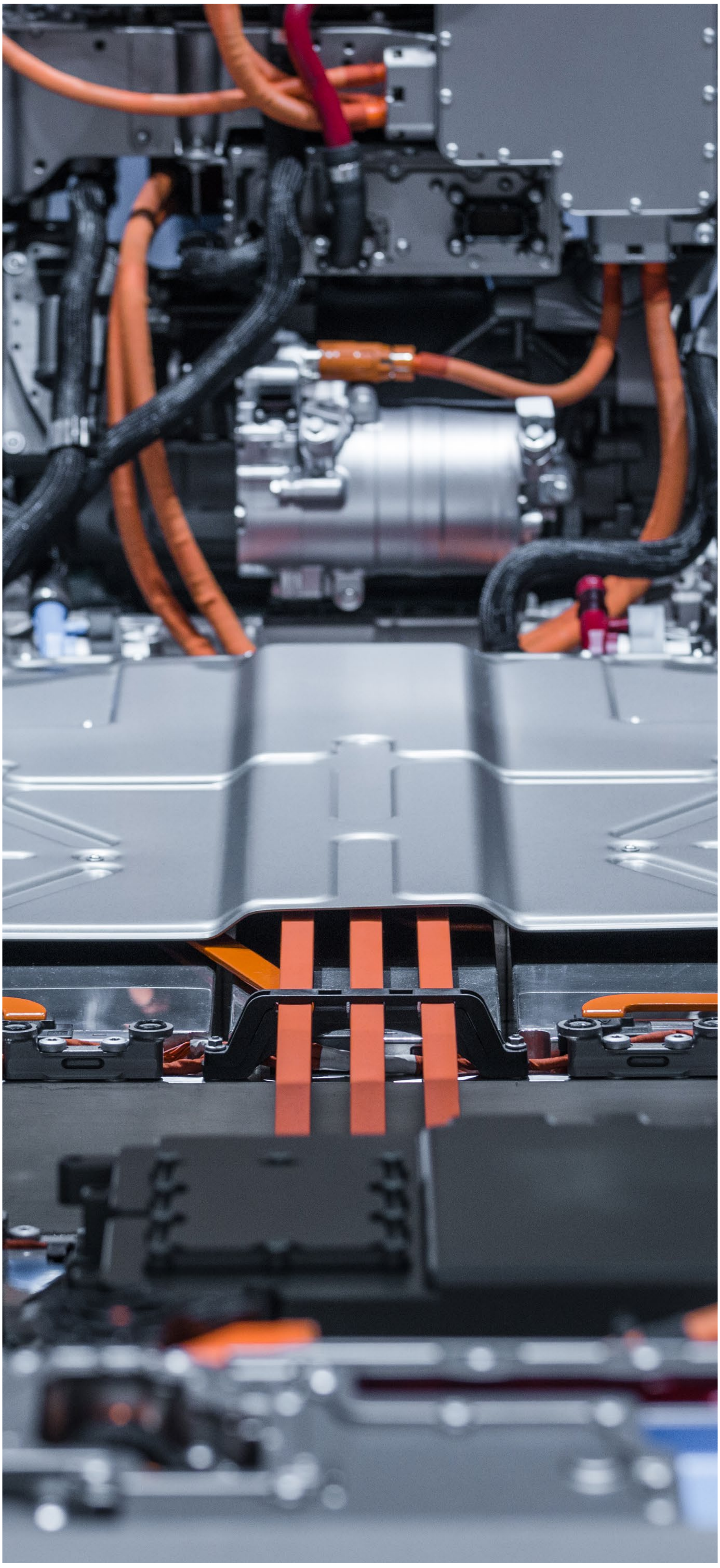
At this point, we all agree that every product should be recycled when it reaches the end of its useful life. This is particularly true for products manufactured with high-value, scarce raw materials – or when the materials or the manufacturing process itself present economic and environmental challenges. Lithium-ion batteries tick all of these boxes, but there are serious challenges when it comes to battery recycling. With electric vehicles entering the market at record rates, most of the batteries being produced today go straight to the vehicle production line. The number of batteries for EVs is certain to keep rising (see Fig. 1). At the same time, stationary energy storage is quickly becoming a key factor in the transition to renewable energy, another strong driver of battery demand. That means double the number of batteries that will eventually have to be recycled. It is time for business and political leaders to face up to these future challenges and come up with a feasible plan to radically change our linear business and consumption models. The latest Deloitte Global Automotive Consumer Study found once again that the majority of respondents are concerned about the environmental impact of batteries. In the eyes of consumer, it is up to the stakeholders along the entire battery value chain to work together and find a solution for collecting, storing and recycling batteries at the end of their useful life.[2]

Fig. 1 – Forecast battery demand in Germany by application



Source: "Paths to a Climate-Neutral Energy System—Update climate neutrality 2045", Fraunhofer ISE, 2021 study

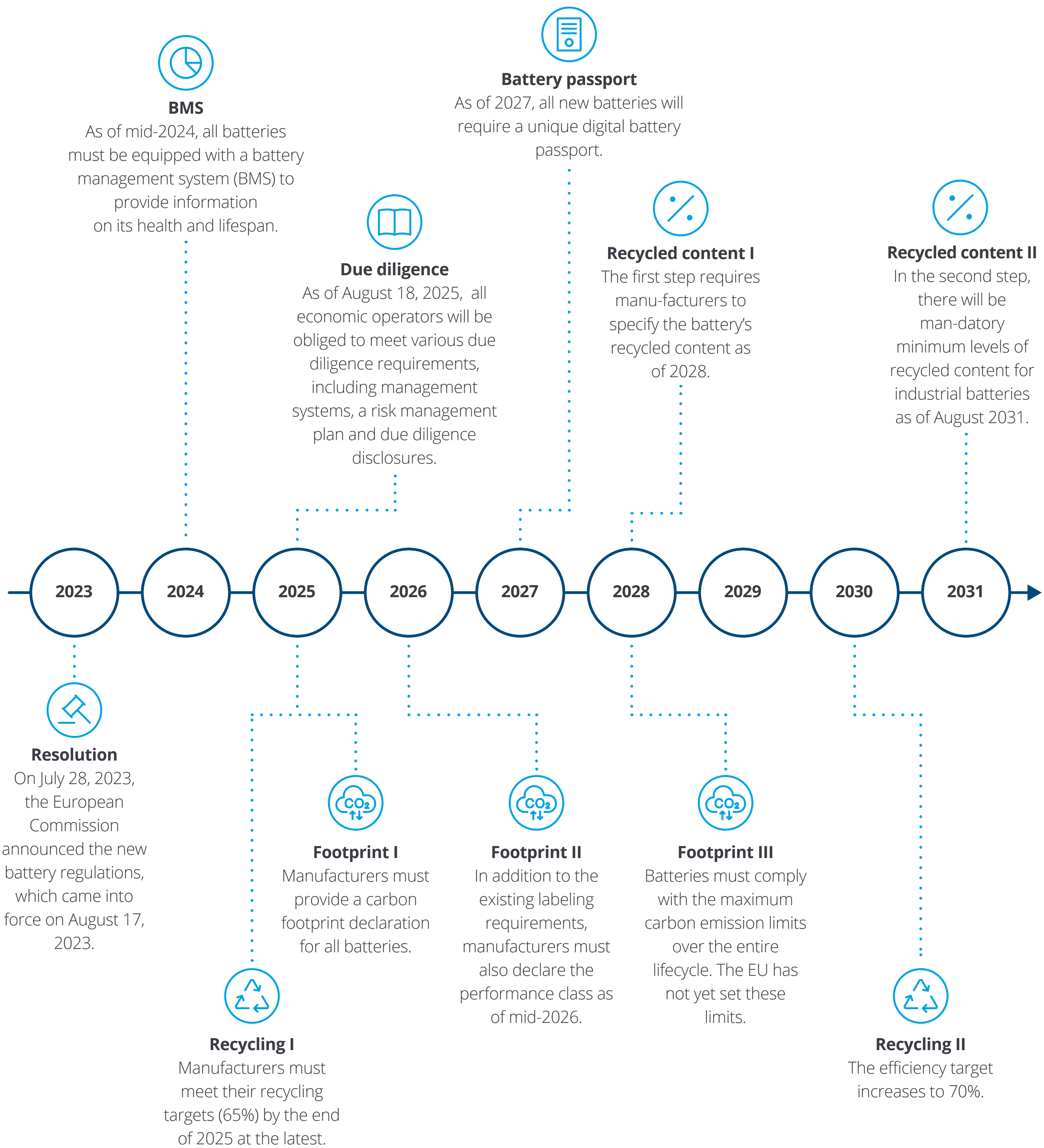
[2] "Global Automotive Consumer Study", Deloitte, 2024.



