Update on used EV battery prices – new indicators, drivers and data

- Average observed prices for used EV batteries increased in 2022 with 3.1% (YoY) to $235/kWh mainly due to battery packs from new EV models becoming available
- Observed prices of comparable units decreased with 10.0% to $198/kWh while the value of verified transactions decreased with 12.8% to $170/kWh
- Diverse market conditions, with large differences in both supply and demand for different types of batteries, behind the prices

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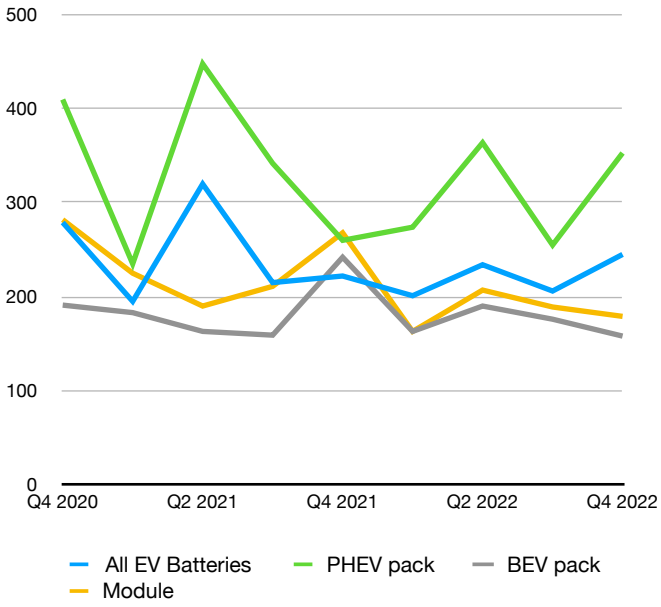
The prices for used EV batteries in Europe and North America have during 2022 moved in both upward and downward directions depending on segment and commercial context, as well as the demand and supply balance for specific batteries. While the average observed prices (not volume adjusted) showed a slight increase this is mainly due to several battery packs for new EV models which are debuting on the market. Comparable units – battery packs and modules that have been listed since 2020 – have decreased in price which mainly is attributed to a larger supply of packs which yet don't have a significant demand. Our analysis do however show that the demand will increase in near time due to fewer vehicles being scrapped while the age of the EV fleet is increases.

Average observed prices for EV batteries (North America and Europe, $/kWh)



Is second life becoming second choice?

The observed prices of EV batteries tracked by Circular Energy Storage derive mainly from car dismantlers and companies selling reused batteries on the open market. They are a combination of unassessed listed prices by the sellers and verified transactions on various market platforms. The covered markets are the United States, the United Kingdom, Germany, France, the Netherlands, Sweden and Norway. Currently the data is comprised of more than 1,400 listings over three years of which more than half are from 2022. As of now there is no volume adjustment made but every single observed listed battery is accounted for. Prices of batteries that are offered by specialised retailers and wholesalers are assessed once every quarter and are accounted for separately.

In 2022 the average price for EV batteries increased with 3.1% compared to 2021. Behind this increase are however several parallel developments taking different batteries in both upward and downward directions. Most notably the value of verified transactions decreased with 12.8% to $170/kWh mainly driven by an increasing supply but likely also due to competition from refurbished cells and overstock batteries from China. There are however clear indicators in the market that the prices for EV batteries as replacement packs can remain high as continued supply chain disruption in the

automotive market keep prices of used vehicles at record high levels, paving the market for repairs and export of current stock of vehicles which add to both a higher demand for replacement batteries but also a tighter supply of end-of-life vehicles from which batteries can be harvested.

The dynamics of the used battery market

The market for used batteries is still a fairly open market where both companies and private persons can trade entire battery packs, modules and cells. Although legislation on extended product responsibility, classification, safety and transportation vary in different jurisdictions, and may in several cases make trade more difficult, the stakeholders in the market usually find their way to new users all over the world.

