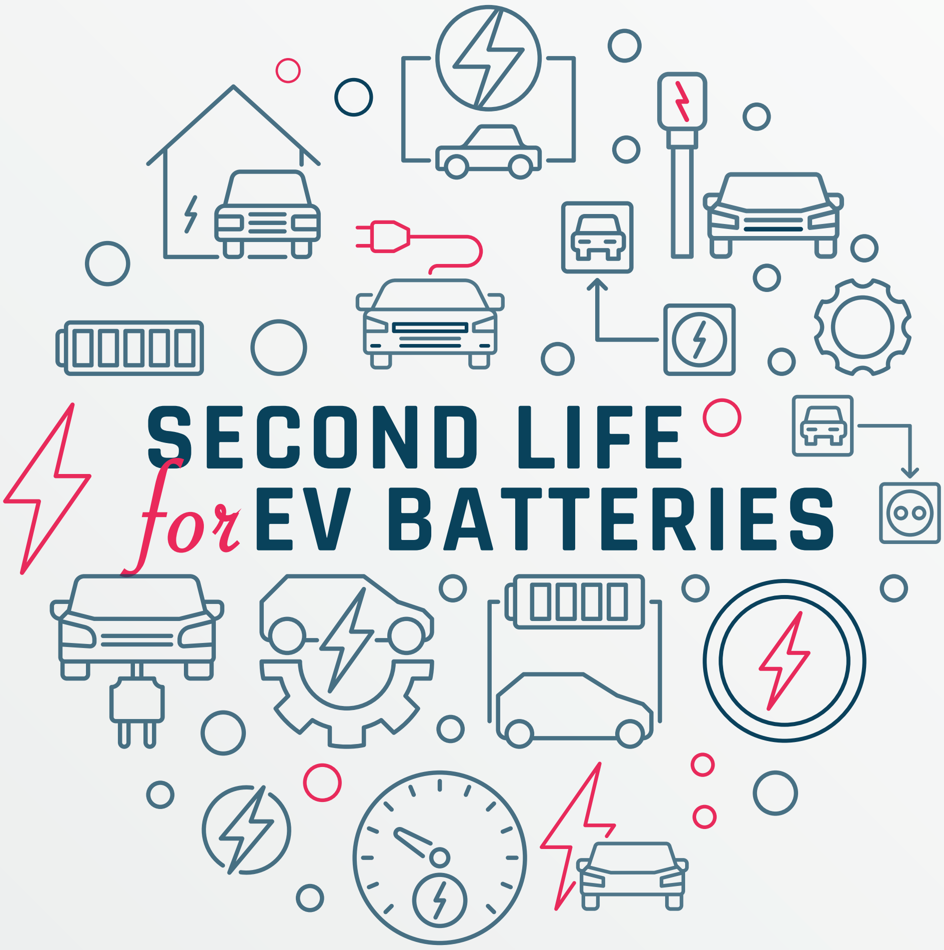
DRIVE



SECOND LIFE *for* EV BATTERIES

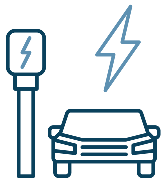
KEEPING TODAY'S INNOVATION FROM BECOMING TOMORROW'S PROBLEM

MAYER CARS AND TRUCKS CO. LTD · HONDA The Power of Dreams · Hertz · ituran · NEC NEC CORPORATION OF AMERICA · VOLVO Volvo Group · VOLVO · COX AUTOMOTIVE

SECOND LIFE *for* EV BATTERIES

EXECUTIVE SUMMARY

This article serves as an in-depth research report exploring the possible fates of first life Lithium-ion (Li-ion) Electric Vehicle (EV) batteries, main players in the industry, factors impacting the second life market, and more. In this report, we will analyze the potential challenges this field faces and will continue to face. Our main goals are to provide a broad, all-encompassingperspective on the subject while identifying potential opportunities and areas for collectiveimprovement as EV batteries continue to become more prominent in the auto industry.



THE PROBLEM

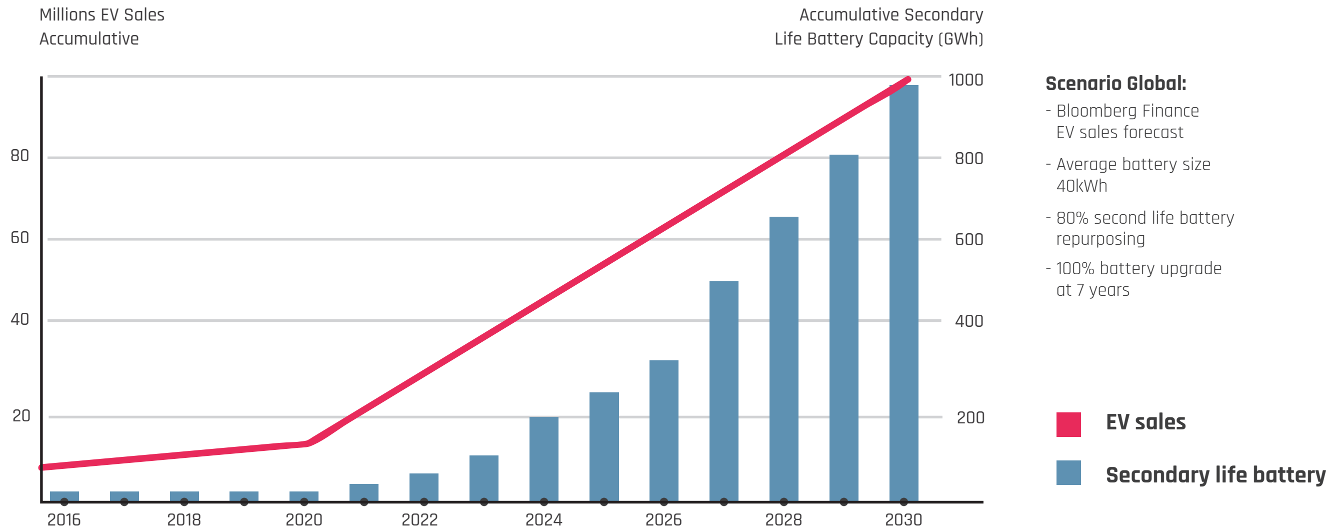
EVs continue to make their debut in the auto industry, as more and more Lithium-ion batteries come into play, with the projection that by 2040 over half of the new-car sales and a third of the global fleet - equivalent to 559 million vehicles will be electric[1]. With the inevitable surge in EV sales, the automotive industry has begun to ask itself a difficult question - what happens once these batteries have run their course? What do we do with them?