Europe must recycle

The European continent does not have the raw materials needed to produce batteries, and that makes us dependent on imports of primary raw materials. To reduce our dependency over time, we have to keep the raw materials within the material cycle and introduce a comprehensive recycling system. The Council of the European Union recently adopted new regulations with stricter recycling requirements, shifting the responsibility for recycling to battery manufacturers. The new regulations require manufacturers to disclose the carbon footprint of their batteries. In a second step, manufacturers will be subject to mandatory limits for the carbon footprint in all phases of the product lifecycle from manufacture to recycling. A series of provisions in these regulations and the new Battery Act gradually pass the responsibility for battery recycling back to manufacturers. The EU also plans to invest heavily in research and development as well as providing incentives for the private sector to ramp up production and recycling capacity.

Fig. 2 – New regulations for traction batteries in the Battery Act[3]



Source: Regulation of the European Parliament and the Council on batteries and waste batteries, amending Directive 2008/98/EG und Regulation (EU) 2019/1020 and repealing Directive 2006/66/EG.

[3] Regulation of the European Parliament and the Council on batteries and waste batteries, amending Directive 2008/98/EG und Regulation (EU) 2019/1020 and repealing Directive 2006/66/EG.

Caveat: Recycling poses serious challenges

The big caveat with recycling is that we are a long way from achieving a closed-loop economic and environmental solution in terms of the efficiency of the recycling process, the technology and energy required as well as the quality of the secondary material. The lack of suitable recycling facilities and suppliers is another important issue. Consumers are well aware of this problem, which is quickly becoming a key factor in their purchasing decisions. According to Deloitte's consumer survey "Future of Automotive Mobility to 2035", 76% of the respondents in the EUROPE-5 region (Germany, France, Italy, Spain and the UK) say that a carefully considered plan for battery reuse and recycling is an major factor in their choice of car brand.[4] Clearly, this plan needs to cover more than just recycling.

The process is too inefficient

One of the key technical factors holding recycling back at the moment is process efficiency. Batteries are made of various metals that are not all equally easy to separate mechanically. In other words, there are certain kinds of raw materials we are unable to recover in their pure form. But it is precisely the pure form of the material we need in order to reuse them. So, at the end of the recycling process, we are left with a certain amount of material that cannot be recycled, known as "black mass". Even the latest, state-of-the-art processes can only recover around 70 percent of the total lithium, which means a third of this precious resource is lost.[5]

EU governments have regulations in place to increase recycling efficiency. However, these targets only apply to the material that is actually sent for recycling. What this means in plain terms is that, by the end of 2025, manufacturers will only be obliged to recycle 325 kilograms of a 500-kilogram battery with a certified recycling company. Incidentally, 185 kilograms of the total weight is already accounted for by easy-to-recycle auxiliary materials such as casings, insulation, cables, etc. It is the rare materials in the battery cells that are difficult to recover, and even with these stricter requirements, we will only be able to actually recycle half of these materials.

Can we even call it recycling?

To make a battery, you need extremely high-quality raw materials. The purity of the raw material, measured in so-called grades, determines its quality, with "battery grade" as the highest quality. This level of purity is impossible to achieve with our current recycling systems, which is why we should probably be using the term downcycling rather than recycling. This is particularly true for the rare raw materials within the battery cells. While we can easily separate and recycle steel casings, polycarbonate insulation or copper electrical cables, this is not the case for the lithium-ion cells inside a battery. There are complex chemical processes available today that will take some of these materials back to battery grade, but they require so much energy that you can only operate these facilities in regions with extremely low industrial energy prices. This solution would provide a truly closed-loop process, but most of the time the raw materials end up as process waste, which is no longer available in the material cycle.

Recycling requires serious effort

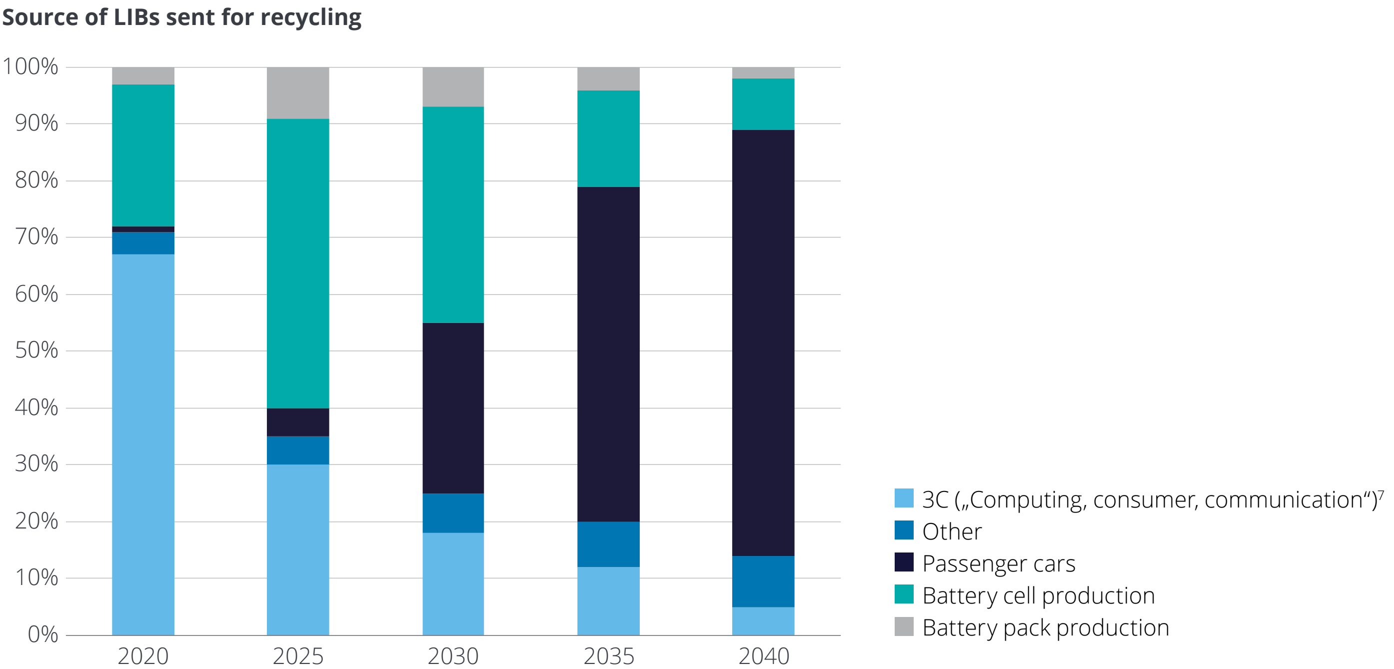
Recycling batteries requires an enormous amount of effort. In addition to the time and technical demands, the recycling process requires a lot of energy as well. Metal is melted at temperatures above 1000°C, resulting in the total loss of all organic raw materials,[6] to say nothing of the increased health and safety risk of some process steps. Battery recycling companies generally get their energy from process heat, and the carbon footprint varies widely depending on the respective energy source. There are various recycling options available today, and each has its pros and cons. For example, the use of strong acids can reduce amount of energy required, but the environmental impact of acids is high. Other methods might be very good at recovering one particular raw material, while destroying others at a higher rate.

Battery recycling is a relatively new industry

It may seem as if there is more than enough recycling capacity in Europe today, but we can expect bottlenecks sooner rather than later considering the number of battery-powered electric vehicles flooding the market. This is due in part to several new battery production facilities currently being built in the EU. These new sites tend to have a disproportionately high rate of production waste during the first few years, which means that half of the waste destined for recycling will be coming directly from cell production. By 2030, a lot of traction batteries will be at the end of their useful life, pushing the capacity of the recycling facilities currently in development to their limits.