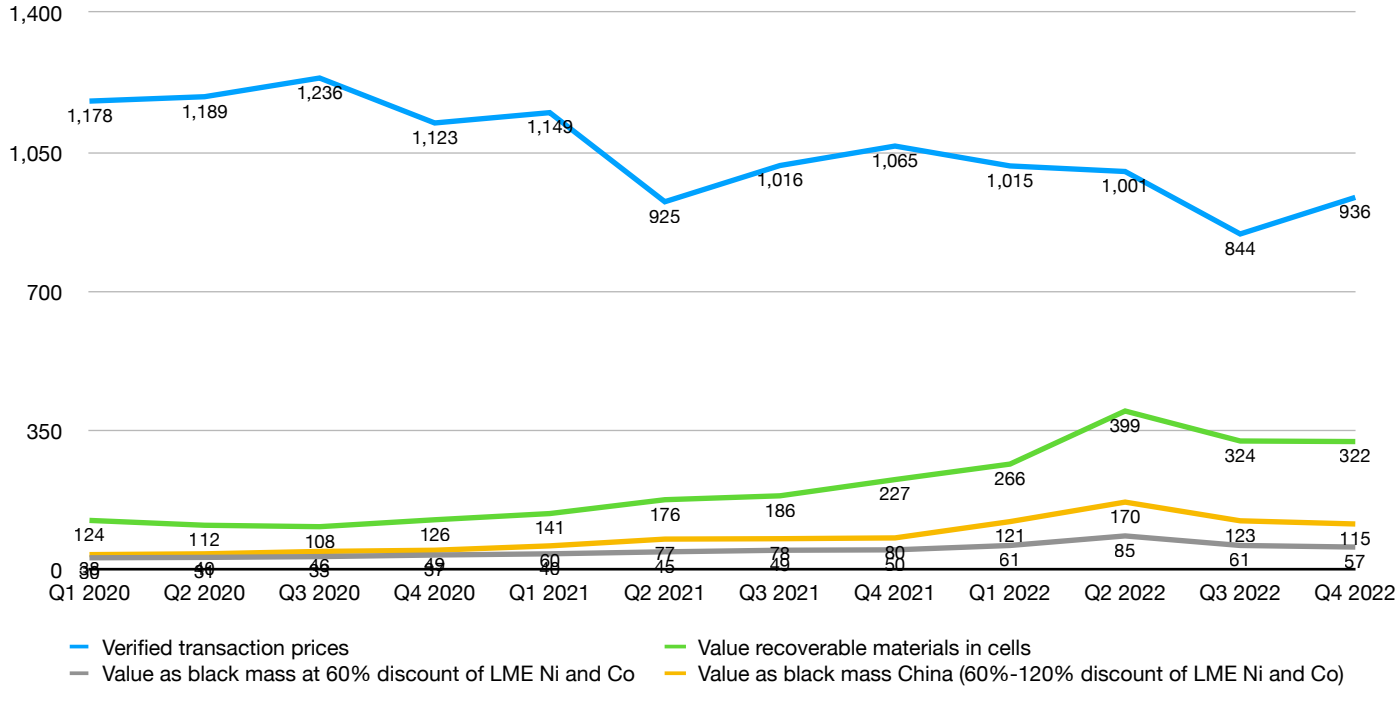
When an EV battery is removed from its original application, the point in time when we classify it as end of life, there are several different routes available for the battery. The battery can be reused in another vehicle, it can be used for remanufacturing of similar packs, it can be repurposed for other applications and can be recycled, meaning the materials will be recovered in different forms.

Which route the battery will take is determined only by one factor – the intention of the battery owner. A recycling company is equipped to recover materials from the battery and will therefore feed cells, modules and packs to its recovery process, even if a higher value theoretically could be captured through reuse of the battery. The acceptable purchase price of the battery for the recycler depends on the value of the end-products minus processing costs and profit requirements. On the other hand, a company that has designed processes to test, redesign and redeploy the batteries in the same, or in new applications, will usually be able to capture a higher value but will not be willing to pay more than what a new battery will cost as long as new batteries are available. Also in these cases the processing costs and profit requirements have to be accounted for.

In all cases the players in the market work under different circumstances, use different processes and have different kind of benchmarks. This affects both pricing and to where batteries ultimately are sold.

An independent dealer which will replace a battery in a car is usually prepared to pay much more for battery that fits the car than what a repurposing company with a process to disassemble and redeploy the battery in a new application might be. This is because the alternative price for a new battery from the OEM is significantly more expensive than new battery cells and modules which can be used for different energy storage applications which can be selected from a wider market.

Value for a Tesla Model S/X 5.3 kWh module compared with recovery value (USD per module)



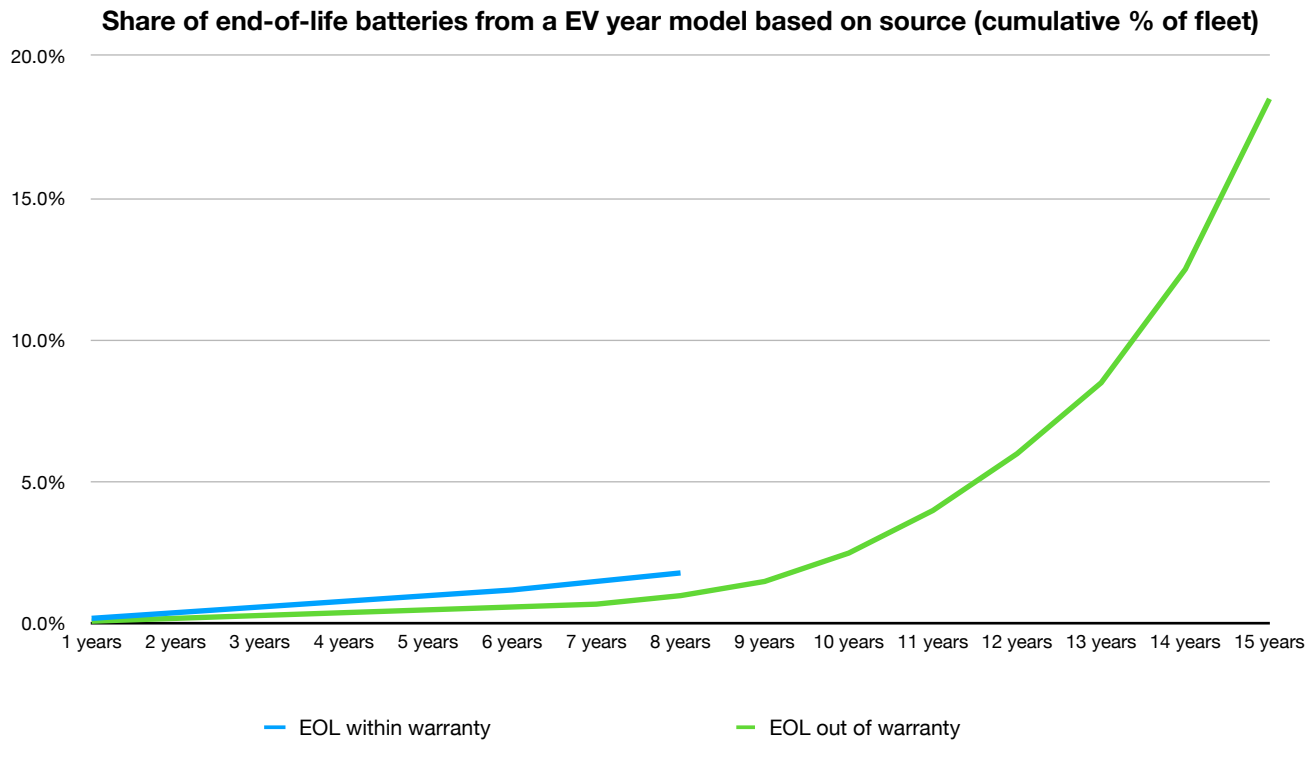
The same market logics applies in the recycling world. A recycling company with the ability to recover lithium can in today's market conditions pay much more for batteries than a recycler which only is able to recover copper, nickel and cobalt. On the other hand will there be traders which might be able to accept smaller quantities and thanks to lower CAPEX will be able to generate profits by selling the batteries overseas where recyclers can pay even more due to higher demand and lack of sufficient supply.