Issues ranging from the emission of toxic waste to the inevitable precious metal supply risk come to mind. The majority of EV batteries come to the end of their useful life after approximately 7-10 years, after which, most are currently thrown away. The estimated global stockpile is forecast to exceed the equivalent of about 3.4 million packs by 2025, in comparison to approximately 55,000 in 2018[2]. With this issue at the forefront of global concern, innovation and new solutions to source a second revenue stream for these batteries are more relevant than ever. These solutions involve the recycling and reuse of batteries in the effort to maximize their potential after they can no longer support their primary function in a car. We could be seeing the same batteries that once powered cars, assume a more low-key role, and be used to chill beer, grill hot dogs, and power homes.

[1] https://www.bloomberg.com/news/features/2018-06-27/where-3-million-electric-vehicle-batteries-will-go-when-they-retire
[2] https://www.bloomberg.com/news/features/2018-06-27/where-3-million-electric-vehicle-batteries-will-go-when-they-retire

BY 2025, THE WORLD COULD BE LOOKING AT ~3.4 MILLION DISCARDED BATTERY PACKS. THIS IS A PROBLEM TO WHICH WE DO NOT CURRENTLY HAVE A FULL SOLUTION.

GLOBAL ACCUMULATIVE SALES OF EV AND SECOND LIFE BATTERIES[3]



The problem at hand is larger than the individual issues mentioned above. The transition to EV is not just an eco-friendly innovation within the automotive industry - it is causing the entire industry to do a systematic 180-degree rotation. The Internal Combustion Engine (ICE) has dictated the characteristics of the automotive field for over a century, with very little change. Ever since we can remember, there have been oil mining companies, conveniently placed gas stations, car dealerships, and even set criteria for emissions tests. The lifecycle of ICE vehicles has designed an entire ecosystem, with an intricate economy, infrastructure, regulators, enforcers, and even consequences with which we are familiar (air pollution). But again, this ecosystem is tailor-made to fit gasoline-driven vehicles. When it comes to EV, there is not yet a mechanism for what the lifecycle is supposed to look like, where the regulators will need to be, resources need to invest in proper infrastructure, and what will drive the economy - thus making the EV battery problem that much more intricate.

[3] https://www.bee-ev.de/fileadmin/Publikationen/Studien/201604_Second_Life-Batterien_als_flexible_Speicher.pdf

THE MARKET

There are three options for handling the battery after it is no longer viable to power a car:

1. Throw away (landfill)
2. Recycle
3. Re-purpose (Second life)

The next section will cover these 3 options, their pros and cons, key players, market influencers, as well as opportunities.

OPTION ONE: THROW AWAY. WHY?

While it may seem pointless to be throwing away batteries that we will discover do have second-life value, there are many different reasons why batteries are difficult to recycle.

Why are we still landfilling?

The first challenge is the large number of battery-pack designs on the market which vary in size, electrode chemistry, and format (cylindrical, prismatic, and pouch). Each battery is designed by its manufacturer and automotive OEM, as they tailor it to fit a given EV model. This increases refurbishing complexity due to lack of standardization and fragmentation of volume.[4]

The second challenge involves falling costs for new batteries. **As new batteries become cheaper, the cost differential between used and new diminishes,** given that the rate of decline in remanufacturing cost is expected to lag the rate of decline in new manufacturing cost.

Challenge number three concerns the performance of second-life-battery standards. No guarantees exist regarding second-life-battery quality or performance.

The fourth challenge is the immature regulatory regime. Today, most markets do not have EV-battery-specific requirements. The lack of regulation creates uncertainties for OEMs, second-life-battery companies, and potential customers and gives rise to regional differences regarding whether recycling or reuse is the dominant pathway.
Although throwing away batteries creates a greater environmental issue, it is still currently the most convenient and most used solution, due to lack of regulations and convenient alternatives.

[4] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/second-life-ev-batteries-the-newest-value-pool-in-energy-storage

ALTHOUGH THROWING AWAY BATTERIES CREATES A GREATER ENVIRONMENTAL ISSUE, IT IS STILL CURRENTLY THE MOST CONVENIENT AND MOST USED SOLUTION, DUE TO LACK OF REGULATIONS AND CONVENIENT ALTERNATIVES.