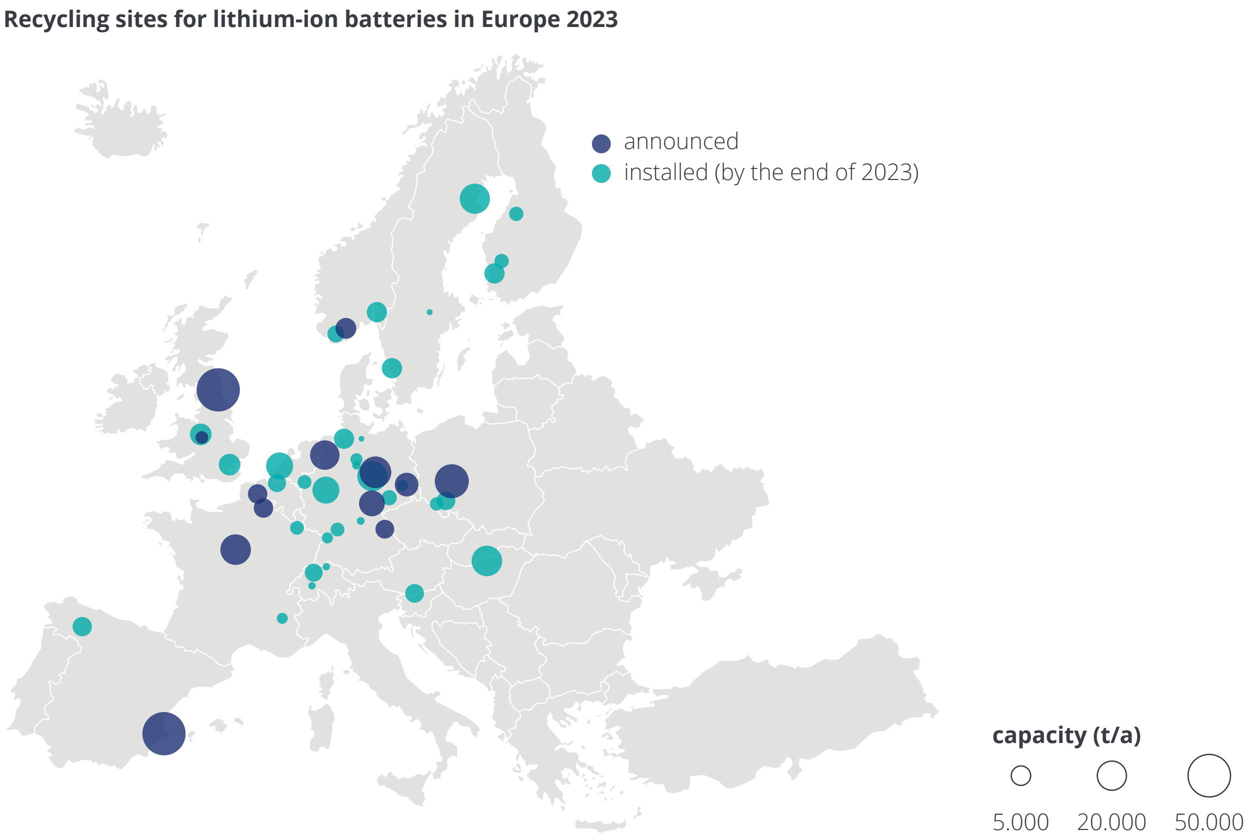
[4] "The future of automotive mobility to 2035", Deloitte, 2023.
[5] Dolotko et al. (2023).
[6] Mohr, et al. (2020).

Fig. 3a – Source of batteries sent for recycling[7]



Source: Neef, C., et al. (2021). Recycling of Lithium-ion Batteries: Opportunities and Challenges for Mechanical and Plant Engineering. Impuls.

Fig. 3b – European battery recycling landscape[8]



Source: Fraunhofer ISI Recycling sites for lithium-ion batteries in Europe 2023 | Created with Datawrapper

[7] Neef, C. et al. (2021): Recycling of Lithium-Ion Batteries: Opportunities and Challenges for Mechanical and Plant Engineering. Commissioned by the IMPULS Think Tank of the VDMA.

[8] Fraunhofer ISI, Recycling sites for lithium-ion batteries in Europe 2023 | Created with Datawrapper, accessed on Feb. 5, 2024.


Car preview
OEM Testing
Graphics
DISCONNECT

Bottom line: Battery recycling is not cost-effective

The raw materials used to make batteries are scarce and expensive. An EV battery with 70 kWh and an NMC cathode is worth €1300 in metal alone. That figure drops by half when we switch the cathode to LFP, which is more and more common today.[9] And yet, for the reasons we outlined above, the recycling process is still so challenging that the costs far exceed the revenue from the sale of secondary raw materials. Recyclers have responded by charging standard fees of €40/kWh and more when they take batteries for recycling.[10] Another key challenge is that today's batteries and cars are not designed for easy recycling. However, even if we managed to modify the design immediately, it would take many years for these recycling friendly designs to arrive at the recycling facilities and allow for easier recovery of valuable raw materials.

Recycling should be a last resort

Of course, batteries don't have an unlimited useful life. Recycling is ultimately unavoidable, but we should do everything to delay it for as long as possible. Even if we extend the lifecycle to the maximum, it will eventually end up at a recycling facility at end of life. The raw materials used in batteries have a high residual value and remain scarce. And since it is often impossible to source these primary raw materials in line with ESG guidelines,[11] we need to reduce demand by creating a closed-loop system. This is not feasible at the moment, so we should focus on continuing to use the batteries until it becomes a reality.

„Batteries are the single most expensive components in an electric vehicle. Production is energy-intensive, and the necessary raw materials are rare and expensive. It makes no sense, economically or environmentally, to recycle such a high-value product too soon – even though it is obvious that we will eventually have to recycle it when it reaches the end of its useful life."

Dr. Harald Proff | Partner | Sector Lead Automotive

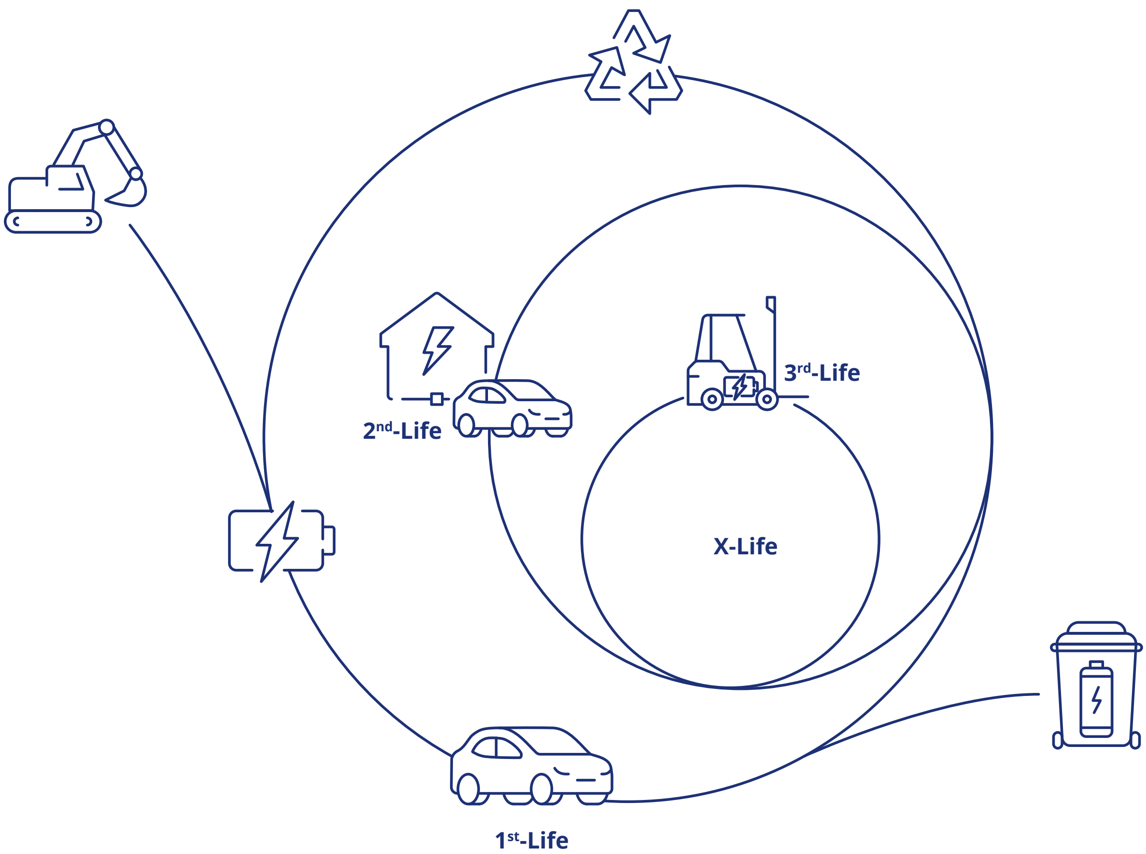
[9] Neef et al. (2021), S 15.
[10] Kampker et al. (2023), S 14.
[11] ESG = environmental, social and corporate governance.