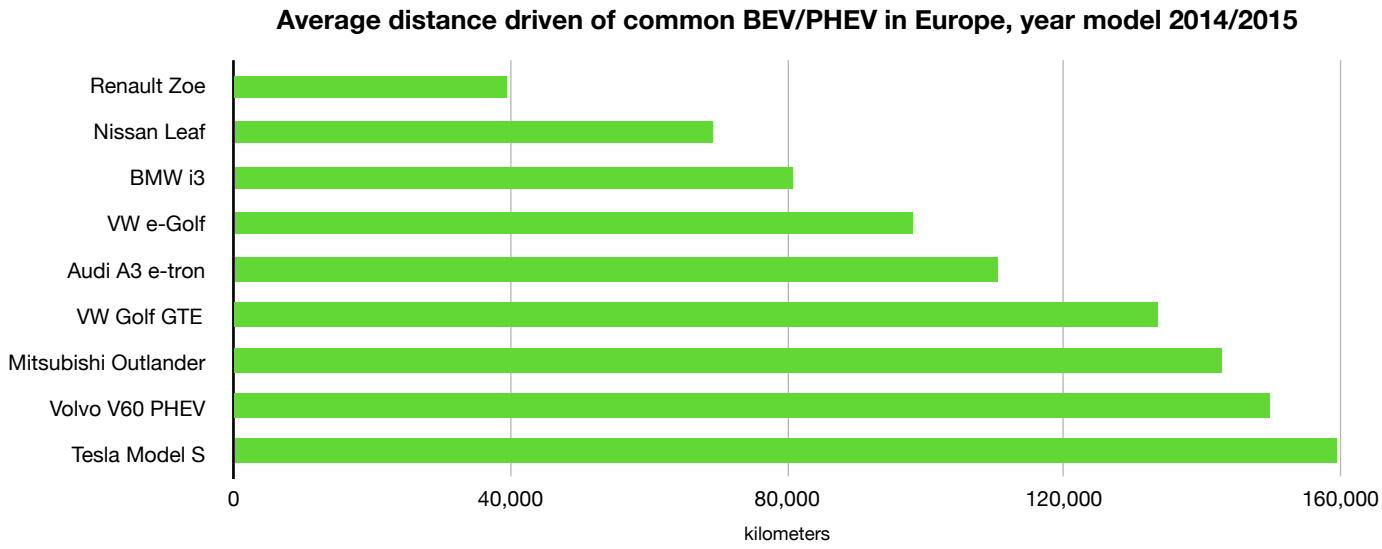
It is often argued that if global battery prices will continue its rapid downward trajectory the difference between the value a recycler can capture and the price for new batteries will be so narrow that a business case for reuse operations will be more difficult. There is however little evidence available that suggest that this will happen any time soon. As can be seen in the chart on page 2 the average value of verified transactions of Tesla S/X modules, which are some of the historically most available end-of-life battery in both North America and Europe, are in Q4 2022, despite a steady decline in price and material prices almost at historical highs, still 190% higher than the theoretical value a recycler can sell the recovered materials for at a 100% recovery rate. The same comparison with a typical price for black mass from the same module, which basically is the maximum cost a pre-processor can pay for the batteries without a negative gross margin, the difference is 1,542%. Even if a large amount of batteries are sold for less than our verified transaction prices there is significant room for the reuse market to keep the batteries in the loop.

Understanding the reuse market

A popular perception is that EV batteries after a first use in electric vehicles will find its use in stationary energy storage systems. There are indeed also several energy storage systems in operation today using retired batteries from both light and heavy electric vehicles. The majority of these systems are however not using batteries that have reached end of life due to degradation. Neither do they use batteries from ordinary end-of-life vehicles. Instead most of the large scale second life systems consist of battery packs previously used in test fleets that by law must be scrapped, or battery packs that have become available through leasing or replacement program. In almost all second life systems which today are in operation there have been a direct involvement by the OEM which originally placed the electric vehicles on the market.

Going forward the main source of batteries will however not come through OEMs. At least not when it comes to light electric vehicles. As can be seen in the chart below the older a vehicle gets the more batteries will of different reasons reach end of life out of warranty which usually means that the OEM doesn't have the direct responsibility but neither any control of the destiny of the battery. The exceptions are





when OEMs are involved in the insurance of the vehicle and through the insurance company work closely with the car dismantlers, or when the batteries are leased from the OEMs which entitles the car maker to take back the battery at end of life. In Europe car makers are also responsible to take back the battery at no cost at its end of life, but there is nothing the entitles the car maker to the battery unless the battery owner wants to get rid of it.