OPTION TWO: RECYCLE

Li-ion EV batteries contain valuable metals and other materials that can be recovered, processed, and reused. However, very little recycling goes on today. Most of the batteries that do get recycled experience a high-temperature melting-and-extraction, or smelting, a process similar to ones used in the mining industry. These operations, which are carried out in large commercial facilities are energy intensive. The plants are also costly to build and operate and require sophisticated equipment to treat harmful emissions generated by the smelting process. Despite the high costs, these plants don't recover all valuable battery materials.

Metrics and Numerical Data

Recycling processes for industrial Li-ion batteries remain immature and expensive, and are not expected to take off for a while. While the cost of fully recycling a battery is falling towards €1 per kg (approx. €10 per kilowatt-hour), this is still approximately 3 times higher than what can be expected from selling the reclaimed materials on the market.[5]
An additional financial hurdle is that the lithium extraction process from first life batteries is currently 5 times more expensive than mined lithium itself.[6]

CHEMICAL PROCESS

Recycling technologies can be categorized into three techniques: hydrometallurgical, pyrometallurgical and mechanical processes. In most cases, a combination of these recycling techniques is used.

Hydrometallurgy is a chemistry-specific leaching-intensive process that can recover lithium, aluminum, and other high-value materials. The process is preceded by mechanical separation and crushing of batteries. A solvent is added to the crushed batteries, and this mixture is filtered. Acid is then used to separate metals. Either precipitation using an alkaline solution or electrolysis is used to recover the metals from the leach solution.

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[5] https://www.capgemini.com/us-en/2019/04/second-life-batteries-a-sustainable-business-opportunity-not-a-conundrum/
[6] https://www.instituteforenergyresearch.org/renewable/the-afterlife-of-electric-vehicles-battery-recycling-and-repurposing/

Pyrometallurgy is a thermal treatment process that includes pyrolysis, smelting, distillation, and refining. High-value materials such as nickel, cobalt and copper can be recovered. Batteries are shredded and slowly heated, after which plastics and solvents are burned in pyrolysis, where organic material is decomposed. The remainder is smelted in a furnace and combined with limestone to create slag. Metals are then separated through distillation. Nickel, cobalt, and copper are recovered, while lithium and manganese usually end up in slag.

PROS AND CONS: RECYCLING

PROS

- Infrastructure and business partnerships have already been established.
- Re-using raw materials instead of mining them reduces the dependency on natural metals.

CONS

- Not a valid solution business-wise, without subsidy it is not profitable.
- Environmentally harmful emissions from chemical processes.

COMPETITIVE LANDSCAPE

Tesla[7]

As the earliest Model Ses reaches 7 years old, the company is receiving its first flow of batteries back after use in their earliest models, and is setting up its own battery recycling facility. The company says lithium, cobalt, aluminum, copper, and steel will be recovered from the batteries in a closed-loop system that optimizes the materials for new battery production. It also states that it expects to save money producing new batteries from the recycled materials, rather than buying new minerals for its batteries.

[7] https://www.greencarreports.com/news/1122631_tesla-launches-battery-recycling-at-nevada-gigafactory

Neometals[8]

Neometals has developed a sustainable proprietary process for the recovery of valuable constituents from cell production scrap and end-of-life lithium-ion batteries.
The
Neometals processing flowsheet targets the recovery of >90% of all battery materials from LIBs that might otherwise be disposed of in landfill or processed in energy-intensive pyrometallurgical recovery circuits.
Specifically, the Neometals' recycling process targets the recovery of valuable materials from consumer electronic batteries (devices with lithium cobalt oxide (LCO) cathodes), and nickel-rich electric vehicle and stationary storage battery chemistries (lithium-nickel-manga- nese-cobalt (NMC) cathodes).

Fortum[9]

Fortum is able to recycle over 80% of lithium-ion battery materials. Their industrial-scale, low-CO2 process allows them to recover the cobalt, manganese and nickel from the battery for reuse in producing new batteries.[10]
To achieve a high recycling rate of 80% with a low-CO2 they use hydrometallurgical recycling processes.11 The lithium-ion batteries are first made safe for mechanical treatment, with plastics, aluminium and copper separated and directed to their own recycling processes. What is left of the battery after these processes are the chemical and mineral components - the 'black mass' and in their facility in Harjavalta, Finland which are later treated on an industrial scale.

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[8] https://www.youtube.com/watch?v=RzO-uWRQcak
[9] https://www.fortum.com/products-and-services/fortum-battery-solutions/recycling/lithium-ion-battery-recycling-solution
[10] https://www.fortum.com/products-and-services/fortum-battery-solutions/recycling/lithium-ion-battery-recycling-solution
[11] https://link.springer.com/article/10.1007/s40831-015-0016-6

Umicore[12]

Umicore, notably partnering with Toyota as their primary recycling company as well as with Tesla, recovers valuable metals from Li-ion, Li-polymer, and Nickel Metal Hydride (NiMH) batteries so that they can be converted into active cathode materials for the production of new rechargeable batteries.[13]

By combining a unique pyro-metallurgical treatment[14] and a state-of-the-art hydro-metallurgical process[15], Umicore is able to recycle all types and all sizes of Li-ion and NiMH batteries. In fact, Umicore has invested €25m (£22.6m) into an industrial pilot plant in Antwerp to recycle lithium-ion batteries.[16] By extracting metals such as Cobalt and Lithium from end-of-life batteries, Umicore is leading the way towards a circular economy, providing solutions to the growing demand for sustainably sourced materials.