Multi-life approach

The more sensible approach from an economic and an environmental standpoint begins long before recycling: The goal is to extend the useful life of a product as far as possible. One promising strategy is the multi-life approach, where we retain the value of the products by using them in different applications, while also reducing energy and CO_2 emissions. The multi-life approach is based on the modular design of various components that offer a variety of uses and make them both more cost-effective and more sustainable. Integrating retired battery modules in other devices and systems opens a wide range of business opportunities. The concept of reuse and repurposing, as the cornerstones of the multi-life approach, are worth reconsidering in the context of industrial design. We can continue to use the various components of a product in different applications after the original use is finished, shifting our understanding of a product as a temporary combination of parts used in different ways for different purposes. To make multi-life batteries a reality, a holistic approach is vital. That way, we can extend the lifecycle, reduce costs and help all users save resources as well as energy. The main focus is obviously on environmental gains through lower energy consumption and CO_2 emissions, but all the better if we can minimize the financial burden on end users at the same time.

One opportunity to reuse batteries as part of the multi-life approach is shown in figure 4. The batteries are manufactured for use in electric vehicles initially, with a focus on future disassembly and reuse early on in the product design stage. When a car reaches the end of its useful life, most batteries are still suitable for reuse. The average car battery is so large that it can still power up to four energy storage units at this stage. It finds a second life as a home storage system for solar power or as a buffer storage system in industrial applications. With both a lower load and a lower capacity-to-weight ratio for batteries in these stationary applications, there are no issues with this type of reuse. In fact, the residual capacity of retired car batteries is more than enough for applications like these. There is also the option to combine several batteries to provide extra storage for applications with higher capacity needs. And after being used in a stationary energy storage system, the same batteries can find a third life in electric forklifts, for example. The performance of retired lithium-ion batteries at this stage is the same if not better than the lead or nickel-cadmium batteries commonly found in forklifts today. This is just one example showing the potential for reuse when subsequent applications have lower performance requirements for the batteries than the previous ones.

Fig. 4 – Basic multi-life concept



Source: Deloitte graphic

How can we make the multi-life model a reality?

Of course, implementing a multi-life business model is not as simple as just repurposing retired batteries. There are multiple hurdles to overcome, and the different stakeholders have to commit to working together. If we are serious about persuading car and battery manufacturers to embrace multi-life use, the vital first step is to determine whether it makes economic sense.

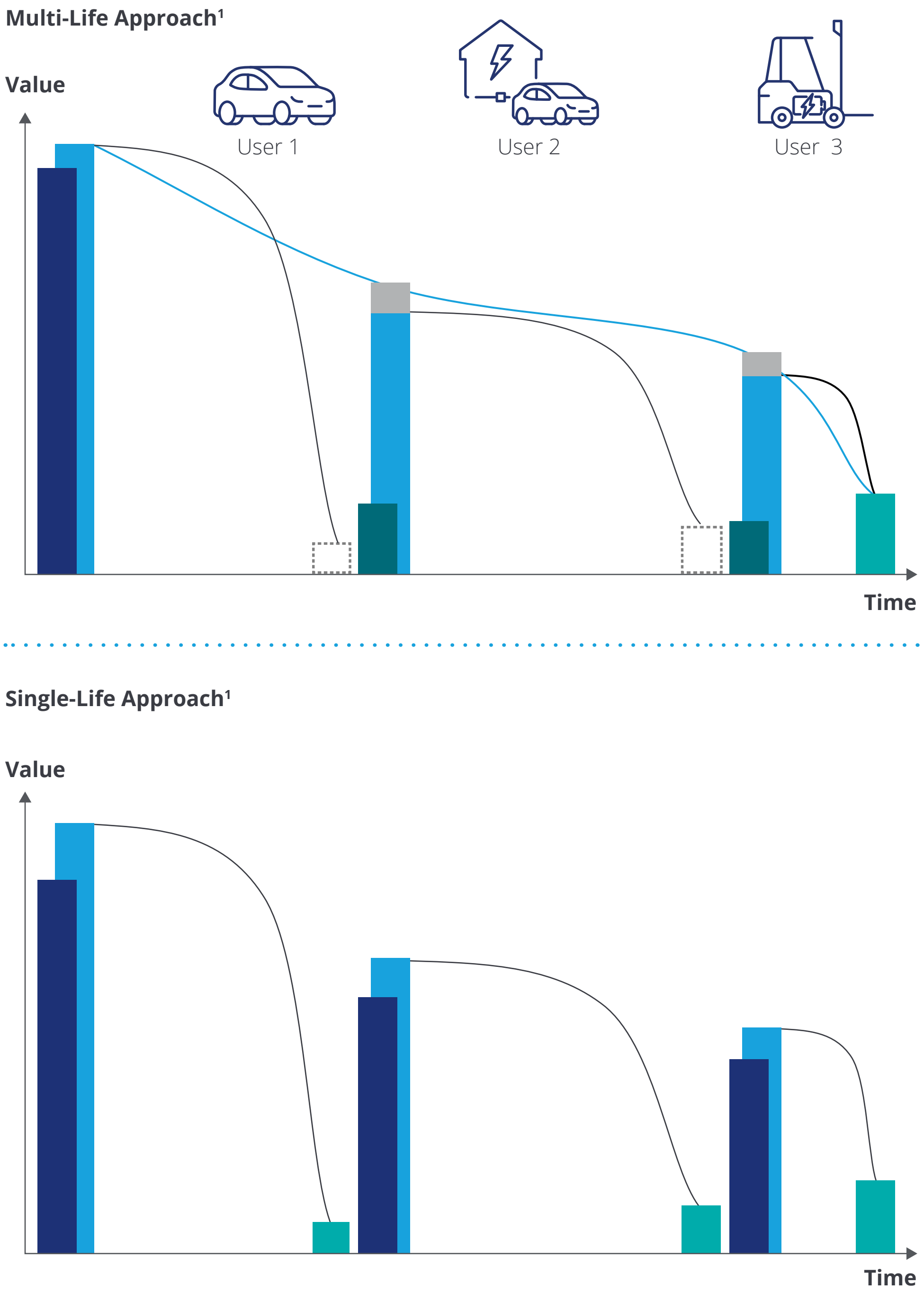
Economic benefits of the multi-life model

Is it possible to generate more profit potential with a multi-life battery over its entire lifecycle than with the batteries we use today? To answer this question, we compared the multi-life approach, which uses one battery for three different applications, with the single-life model in use today. Figure 5 outlines the basic concept of these two models. The added value is evident after the first use! While the battery performance in the car has deteriorated to the extent that it must be replaced, there is still plenty of residual capacity available in this battery. We calculate the added value as the difference between the value attributed to the battery by its users and its actual technical value: The user's subjective view is that the battery no longer provides sufficient power for their electric car, presenting a clear difference between the battery's perceived and actual value. The battery is essentially worthless to the car owner, although its residual capacity is still perfectly suitable for a second life in another application. The user then returns the battery to the manufacturer at no cost or only for a low buy-back price. As soon as it is repurposed for a suitable application, the battery increases significantly in value.