Therefore, in most cases when batteries are reaching end of life they will become the property of car dismantlers which are free to sell the battery to the highest bidder. The business model of car dismantlers, breakers, or authorised treatment facilities, as they are called in Europe, is to harvest components that can be used as spare parts by independent workshops. Battery packs are no exception. A totalled, or written off, vehicle is despite its status rarely damaged in its entirety and most batteries from vehicles that are classified as end of life are in a good condition.

There is however a dilemma as warranties of batteries for most vehicles last as long as 8 years, or when they have reached 100,000 miles or 160,000 km. As can be seen in the chart above, in most cases, it's the calendar life that will end the warranty coverage as most cars have not been driven past the mileage limit. This means the market for replacement batteries will be limited during this period as it's rare that battery failures would not be covered by the warranty which means that they usually will be taken care of by the OEMs. At least as of today most OEMs would not accept batteries from car dismantlers to be used as replacement batteries but will rather use their own remanufactured batteries or completely new packs.

For PHEVs there are more batteries that might loose its warranty coverage before 8 years due to higher mileage. The same chart above also clearly shows that larger batteries, as in the case of Tesla Model S, correlate with higher mileage, which indicates that the more electric cars in the future might lose its warranty cover earlier than the first generation of EVs due to larger capacity.

Still, a majority of cars are expected to remain under warranty the full period. This drives the market for repurposing where batteries are reused in other applications when the market for replacement is not available. What these applications are is totally up to the market to decide. While different types of stationary energy storage solutions have been suggested from everything from academics to policy makers more common use cases have been conversion of ICE vehicles to electric, mostly classic or vintage cars but also for commercial vehicles such as vans. Similar conversions are also done with boats. Modules from EVs are also used for energy storage in recreational vehicles, RVs and for different backup solutions.

The market segments for repurposing are usually made up by smaller companies which have developed solutions around the availability of certain battery modules. For several years modules from Tesla Model S/X and Nissan Leaf have been used in both EV conversion and for smaller energy storage applications. These are purchased either from car dismantlers, or in some cases directly through remarketing auctions where whole vehicles are being purchased and harvested.

Another growing market is the DIY community where private persons are involved in similar projects such as EV conversion and DIY residential energy storage. These communities which can be found worldwide started several years ago using 18650 cells from laptop batteries but are increasingly using EV batteries when available. The

increasing DIY community has paved the way for professional retailers who buy batteries from car dismantlers and sometimes directly from OEMs and battery companies and sell the batteries to both private persons and smaller companies with warranty.

Different segment's impact on prices

The segments of the reuse market differ in characteristics in everything from benchmark price, product visibility, purchase power and volume requirements. Which segment to address has also a big impact on the seller's activity and responsibility. For car dismantlers to sell battery packs removed from the vehicles require only limited labour and expertise compared to a full disassembly down to module level. Usually the benchmark price, the price a buyer has to pay for a similar product, is very high in this segment. Replacement batteries for a Nissan Leaf 24 kWh have been quoted to more than $6,500 and PHEV batteries for Mitsubishi Outlander or Volvo V60 have been quoted to over $10,000 in several markets. This is the perfect combination for a car dismantler. Batteries for repurposing are the direct opposite with more labour involved as well as lower benchmark prices as the alternatives range from all kinds of batteries including new large format LFP cells from China.

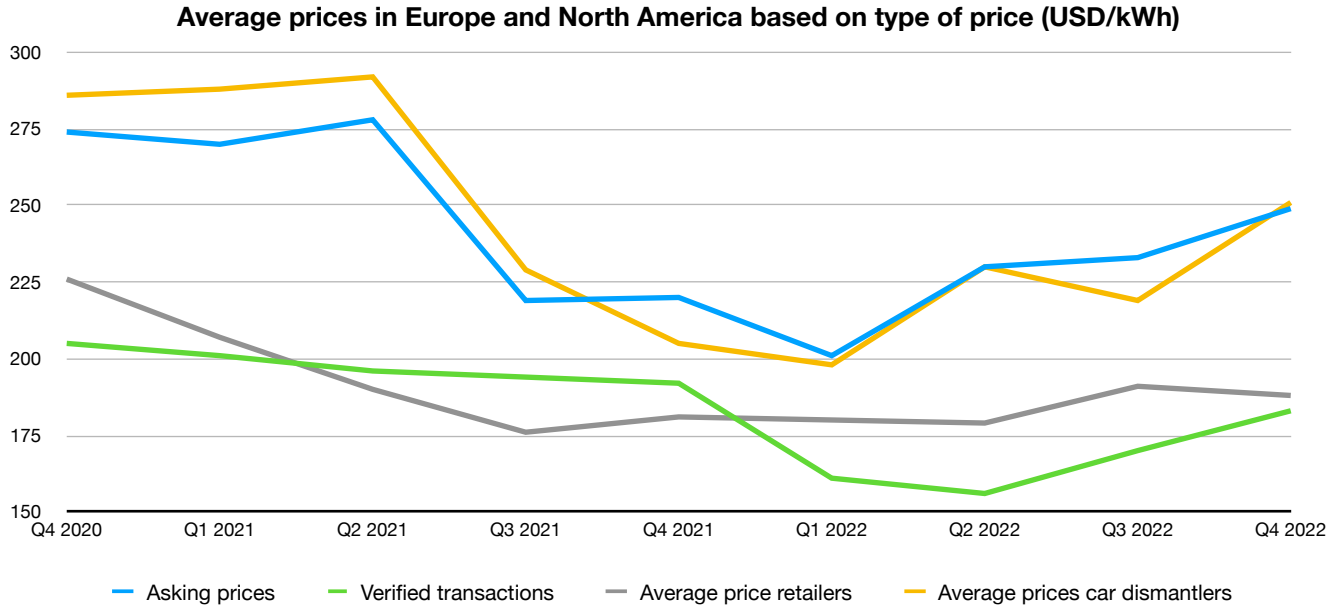
Certain modules do however attract very high prices. The aforementioned Tesla Model S/X module is the perfect example of a battery that due to its relative high availability (as Tesla Model S in several market has been one of the best-selling vehicles) and versatile format has attracted a high demand in both Europe and North America. This can be compared with modules from Tesla Model 3 which already are available in larger volumes but with a less attractive format and being more difficult to repurpose into other applications.