American Manganese[17]

American Manganese takes consumer battery waste sourced from urban areas and processed for reuse in lithium-ion batteries. They use a closed-loop hydrometallurgical system with no GreenHouse Gas emissions, no landfill waste, low energy consumption, and recycling of process water and reagents while also reducing reliance on mining raw materials.

[12] https://csm.umicore.com/en/battery-recycling/
[13] https://csm.umicore.com/en/recycling/battery-recycling/
[14] https://en.wikipedia.org/wiki/Pyrometallurgy
[15] https://www.researchgate.net/publication/272662523_Battery_Re-cycling_Technologies_Recycling_Waste_Lithium_Ion_Batteries_with_the_Impact_on_the_Environment_In-View
[16] https://www.theguardian.com/sustainable-business/2017/aug/10/electric-cars-big-battery-waste-problem-lithium-recycling
[17] https://www.youtube.com/watch?v=YoLREWte_Gw&feature=youtu.be

HydroVolt

Aluminum and renewable energy company Hydro has partnered with Swedish battery developer Northvolt to create a joint venture (JV) for recycling battery materials in Norway. Hydro Volt will open a pilot plant this year and a full-scale recycling center in 2021, taking in batteries from the Norwegian EV market through Northvolt's Revolt project. This is expected to reduce Northvolt's mining operations. The company has a target of obtaining 50% of its raw materials from recycled batteries by 2030.[18]

THERE IS AMPLE COMPETITION IN EV BATTERY RECYCLING, MOST COMPANIES HAVE SIMILAR END GOALS. THE MINOR DIFFERENCES ARE IN THE CHOSEN METALS FOR EXTRACTION, SLIGHT IMPROVEMENTS IN COSTS, AND LEVEL OF ECO-FRIENDLINESS.

OPTION THREE: SECOND LIFE

There is a third, more sustainable alternative - to repurpose or give a second life to the battery. At the point of retirement, the battery still has approx. 70% energy storage and discharge capacity; this option extends the lifetime value of the battery and gives it a less demanding purpose than in its previous job in powering a vehicle. It can, therefore, be utilized in other applications in a more economic capacity such as stationary energy storage in different scales or in grid support.

Stationary Energy Storage (SES)

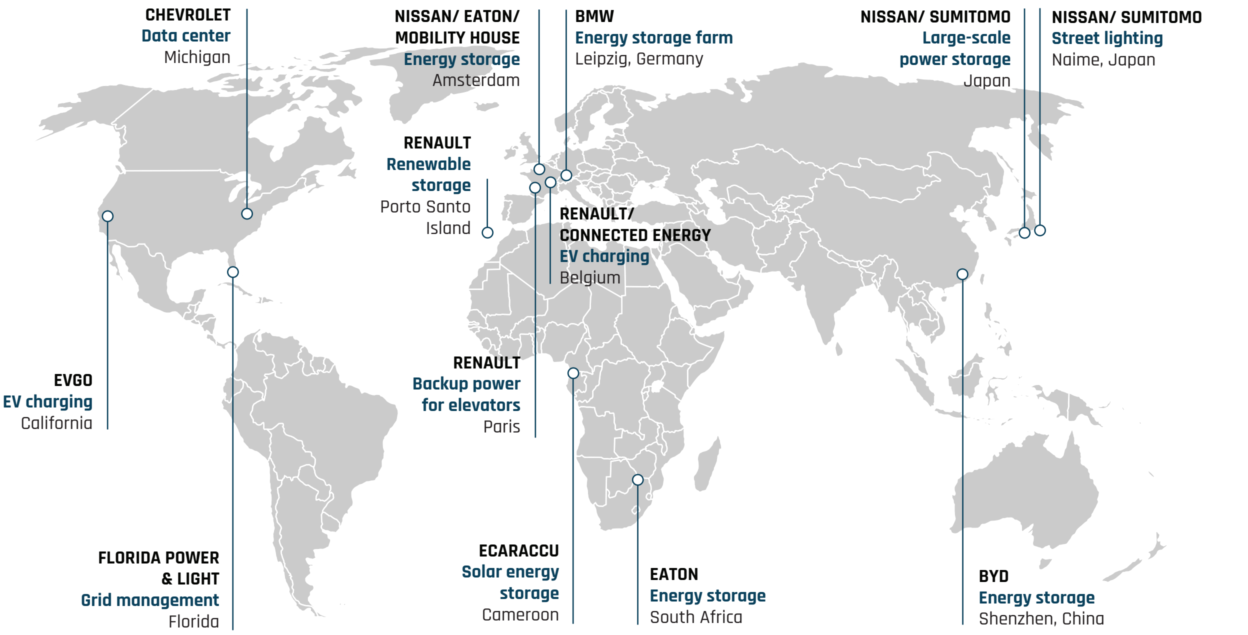
If automobile companies do not choose to recycle the batteries for parts or throw them away, the most common second-life usage is SES. A stationary energy storage system can store energy and release it in the form of electricity when it is needed. In most cases, an SES system will include an array of batteries, an electronic control system, an inverter and a thermal management system within an enclosure. In most cases, the energy source that charges those batteries will be from renewable energy sources (solar, wind).