„When a car battery no longer meets the requirements of the driver, it doesn't mean the battery is at the end of its useful life. There are still plenty of applications it is very well suited for, for example as buffer storage for solar power, an area that will only increase in importance as the energy transition advances."

Dr. Harald Proff | Partner | Sector Lead Automotive

Fig. 5 – What is the basis for comparison in the multi-life model? (not to scale)



Explanation

The total potential is calculated as a sum of the individual earnings and the recycling earnings.

[1] In each case, we use a new battery of the same value for comparison.

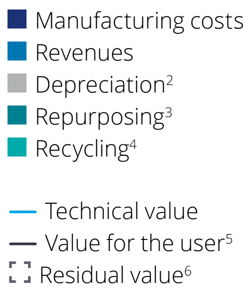
[2] The customer pays less for the retired battery, even if it is in perfect technical condition.

[3] Costs for reconditioning, deinstallation, installation and sales.

[4] Recycling has both a cost and a revenue component. The costs exceed the revenues, particularly until 2035.

[5] The battery has no value for the user once it is no longer suitable for the specific application.

[6] The perceived residual value for the user is equal to the revenue from recycling, which may have to be reimbursed.



Source: Deloitte graphic

With the multi-life approach, we use batteries several times throughout the course of its useful life. The single-life approach requires three separate batteries. The costs and revenues vary between the two approaches, making it difficult to achieve a meaningful comparison. So, we focused instead on the consequences. In order to create a reliable baseline, we compare the multi-life battery to a battery with the same technical specifications as the retired battery moving to a different application. The loss in value of the multi-life battery seen in the graphic is mainly due to the fact that customers generally expect to pay less for a used product and would always opt for a new product if the price were equal. That is why we use a lower revenue figure here in our model. There are various factors impacting each of the parameters in the graphic, which we will discuss in more detail in figure 6. By combining the costs and revenues of the different models, we can calculate the added economic value of multi-life batteries, which we call "multi-life potential".