Observed prices vs real prices

Circular Energy Storage's observed prices are mostly based on seller's asking prices. In a mature market this would be enough to verify the real prices but in a market with limited visibility and different sales models the prices primarily serve as an indication of the batteries' attractiveness over time and in comparison between types and models. Transactions of larger volumes of batteries will usually be done on lower levels, even if prices between OEMs and second life companies seems to have increased over the last year not least due to a smaller supply of batteries overall. Transactions have been recorded at everything from $60 to $125 per kWh in both the US and Europe.

The observed prices in our assessment are significantly higher which of course could indicate that the underlying transaction value is lower or that no transactions are taking place at all. Our view is however that prices will over time correct themselves as competition between players and an ever increasing supply will disqualify an opportunity price strategy.

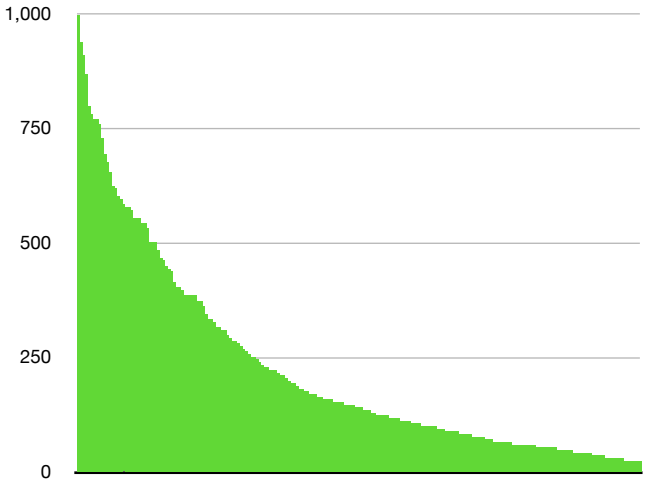
This becomes even more obvious for prices set by retailers and wholesalers who's only job is to trade batteries. If batteries are set to a level which have a negative effect on demand the business model would simply not work. In the chart below it becomes clear that the verified transactions are close to retailer's pricing. Both of these categories



consist predominately of either BEV modules or BEV packs. Car dismantlers' prices are to a higher degree consisting of PHEV batteries which, due to the pricing of them as components, rather than energy storage, are much higher than BEV batteries when measured in price per kWh.

We have also compared prices with asking prices from Northern Europe in the dedicated EV battery trading platform launched by the Swedish company Cling Systems. The distribution follow a very similar pattern with high prices for PHEV batteries while the company also list hybrid and mild hybrid batteries that list to lower prices than traction battery packs. The average prices correlate well with our overall prices.

Distribution of asking prices at Cling Systems, November 2022 (€/kWh)



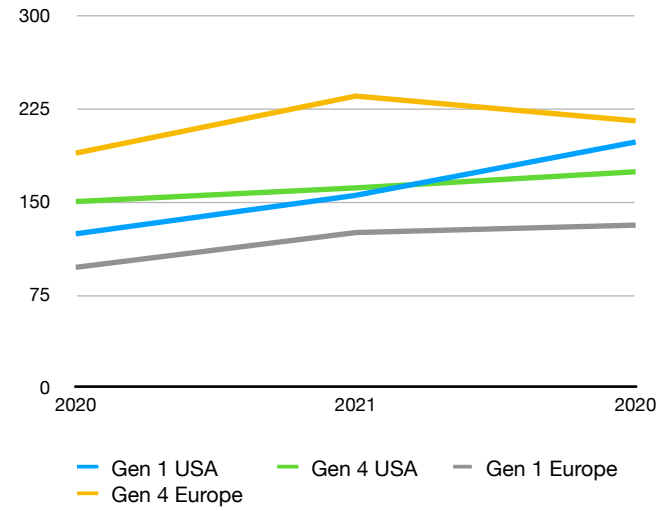
Used BEV pack prices in 2022

The average observed prices for used EV batteries increased with 3.1% compared to the prices in 2021. However, for comparable units the prices decreased with 10%. New batteries, in particular from PHEV, in some cases in higher volumes, contributed to the perceived higher value.