[18] https://app.curationcorp.com/story/B8528CF7-2853-43A8-92D9-86881FB68BC0

COMPETITIVE LANDSCAPE

A New Lease on Life

Where electric-vehicle batteries are being used and tested for new roles



Source: Company filings
Bloomberg

Powervault[19]

Powervault is an innovative home battery system, which enables homeowners to live smarter by increasing their ability to store and use the solar energy freely-generated from their own solar panels. Powervault units can also automatically charge using low cost, off-peak energy from the grid. The Powervault system sits at the heart of the smart home and the optimisation of energy usage within it. As well as reducing the cost of production of a Powervault, the use of second life batteries will also optimize the life-cycle of the Renault batteries before they are recycled.

Powervault and Renault announced a partnership in 2017[20] to re-use electric vehicle (EV) batteries in home energy storage units. This partnership will reduce the cost of a Powervault smart battery unit by 30%, helping Powervault to bring home energy storage to the tipping point of mass-market roll-out in the UK. Powervault is placing 50 trial units, powered by second life batteries provided by Renault, in the homes of customers who already have solar panels installed. The trial will explore the technical performance of second life batteries as well as customer reaction to home energy storage to help develop a roll-out strategy for the mass-market.

[19] https://www.powervault.co.uk/technical/solar-battery-technology/

[20] https://www.powervault.co.uk/article/powervault-and-renault-give-ev-batteries-a-second-life-in-smart-energy-deal/

Volkswagen[21]

At the beginning of 2019, VW unveiled its "power bank for the e-car", a mobile rapid charger consisting of up to 360kWh second-life EV batteries that can charge up to four vehicles simultaneously.[22] The charging process only takes an average of 17 minutes. If the energy content of the installed battery set is less than 20 percent, the depleted charging station is simply exchanged for a charged one. If, however, it is permanently attached to the power supply with up to 30 kW via alternating current, the battery pack perpetually recharges itself. In case the charging process is based on renewable power supply, the charging station furthermore allows the temporary storage of sustainably generated power, such as solar or wind energy – and therefore CO2-neutral mobility.

WITH ALL THESE COMPETITORS CONTRIBUTING TO THE FUTURE OF THE "SECOND-LIFE" MARKET, IT IS ONLY A MATTER OF TIME BEFORE SUCH SOLUTIONS BECOME ACCESSIBLE TO THE AVERAGE CONSUMER.

Hyundai

Korean carmaker Hyundai will branch into the energy storage space to eke more value out of used EV batteries. Hyundai is pairing up with solar cell manufacturers to develop energy storage systems with used EV batteries. They plan to develop home use products.
The companies are designing a storage system at the scale of 1 megawatt-hour, composed of second-life batteries from the Hyundai Ioniq Electric and Kia Soul Electric cars.
"By repurposing resource-intensive products like EV batteries, we eliminate disposal costs and extend the value of the R&D investment that goes into manufacturing the technology."[23]

Renault + Mitsui

A German storage project utilising second-life EV batteries, with a target installed capacity of 20 MW, is being developed via a joint project by Groupe Renault, The Mobility House, Mitsui and Demeter. Renault will provide the batteries and Mobility House will sell storage capacity for network services and industrial requirements. The project is reportedly the country's largest stationary power storage system using EV batteries and follows a 45 MW project in France. The system is part of the Advanced Battery Storage project announced by Renault in 2018.[24]

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[21] https://www.smart-energy.com/industry-sectors/electric-vehicles/second-life-for-electric-vehicle-batteries-says-vw/
[22] https://www.volkswagenag.com/en/news/stories/2018/12/the-first-power-bank-for-the-e-car.html
[23] https://www.greentechmedia.com/articles/read/hyundai-enters-stationary-storage-market-with-greensmith-partnership
[24] https://www.energy-storage.news/news/storage-system-using-renault-ev-batteries-to-be-built-in-germany

GRID USE SOLUTION

Another use case for second-life batteries, is to support the grid, either in times of failure, or pick demand. Some examples of such projects are listed below.

Porto Santo Smart Fossil Free Island[25]

The Porto Santo Fossil Free Island project in the Madeira archipelago has two stationary energy storage systems that use second-hand batteries. These batteries come from Renault electric vehicles and are no longer up to the demands of powering a car. They are, however, perfectly suited for stationary use. They now act as voltage regulators and network stabilizers, and store intermittent energy produced by the solar and wind farms on the island, which is kept for local use.

FlexMobi'ile[26]

This first French smart island project is an experiment on developing an electric vehicle ecosystem for the whole island of Belle-Ile. It aims to reduce the carbon footprint by limiting the number of petrol deliveries from the mainland, and also reduce the island's carbon emissions due to heating and transportation, without compromising on the quality of services.[27]

Nissan + Eaton

In 2016, auto company Nissan partnered with Eaton, a power management company. Together, Nissan and Eaton utilize both new and used EV batteries for cost-competitive energy storage in locations ranging from Eaton's facility in South Africa, to the application of the xStorage Building System in the Amsterdam ArenA and the xStorage Home portfolio for widespread residential use in Europe. The implementation in the Amsterdam ArenA is known as one of Europe's largest energy storage systems in a commercial building, using "a combination of used and new EV battery packs - the equivalent to 63 second life Nissan LEAF battery packs and 85 new Nissan LEAF battery packs."[28] These large scale energy storage plans are already showing promising yields, as the South Africa Eaton facility claims to have achieved 56.5% in operational savings between March 2018 and May 2019.[29]