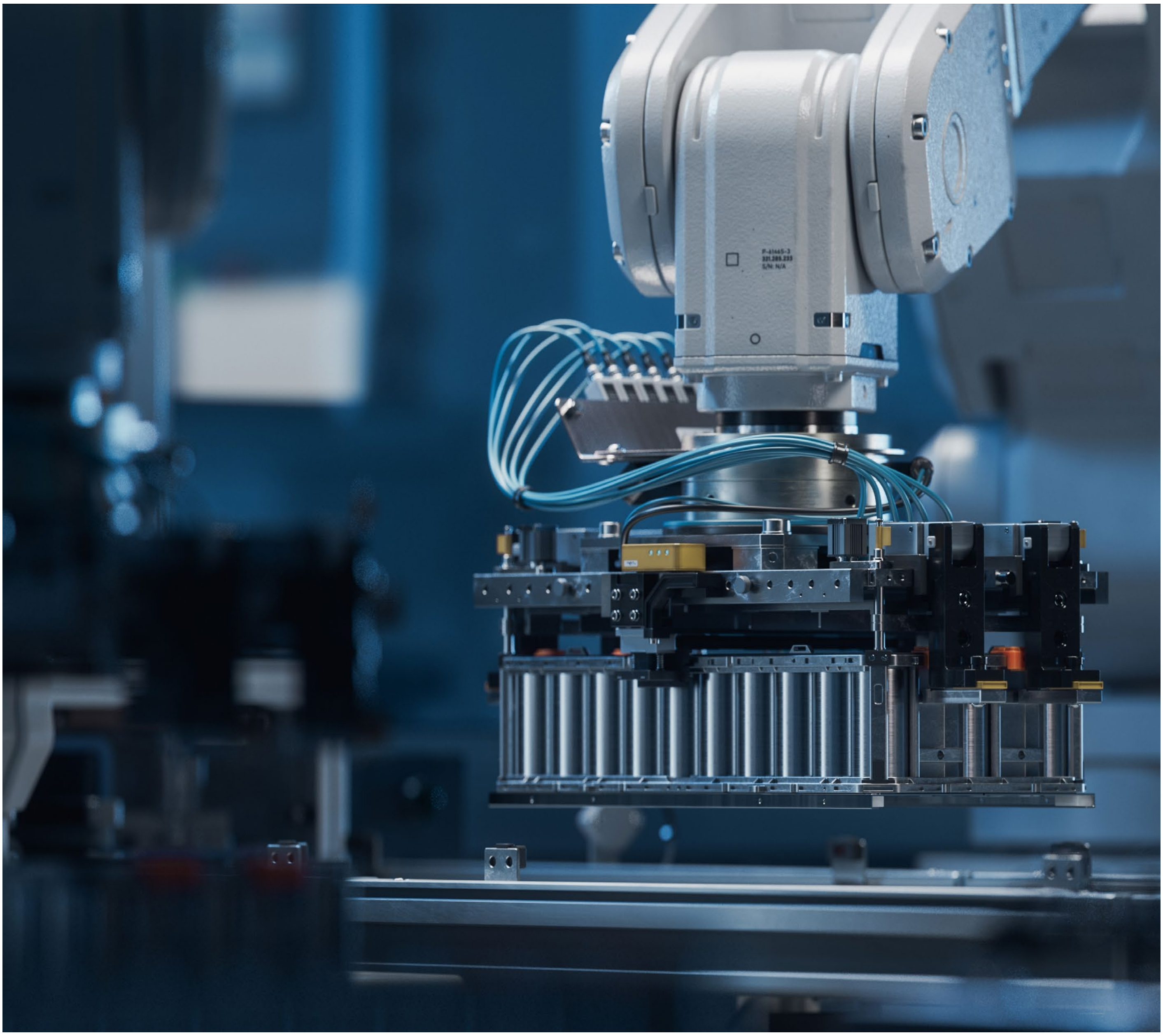


Fig. 6 – Key parameters impacting the multi-life model

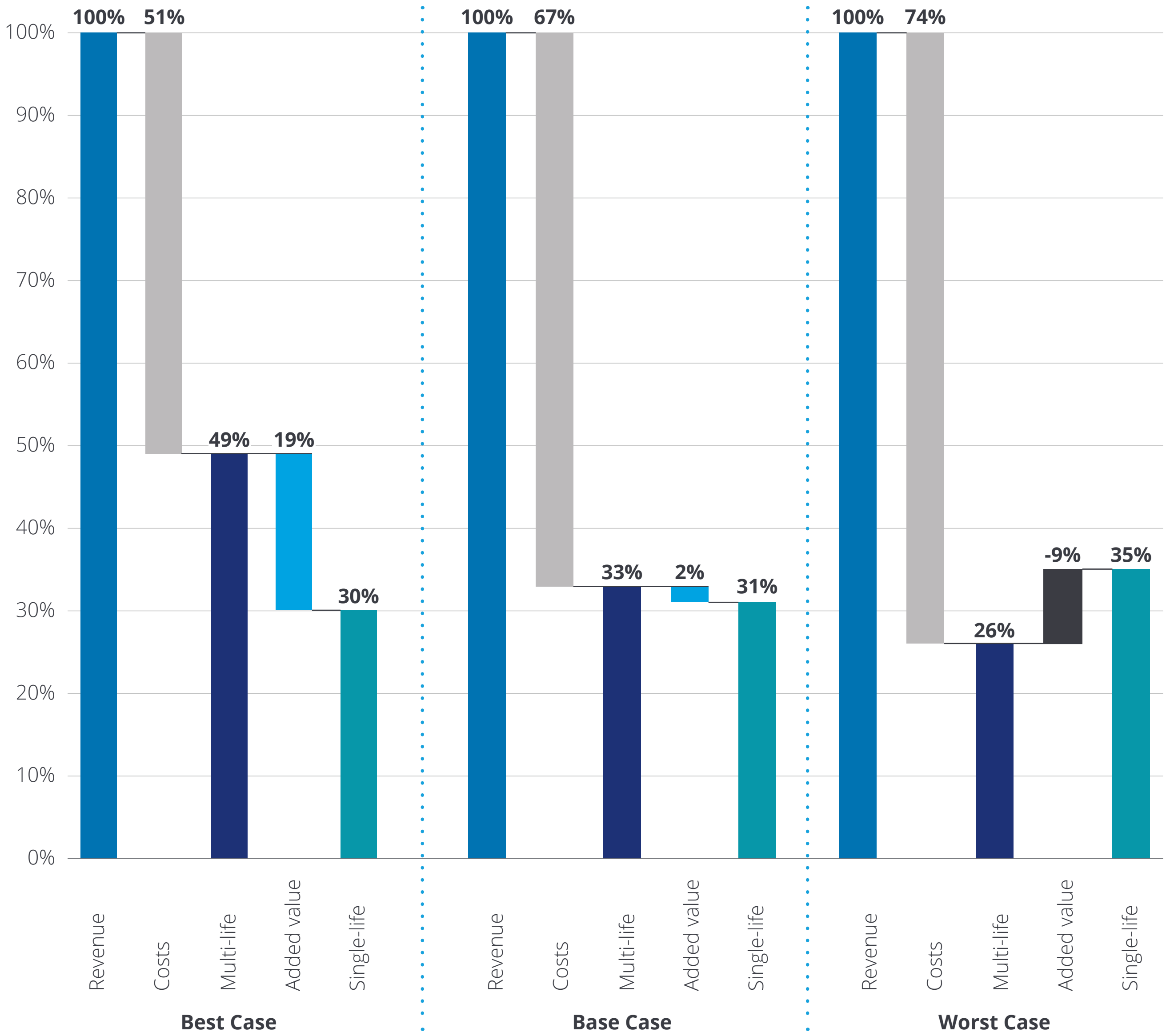
	Explanation	Impact on multi-life
Battery capacity	The battery capacity of the EVs determines how much capacity can be expected at the end of life. The average battery capacity is increasing at the moment but is expected to eventually level out.	Larger vehicle batteries mean more capacity available for each additional life, which can be allocated as needed for each application.
Reusability	Improved battery technology means a longer useful life, in the EV as well.	Reusability has a strong impact on the value of the battery after each use. Any increase in reusability is positive for multi-life use.
Repurposing	The costs for repurposing are high at present. The more design-to-multi-life principles and the more automation we introduce, the more costs will fall.	If the repurposing costs go down, it will have a very positive effect on the added value of multi-life use.
Recycling	Technological advances and an increase in the number of recycling facilities available will lower costs, while revenue from the sale of recycled metal is likely to stay relatively stable.	High recycling costs amplify the benefits offered by multi-life. If recycling is highly profitable, the benefits decrease.
Battery price	The price for batteries will continue to fall, though this is not evident in all applications. Prices of home storage systems, for example, is significantly higher than that of electric cars today.	The battery price at the time of repurposing is decisive for the potential revenue after switching to a new application and therefore for the multi-life potential.
Demand	The market for energy storage systems is still in the early stages. Decentralized energy production and the storage needs for renewable energies such as wind and solar power will further increase demand.	Where demand is high, reuse will be an attractive option for more customers. Greater awareness about environmental issues is particularly positive for the multi-life model.
Willingness to pay	Customers' willingness to pay fluctuates significantly in line with public sentiment. Following the energy crisis, for example, we saw a sharp increase in demand and in the willingness to pay for private energy storage.	Each of the above factors will influence customer behavior and make the price they are willing to pay relative to that of a new product.

Source: Deloitte graphic

We calculated three scenarios in our model to ensure we are able today to model different future developments today and forecast their impact. Varying the parameters within the expected range not only influences the actual value, but also whether it is classified as cost or revenue. Figure 7 compares the outcomes of the different scenarios based on our calculations, presenting a best case, a base case and a worst case. The best and worst cases are the scenarios calculated with parameters at the outer limits of the expected range. The base case parameters are at the midpoint of the range and approximate the situation as it stands today.

Fig. 7 – Added economic value

Multi-life vs. Single-life



Source: Deloitte graphic

By converting the multi-life potential from a relative to an absolute amount, we estimate an additional €50/kWh in revenue in the best case scenario. That means €3000 in added value, based on the average battery size[12] and optimal use of the battery. It will take smart ideas and bold entrepreneurs to generate sufficient added value to reduce costs for users and make both EVs and home storage systems more affordable.

What do these results mean in the real world?

The multi-life approach is a profitable business model! In every scenario we calculated, the total revenues exceed the costs, though the added revenue is 9 percent lower in the worst case scenario. There is clearly a viable business case for reusing retired EV batteries. Based on the three applications in our model, even our calculations with the most realistic multi-life parameters (base case) show slight added value over the current single-life concept – with a good chance of more value added as we move towards the best case scenario.

This is not to say that the multi-life approach is a guaranteed success. In our base case scenario, the added value is too low and the risk of ending up in worst case territory is too high to appeal to industry leaders. That's where the government comes into play. The private sector definitely needs regulatory support, particularly during the first few years, to help reduce the risk and increase the benefit. In Section 5, we provide an indepth explanation of the potential impact regulatory policies can have on the multi-life model.

What factors can make or break the multi-life model?

There are some parameters in our model that are subject to uncertainty. And then there are others that are highly interdependent, making it difficult to adjust them separately. But we found a way to vary the parameters within the expected range and analyze the results to forecast the outcomes in the different scenarios.

Note

Our model calculates a large number of different variants. And in some cases, different combinations of our parameters produced the same result. The three scenarios presented here are designed to represent the outer limits of what is plausible. We calculated the average of the three most extreme outcomes for our best and worst case scenarios to ensure our results were robust enough to avoid statistical error. This method does indeed improve the results, but does not allow us to draw direct conclusions about the individual parameters.

The multi-life model has huge potential to add value, particularly when repurposing costs are kept to a minimum, when there is no incentive for users to return batteries at the end of life and when the product design costs for multi-life applications do not adversely impact battery production and installation. At the same time, there are benefits to keeping battery recycling as a cost factor. This is certainly the case with the single-life model. Along with some others, varying this parameter produced our best case result. In the worst case scenario, by contrast, there were virtually no changes to the battery design, driving repurposing costs up and making the recycling option more profitable at an earlier stage. This would definitely not incentivize users or manufacturers to go to the effort of reusing retired batteries.

[12] The average battery size for EVs on the German market is 60 kWh.

Further requirements for multi-life

There are several steps to go through before we can achieve the economic benefits of the multi-life approach. It is vital to tackle all of these steps in advance before you can take the finished product and business model to market.

When regulatory policies constantly change, that means all players involved have to keep changing their business practices as well. So, the first step would be to create a reliable, uniform regulatory framework with clear guidelines for the products and for the manufacturers and users. Where the added value is not sufficient, additional political intervention may be necessary. Another key step is to set up the right organization. The multi-life model needs a coordinator that can bring all of the stakeholders involved together. Filling that position will require OEMs to redefine their own role. A further step involves the technical implementation and the design-to-multi-life concept.

Regulatory policies

In terms of the regulatory framework, clear guidelines will enable industry leaders to make longterm plans. But we also need political intervention to increase the appeal of the multi-life battery business model. All of the scenarios we calculated need some political intervention, at least initially, to generate enough added value to make multi-life a viable option.

To establish the regulatory framework for political and industry leaders, we must first define a clear goal. The ideal compromise would challenge manufacturers, but not include any mandates that put them in a weaker position than their foreign competitors. In addition, this framework will only be effective if it applies equally to all stakeholders in as many countries as possible. Lawmakers in the EU and Germany are already working on this, but many of the initiatives are still at an early stage or would only come into effect after a long transition period.

Stricter recycling regulations for batteries, for example in the Battery Act (see figure 2), will help shift the focus more towards the multi-life approach. When manufacturers are faced with costly recycling fees for retired batteries, extending the useful life to the maximum (and therefore the multi-life option) will seem like a better, more logical alternative. There are, however, other political levers that will make the multi-life model more realistic.