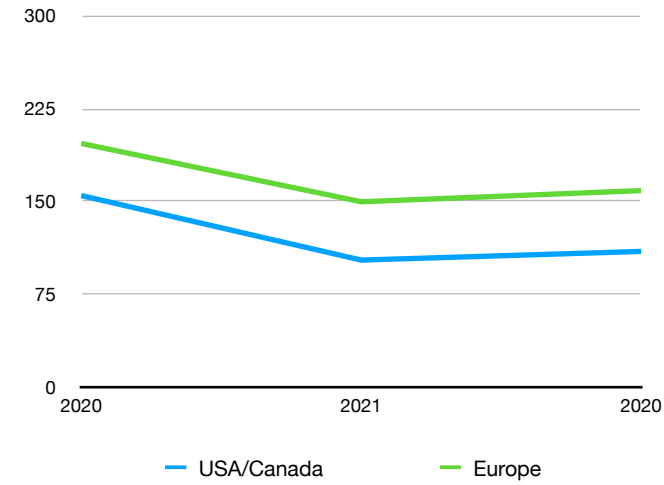
The general conclusion is however that used EV batteries are priced due to their individual model's supply and demand more than on a general market for energy storage capacity. A good example of this is the different Nissan Leaf battery packs which in most cases have increased in price over the last two years. There are mainly two reasons for this. First of all the supply of Generation 1 (24 kWh) packs and modules has decreased significantly compared to the years of 2017-2020 when large amounts of in-warranty packs found their way to the reuse market in North America. During these years both repurposing companies and the DIY market started to use Nissan Leaf modules in North America and Europe. When this supply ceased there was still a high demand for the modules as several systems now were based on the specific battery type.

Secondly the need for replacement packs in Nissan Leaf has increased as batteries in vehicles placed on the market between 2011 and 2014 are now out of warranty. This is an emerging market and there are now over 30 companies around the world that are performing replacements of Nissan Leaf batteries which now need to be sourced from car dismantlers rather from previous in-warranty volumes. As there is still a demand for modules from the repurposing market, the packs that are being replaced can be disassembled and the modules can be sold with a profit even after replacement companies have payed for the packs.

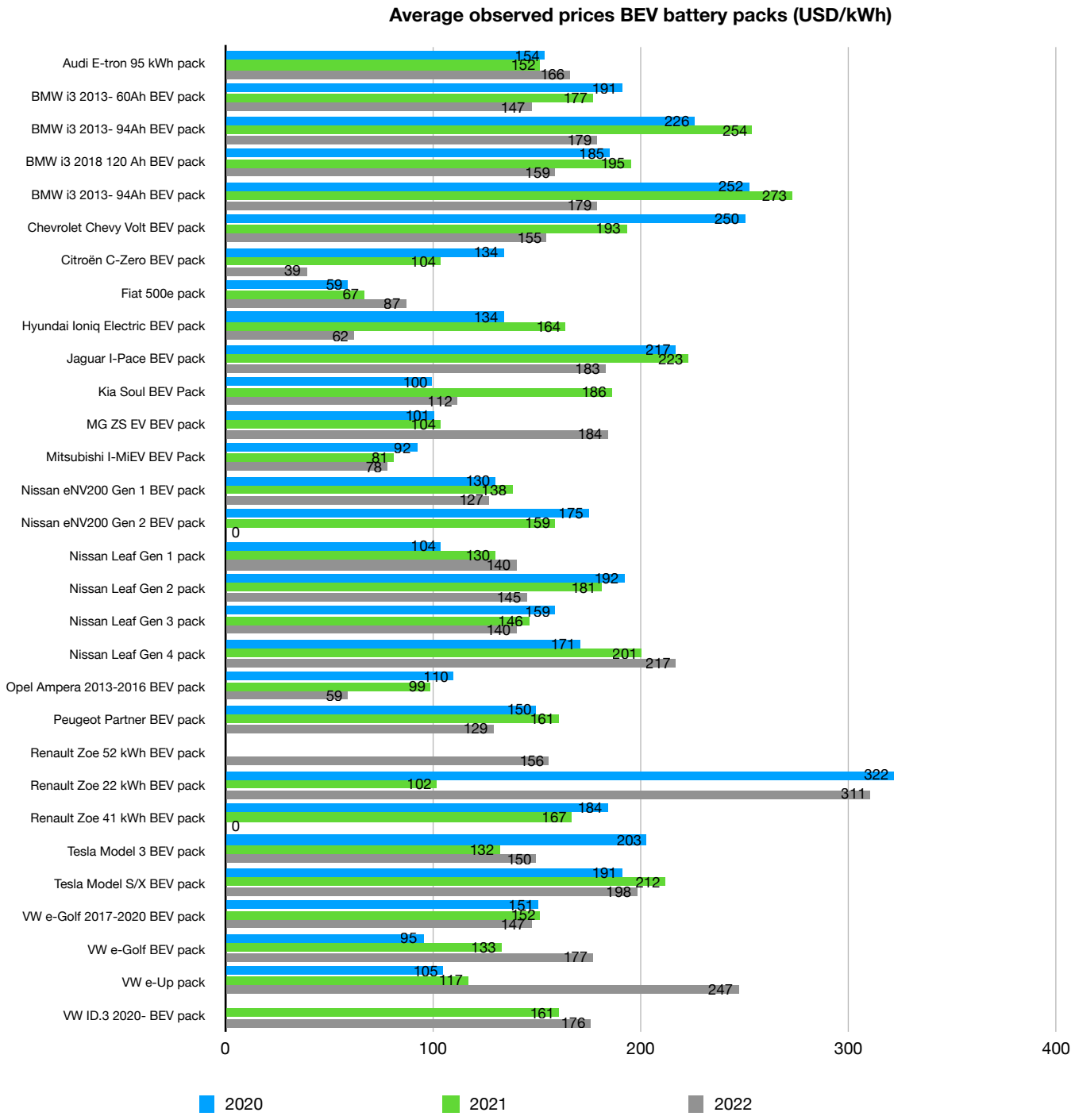
Average price for for Nissan Leaf battery packs ($/kWh)