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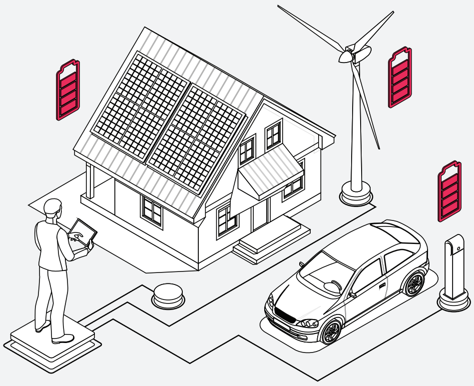
[25] https://www.youtube.com/watch?v=Hvipn7G9ecc
[26] https://smile-smartgrids.fr/en/projects/projects/flexmobile.html
[27] https://smile-smartgrids.fr/en/projects/projects/flexmobile.html
[28] http://www.eaton.de/Europe/OurCompany/News/PRCompany/PCT_3241008
[29] https://microgridknowledge.com/second-life-electric-vehicle-batteries-eaton-microgrid/

PROS AND CONS: SECOND LIFE



PROS

- Often more cost-effective compared to recycling.
- Could optimize existing energy solutions.
- A wide spectrum of use cases, allowing for a larger potential market.

CONS

- Price difference between new and used batteries may not justify second use.
- Not every battery is suitable to be given second life (damaged cells, performance issues.
- Sorting process to determine viability is expensive.

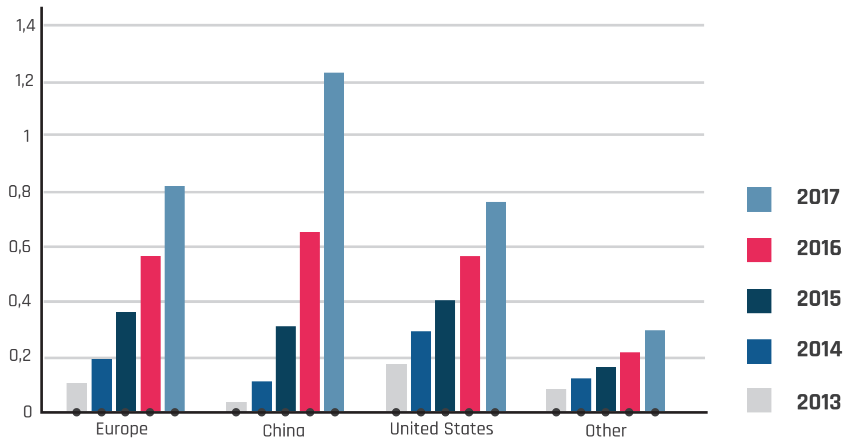
ACCOUNTABILITY - WHO IS RESPONSIBLE FOR THESE BATTERIES?

To better grasp what the future holds for second life EV batteries, the first step is to try and understand whose "problem" depleted first life EV batteries is. Who is in a place of potential loss, gain, and accountability for second life batteries? Is the onus on the OEM, the consumer, or is it on a country's respective legislative body?
The second life EV battery market is new and premature; while it may be too soon to tell the answer to this question, we understand that it may vary from country to country based on current and projected use of EV's and economical global leverage.

The next section will cover legislative and regulatory aspects in the following regions: China, EU, US.

Global Surge in EV Circulation

Figure 1 - Number of electric cars in circulation, 2013-2017 in millions)



Sourse: Global EV Outlook, 2018.

LEGISLATIVE LIABILITY:

China

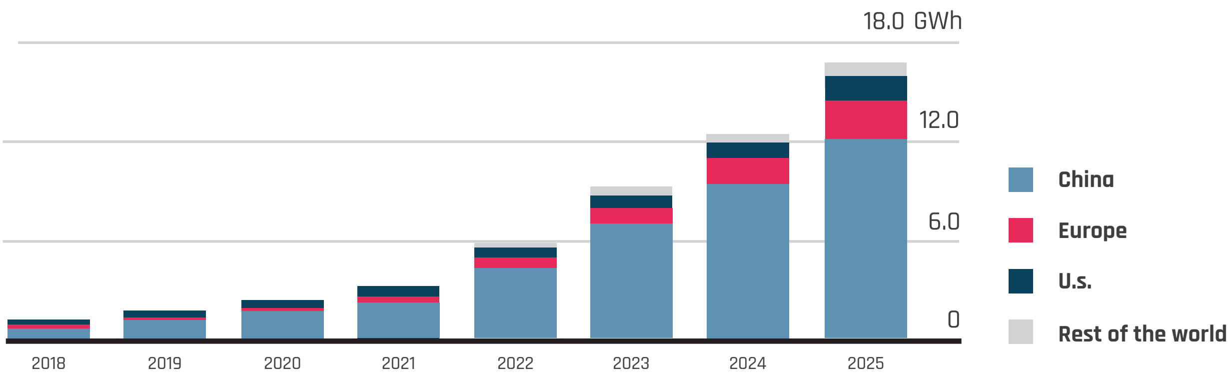
When looking at China for instance, we see a country whose **EV usage accounts for over 40% of the EV's sold worldwide** with an 87% increase in sales from 2015 to 2016.[30] This staggering data can be attributed to China's significant subsidization of these vehicles, often making citizens living in dense cities requiring mostly short distance travel an offer they cannot refuse. Due to China's advanced placement in the EV field, the predicament they face with battery depletion is increasingly tangible.