Table 1 – Possible actions

Design	• Standardized design specifications, connectors and controls • Specifications for design-to-multi-life applications
Use	• Legal provisions for longer service life (across all applications) • Strict CO_2 footprint regulations across the entire lifecycle
Research and development	• Grants for development work on automated repurposing • Research on improving reusability
Demand creation	• Subsidies for EVs with modified design • Subsidies for using retired batteries in multi-life applications

Some of our proposals for regulatory action only impact the multi-life potential indirectly, while others have a direct effect. If we are serious about promoting the multi-life approach, it is also worth considering when these regulatory interventions take effect. Subsidizing the purchase of applications that feature retired batteries could offer a huge advantage for the multi-life approach, but not until ten to fifteen years from now. And even though some measures would theoretically boost the potential of the multi-life approach, they could actually adversely impact the goal of broader EV adoption. So, we have to make sure our interventions are very targeted, particularly given that some subsidies are currently being phased out.

Lawmakers have the opportunity to make the multi-life model the European standard for batteries. There are currently no provisions designed specifically to mandate multi-life battery use in the Circular Economy Act, the new EU Battery Regulation or Germany's Battery Act. However, the EU Battery Regulation is the first piece of legislation to stipulate a full lifecycle approach taking the environmental footprint of procurement, production, use and recycling into account. The stricter they enforce the maximum carbon footprint limits, the more attractive the multi-life approach will become. Lawmakers should step in here and make the multi-life model mandatory, either directly or indirectly.

Organizational structure

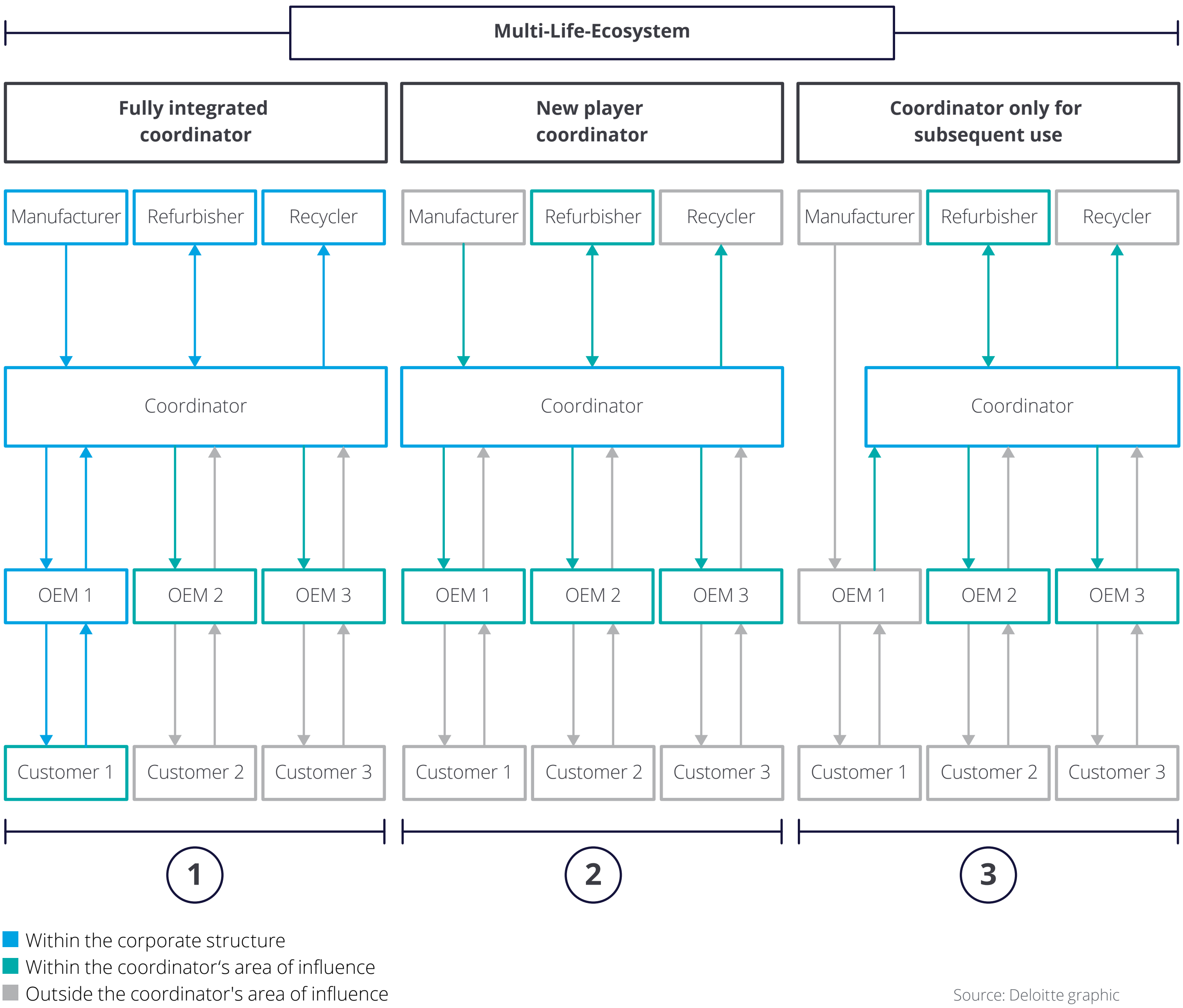
Who is responsible for coordinating the new ecosystem?

There is a critical question when it comes to designing this new ecosystem: Who is going to coordinate it? Without precise monitoring and management of a multi-life battery's lives, we will not be able to make the most of this model. Other questions arise, such as: When is the battery best suited for which application, and who are the most suitable customers? When the time comes to switch applications, do the batteries have to meet certain requirements? And how do we match supply to demand? No single manufacturer or sales partner will be able to answer these questions on their own; this is where the coordinator comes into play. Though similar to the wellknown battery-as-a-service concept, this business model takes it one step further. Now, the question is: Which stakeholder is best suited to acting as coordinator, and what impact will this have on the role of the OEM?[13] There are essentially three possible approaches.

NB

When it comes to calculating the effect of the multi-life model, we believe the multi-life battery should remain in the possession of one owner across several applications, but be used by different customers. The manufacturer could also conceivably buy back the battery after use, but this would reduce the revenue potential to such an extent that the system no longer makes economic sense.

Fig. 8 –Ecosystem design



Source: Deloitte graphic

[13] The term OEM (original equipment manufacturer) is used in reference to the manufacturers who install the batteries in the respective products. OEM 1 here is the car manufacturer; OEM 2 and 3 are not specified.

1. Fully integrated coordinator

To maximize the economic potential with this option, the coordinator needs to be fully integrated in various areas of the multi-life ecosystem. The more focus placed on this issue, the more leeway stakeholders will have in designing the ecosystem. A coordinator that is affiliated with the manufacturer within a corporate structure will find it easier to apply design-to-multi-life principles. The OEM will be able to impact the primary use, for example by setting a fixed service life, while also using the multi-life potential to make the battery more affordable. Adding refurbishment and recycling to the mix will provide additional benefits, since the coordinator will be able to keep initial repurposing costs under control and complete the close-loop cycle at a later date.

2. New player coordinator

Another option is to separate the coordinator's business model from both production and use. Acting as a facilitator and an interface between the individual players, the coordinator in this option oversees the ecosystem. The influence on the way the product is manufactured and used is limited, but the coordinator can still work to maximize the multi-life potential and make the model accessible for OEMs. If it is possible to reduce costs through longer use, the coordinator could be in a stronger market position than the battery manufacturer. Having a longer-term business model enables the coordinator to use subsequent earnings to sell the battery to any OEM at a much cheaper price than a single-life battery manufacturer could.

3. Coordinator only for subsequent use

The third option has less to do with the original concept of an ecosystem coordinator, and to some extent we are already seeing this option play out today. In this case, the coordinator only appears on the scene after the first use is finished, acting as an intermediary for products already in use. The coordinator can bundle demand and have an indirect impact on production by offering the first OEM enough added value to justify repurposing the battery for subsequent resale – even if it means other downsides for the OEM. The coordinator in this option is essentially a platform operator and will have to proactively buy batteries to ensure sufficient supply.