Average observed prices for Tesla model 3 battery packs ($/kWh)



What is interesting is that the replacement market for Nissan Leaf also has a positive effect on the fourth generation battery pack, even if this pack was installed first in 2018 in the new 40 kWh Nissan Leaf, still with another 3-4 years of warranty coverage. However this pack can be fitted even in the old Nissan Leaf which has caused a strong demand for the pack and prices upwards $8,000-$9,000 per pack. This can be compared with packs from Tesla Model 3. The first Model 3 has still another 3 years of warranty and has rarely disappointed its owners. This, together with the limited possibilities to use the modules for repurposing has kept the prices on this pack in the lower range of BEV packs. In fact prices are to some extent kept even higher than what they could have, wasn't it for the fact that many Tesla Model 3

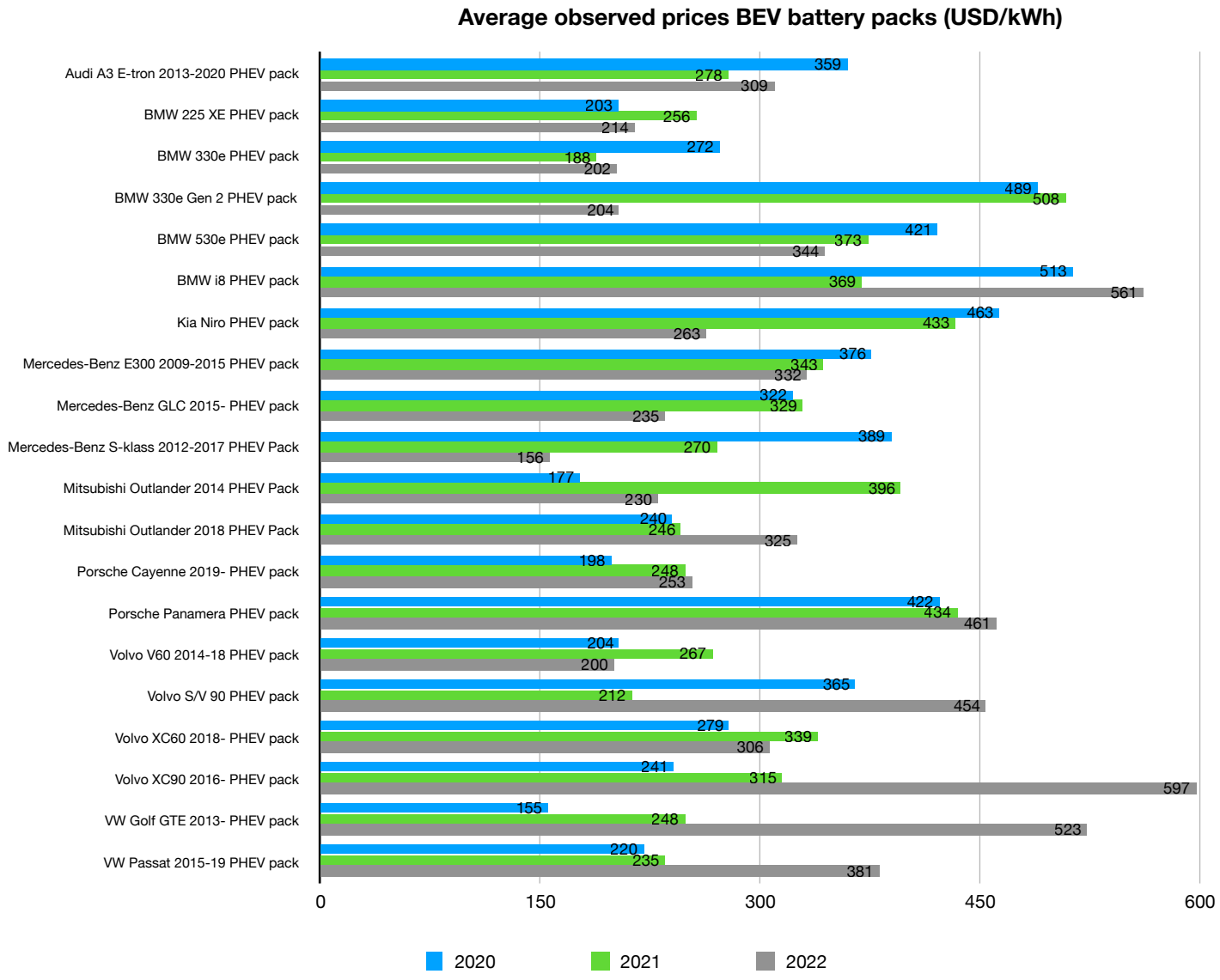


packs have been sold to the cell harvesting market for prices less than twice the recovery value.

Packs from BMW i3, Renault Zoe and both main models from Tesla can also be used for upgrades, where a newer battery with higher capacity can replace an older lower capacity pack. Renault Zoe packs are also in high demand due to the company's previous leasing model under which the car owners don't own the battery which makes the cars less attractive to repair and put back on the road unless batteries can be sourced to the vehicles.