China already has a set of policies in place to mitigate inevitable issues - in early 2018 Beijing published regulations holding EV manufacturers accountable for not only battery recycling, but also collection. Recognizing the weight of this task, the industry ministry has called for a service network which consumers can utilize to repair or exchange old batteries. **These new rules implore EV makers to arrange recycling and service outlets which can collect from the public, store, and transfer used batteries to recycling companies**.

The commitment to this effort is substantial - Beijing has called for vehicle manufacturers to arrange a tracking system to trace owners of these discarded batteries.[31]

China's Prize

Country will dominate second-life capacity from retired car and bus batteries



Sourse: Circular Energy Storage

Global energy capacity of re-purposed batteries[32]

[30] https://www.instituteforenergyresearch.org/uncategorized/chinas-new-environmental-problem-battery-disposal/

[31] https://www.electrive.com/2018/02/26/china-requires-ev-makers-recycle-batteries/

[32] https://www.bloomberg.com/news/features/2018-06-27/where-3-million-electric-vehicle-batteries-will-go-when-they-retire

Europe

With Asia (notably China) as leaders in second life innovation, the EU is motivated to be a relevant competitor, thus assuming certain liability for second life. The UK for example, requires battery manufacturers to back the costs of collecting, treating and recycling all collected batteries.[33] The EU Batteries directive is the authority on European battery regulation. Per the directive, **"Producers of batteries and accumulators and producers of other products incorporating a battery or accumulator are given responsibility for the waste management of batteries and accumulators that they place on the market."**[34]
This statement in and of itself is not completely clear in designating responsibility (OEM? Battery manufacturer?) and does not state a specific methodology with which to implement this responsibility. Part of the issue may be with the rate of amendment and revision of the directive, with some critics commenting that the industry is developing quickly, leaving little time for the directive to adapt to the dynamic reality. Some examples of delay in adaptation include lack of centralized universal battery collection hubs, and a relatively low requirement to recycle Li-ion batteries - currently at 50%.[35]

US

In the US, the potential issues have been identified, as the US Department of Energy states that "the growth in demand for lithium-ion batteries for EVs will establish EVs as the largest end user of cobalt and lithium, and could create a particularly high supply risk for cobalt". As part of the policy for mitigating this issue, the DOE intends to "promot[e] recycling, reuse and more efficient use to significantly lower global demand for critical materials." A method the DOE plans to implement is to incentivize American entrepreneurs, with prizes such as 5.5 million dollars to find innovations for alternatives to discarding batteries.[36] It seems that US legislation **only goes as far as to hold the auto OEM responsible for ensuring the presence of a recycling facility, but does not place the auto OEM or battery manufacturer responsible for the cost of dealing with these batteries** - leaving an awkward and heavy responsibility on none other than the vehicle owner.[37]
The above data may indicate that the US government will impose legislation enforcing a second life future, but we have yet to find a clear-cut answer to the extent of the enforced second life, or if they will assign a specific responsible entity.

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[33] https://www.gov.uk/guidance/waste-batteries-producer-responsibility
[34] https://ec.europa.eu/environment/waste/batteries/
[35] https://energypost.eu/europe-needs-its-own-ev-battery-recycling-industry/
[36] https://www.energy.gov/sites/prod/files/2019/07/f64/112306-battery-recycling-brochure-June-2019%202-web150.pdf
[37] https://fortune.com/2020/01/28/lithium-ion-battery-recycling-electric-vehicles/

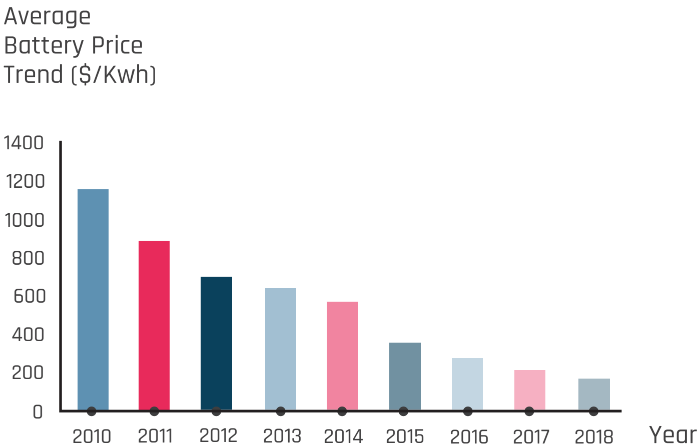
CHINA IS FACING THE MOST IMMINENT CONSEQUENCES FROM DISCARDED EV BATTERIES, THUS, IT HAS THE MOST DEVELOPED ACCOUNTABILITY MODEL. IN EUROPE AND THE US, EV BATTERY ACCOUNTABILITY SEEMS PREMATURE IN COMPARISON. IN EUROPE, WITH EMERGING DIRECTIVES, THERE SEEMS TO BE AN OUTLINED PLAN OF INTENT. MEANWHILE IN THE US, WITH STATE-WIDE POLICIES, THERE IS A LACK IN FEDERAL DIRECTION REGARDING THE SUBJECT.