The first option, where the multi-life coordinator is fully integrated, offers the greatest leeway in terms of ecosystem design. This not only allows stakeholders to generate maximum revenue in all relevant stages of the product lifecycle; having a fully integrated coordinator also offers the best opportunities to manage the different product lives and reduce dependencies.

The technical side of the multi-life approach

Design-to-multi-life

To determine whether repurposing is economically viable, it ultimately comes down to the technical effort required. This is where the multi-life approach differs significantly from previous reuse initiatives. Manufacturers that succeed in establishing design-to-multi-life as standard will be able to avoid many of the previously necessary processes and reduce costs by as much as 50 percent.[14] Design-to-multi-life is not just about modifying the shape and size of a battery, there are other aspects involved here as well:

- We need to define standardized battery modules for manufacturers. Traction batteries for EVs are already on the right track, but different manufacturers still use different systems.

- There has to be a system of standardized connectors. In addition to electrical energy, these connectors must also transmit data on the health of individual cells and make it accessible for the various players in the value chain.

- Stakeholders need a digital platform where they can interact. The so-called EU battery passport is a good first step.

- Batteries should be long-lasting by design. In some situations, this may involve limitations in certain areas of application, which we will just have to accept.

- It is also vital to design for disassembly; in other words, it should be easy – or perhaps even automated – to remove and dismantle the batteries using standard tools.

If we adopt these changes in the product design, it will take significantly less effort at the end of the primary use and make the transition to the next life much easier. This is what distinguishes the multi-life approach from the alternatives often referred to as “second life”, which only start considering the realities of the next phase when it is already too late.

[14] See Kampker et al. (2023), Pluhnau et al. (2023).

Conclusion

We all know that the circular economy is the future, but it is virtually impossible to predict how the transition will play out in the real world. Our current battery recycling system, despite considerable technological advances, clearly does not have the capacity we need and has considerable room for improvement in both environmental and economic terms. Multi-life batteries not only generate added value that could help make electric cars more affordable for consumers and promote more widespread adoption, among other things; they could also represent a major step towards more sustainable use of resources.

Making multi-life a reality does, however, have its challenges. It will take a range of economic factors as well as decisive regulatory intervention to make this model a success, particularly if the multi-life approach seems too expensive. We cannot put the responsibility for change solely on industry; politicians need to be proactive to ensure the right regulatory policies are in place.

The multi-life approach is hardly a guaranteed success. It requires a coordinated effort from various players, including manufacturing companies, research institutes and political decision-makers. Without this close collaboration, we will be unable to reap the economic rewards or meet our sustainable development goals.

Finally, we must acknowledge that it will take a considerable amount of time to produce cars with multi-life batteries destined for reuse. That is why it is so urgent to take action now and speed up the transition as well as promote the sustainable use of batteries in electric cars.

The multi-life approach for car batteries is only the first step. We need to extend this idea to the entire vehicle and find closed-loop solutions for various different components. This applies to every part of the car, from plastic fittings, which can easily be converted into recyclable material, to displays, which are becoming an increasingly important feature in today's vehicles.

Bibliography

Deloitte (2023): The future of automotive mobility to 2035, in: Deloitte Thought Leadership Issue 02/2023.

Deloitte (2024): Global Automotive Consumer Study, 2024.

Dolotko, O. et al. (2023): Universal and efficient extraction of lithium for lithium-ion battery recycling using mechanochemistry. Communications Chemistry, 6(1), 49.

EU (2023): Regulation (EU) 2023/1542 of the European Parliament and of the Council concerning battery and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC, Brussels.

Kampker, A. et al. (2023): Cost-Benefit Analysis of Downstream Applications for Retired Electric Vehicle Batteries. World Electric Vehicle Journal, 14(4).

Mohr, M. et al. (2020): Recycling of Lithium-Ion Batteries, in: Encyclopedia of Electrochemistry (S. 1–33).

Neef, C. et al. (2021): Recycling of Lithium-Ion Batteries: Opportunities and Challenges for Mechanical and Plant Engineering. Commissioned by the IMPULS Think Tank of the VDMA.

Pluhnau, R. et al. (2023). Multi-Life-Products – towards a new paradigm of product development aligning on module's multiple usage-scenarios. Procedia CIRP, 119, S. 873–878.

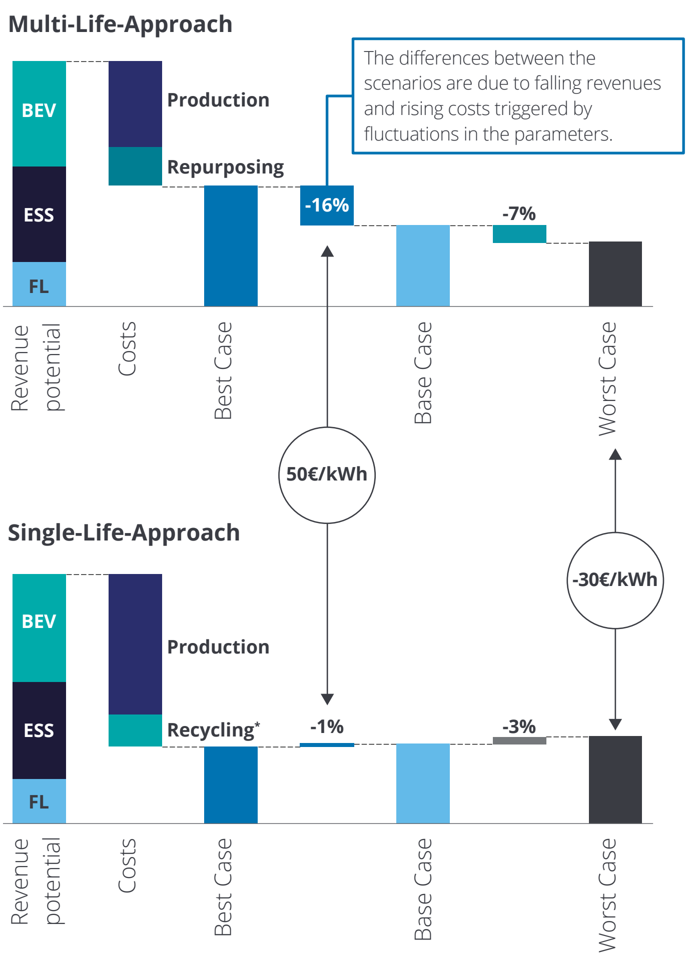
Appendix

What factors impact multi-life potential?

The economic potential of multi-life use is based on the comparison between multi-life and single-life batteries. The results are shown in Fig. 9, which also highlights the parameters that impact results and where this is evident.

The graphic show that the maximum and minimum values, which define the range between the best and worst case, are primarily evident in the multi-life approach. When we vary the initial parameters, the result jumps by 16 or 7 percent, while the differences are in the low single-digit range in the single-life approach. Designing the multi-life business model clearly offers the best opportunities and gives industry a lot of leeway. One key aspect here is the proportion of costs attributable to repurposing. If batteries are designed for repurposing from the outset and easy to assemble and disassemble in all applications, the costs go down significantly. In the past, German companies made a name for themselves as experts in process efficiency – a skill that offers a decisive advantage in this area as well.

Abb. 9 – Multi-Life-Potenzial



Impact of the parameters on the result	Single-Life Costs	Single-Life Revenue	Multi-Life Costs	Multi-Life Revenue
Battery capacity	✓	✓	✓	✓
Reusability	–	–	✓	–
Repurposing	–	–	✓	✓
Recycling	✓	✓	✓	✓
Battery price	✓	✓	✓	✓
Demand	–	✓	–	✓
Willingness to pay	–	✓	–	✓

Source: Deloitte graphic

BEV – battery-powered electric vehicle, ESS – energy storage system, FL – forklift. * In the best case scenario, recycling is only profitable after the third use; in other words, it costs more to recycle than to reuse in the first and second use.

Contacts

Dr. Harald Proff
Partner
Sector Lead Automotive
hproff@deloitte.de

Max Eickhoff
Researcher
Automotive Sector Research
maeickhoff@deloitte.de

Nicolas Zauner
Senior Researcher
Automotive Sector Research
nzauner@deloitte.de

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