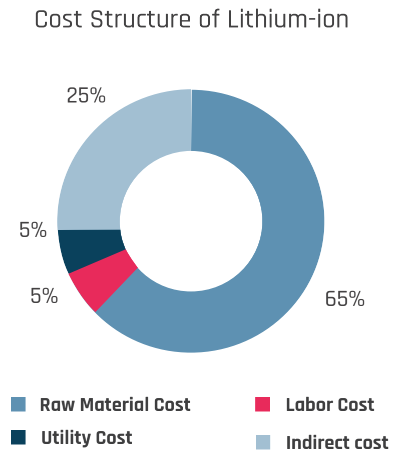
KEY TRENDS

EV LI-ION BATTERY PRICES[38 39]

At the opening of the decade, the cost of an EV Li-ion battery was unattainably expensive with a range between 7,000-20,000 dollars. As technology rapidly develops, and more and more manufacturers efficiently produce batteries, the unit price has plummeted significantly more than projected. With an 80-85% decrease in price, a current average of 176$/kWh and a continued estimation to reach as low as 60$/kWh.

Average Li-Ion Battery Price & Dost Structure





Sourse: Bloomberg, Bero Cost Model, Cost Projection of state of the Art Lithium-Ion Batteries (Gert Berckams)

This drop in price is naturally attributed to the technological advancements in the field, however, another major contributing factor is the anticipation among the industry manufacturers. Li-ion battery suppliers around the world are preparing for the surge in EV use in most modes of transportation by investing in high capacity, mass producing facilities to meet the inevitably high demand.

[38] https://www.beroeinc.com/article/lithium-ion-batteries-price-trend-cost-structure/
[39] https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

When analyzing the elements that compose and assemble the battery itself and how they affect the final price, the results may not be exactly what we think. The cost drivers of these batteries seem to be the tools used to assemble the batteries (i.e. electrodes, electrolyte separator and assembly modules) as they contribute to approx. 50% of the overall average price. The valuable raw metals such as Lithium, Nickel and Cobalt which compose the battery itself, only account for less than 16%.[40] Bloomberg further analyzes that the correlation between battery pack prices and commodity prices isn't as sensitive as we may have thought. They explain that a 50% increase in lithium prices would lead to an increase in the battery pack price of a nickel-manganese-cobalt battery by less than 4%; and a doubling of cobalt prices would result in a meager 3% increase in the overall pack price.[41]

PRICES OF BATTERIES ARE EXPECTED TO CONTINUE DECREASING. THIS WILL LIKELY DIRECTLY IMPACT RECYCLING, AS IT MAY BECOME LESS PROFITABLE. SECOND LIFE SOLUTIONS, HOWEVER, MAY BE LESS SCATHED, SINCE THE EXTRACTION OF EXTRA VALUE FROM EXISTING BATTERIES IS LESS COSTLY AND COMPLEX. SECOND LIFE SOLUTIONS ALSO OFFER AN ENERGY CONSERVATION ASPECT (MONEY-SAVING) THAT IS ATTRACTIVE TO BOTH THE AVERAGE CONSUMER AS WELL AS THE BIG CORPORATION.

[40] https://www.beroeinc.com/article/lithium-ion-batteries-price-trend-cost-structure/
[41] https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

CONCLUSION

The difficulty to landfill, the cost efficiency of recycling, the innovation of second life solutions, and countries' ability to designate responsibility effectively, will all determine how the next few decades will look in regards to EV batteries. The environmental case for finding a solution to the EV battery problem is clear. It is unclear what the lucrative incentive is for auto corporations who are just starting to gain an interest in finding battery solutions. There is a clear disparity between the deep understanding of environmental problems EV batteries pose, and the clarity of the path to a solution that makes sense economically.

KEY TAKEAWAYS

1. Market potential exists, since legislation will not allow landfilling in the long term, and without significant subsidies, recycling does not prove to be a profitable business. Thus, there will be a significant amount of used EV batteries available which can be repurposed with the right business model.
    a. The business model for repurposing used EV batteries - the financial aspect of deploying such solutions has not yet taken shape. The value that the second-hand battery provides must be significant, not only environmentally, but also economically. Also, the price of logistics (collection, testing, refurbishment) has to justify the use of those batteries and not new ones.
2. Defining liability is key in order to project the future of the second life EV battery market. Itbegins at the legislative level with national regulations on OEMs - designating them responsible for battery handling (the level of total responsibility will likely vary by region). This continues with how the OEMs choose to apply the responsibility they are given, resulting in their effectiveness in working with the consumer to retrieve the retired battery as well as the quality of the OEM-second life company partnerships. In order to function well in the long term, governments, OEMs, battery manufacturers, and recycling companies may need to find a way to share the liability of a costly business - something that remains largely unclear.
3. The success of the second life market is significantly dependent upon the OEMs ability to bring practical and applicable solutions to the table - to invest the time and resources in order to apply government regulation. This requires systematic optimization of mechanisms for battery collection from consumers, mass battery storage, standardized battery extraction capabilities, and efficient transfer to recycling companies.

WHERE CAN CORPORATIONS KEEP AN EYE OUT FOR INNOVATION?

With a new booming field, comes the potential for up and coming ideas and innovations to take center stage. Below are just few concepts where our partners can gain leadership and see profits:

- Facilities to assess battery health easily and quickly to help determine future use.
- Customer service unit to help with the collection of batteries from consumers.
- Strategic partnerships to allow a wide variety of use cases for second-life batteries.
- Diagnostic tools to help decide what kind of SES or Grid use could be relevant for that specific battery.
- Fire and explosion safe containers/storage units for Li-on batteries to be disposed of safely.
- Universal standardization technology for dismantling and handling different types of Li-ion batteries from vehicles.