Used PHEV pack prices in 2022

Battery packs from PHEV cars have generally higher price per kWh. The main reason for this is that the packs aren't primarily priced due their capacity just like other batteries, but rather their function and perceived market value. The PHEV batteries reach the repurposing market to a lesser extent than the BEV packs not least because the batteries require more labour for disassembly relative to its capacity and that modules not always are ideal for repurposing. But there could also be a higher demand for some of the modules. Like the chart on page 4 showed the distance driven by PHEV vehicles are usually much longer than the early BEVs. This means that some of these batteries have lost their warranty coverage earlier than most BEV. There are also examples of batteries that have been in need for early replacement while there are even more examples of batteries that have barely been used at all but the vehicles have been purchased mainly for different types of benefits. However for the reuse market this creates a good match

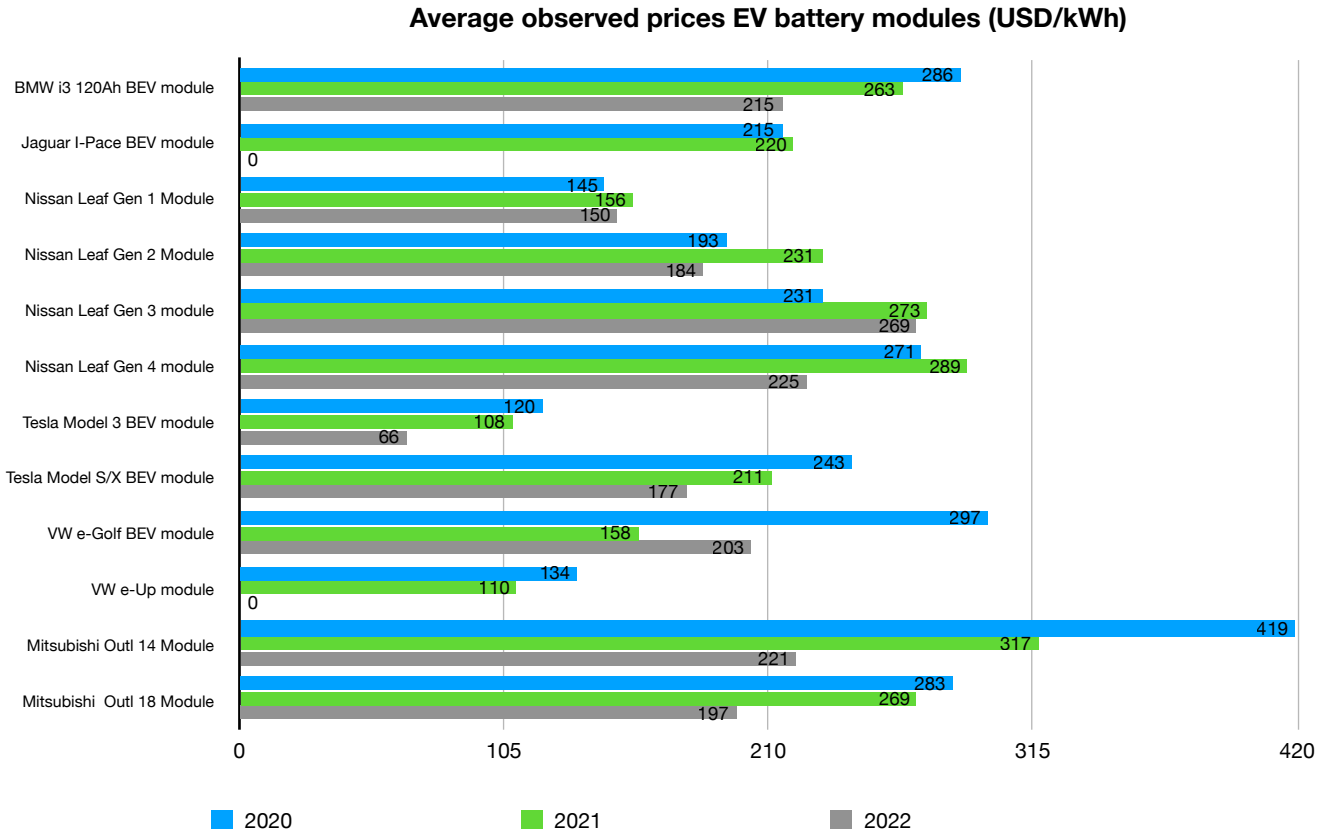


with a good supply of batteries that might not have been in heavy use and a demand for these to replace the battery that have been used.

One of the most common replacement PHEV battery is the pack in Mitsubishi Highlander which comes in two versions. These are however not completely replaceable but require remanufacturing if for instance the new, with slightly higher capacity, should be used in an older vehicle. This is something we have seen for Toyota Prius where the small HEV battery pack is remanufactured by third party repair shops and even by larger white label manufacturers.

Used EV battery module prices in 2022

During 2022 there has been a clear downward trend on the prices for battery modules. There can be several explanations to this, one being an increased competition from new battery cells and modules from China which are becoming increasingly popular in many of the segments that traditionally have been using Tesla and Nissan Leaf batteries. With a fairly large amount of batteries going into the DIY and car conversion markets we might of course also see an effect of tougher economic climate in several countries with an increased cost of living for more and more people. A third explanation is that we also start to



see older batteries in the market and even modules which are on their way to get a third life. This might cause lower prices even if the general demand is high.

The most remarkable module is the Tesla Model 3 which in some cases is worth less than its recovery value, before processing. This may represent an opportunity for repurposing players that may find a way to capture value from the high volume battery pack which increasingly will com with LFP cells. It may also mean that Tesla will be one of the first players in Europe that in large scale will need to finance the take back of batteries for recycling.

There have been expectations that modules from Volkswagen's MEB platform could be the successor of Nissan's easy-to-use modules for all kinds of repurposing, not least when Volkswagen, through its subsidiary Volkswagen Components, are selling new modules to the

the EV conversion market. The modules are also available through retailers but in the open market they have not become particularly common.

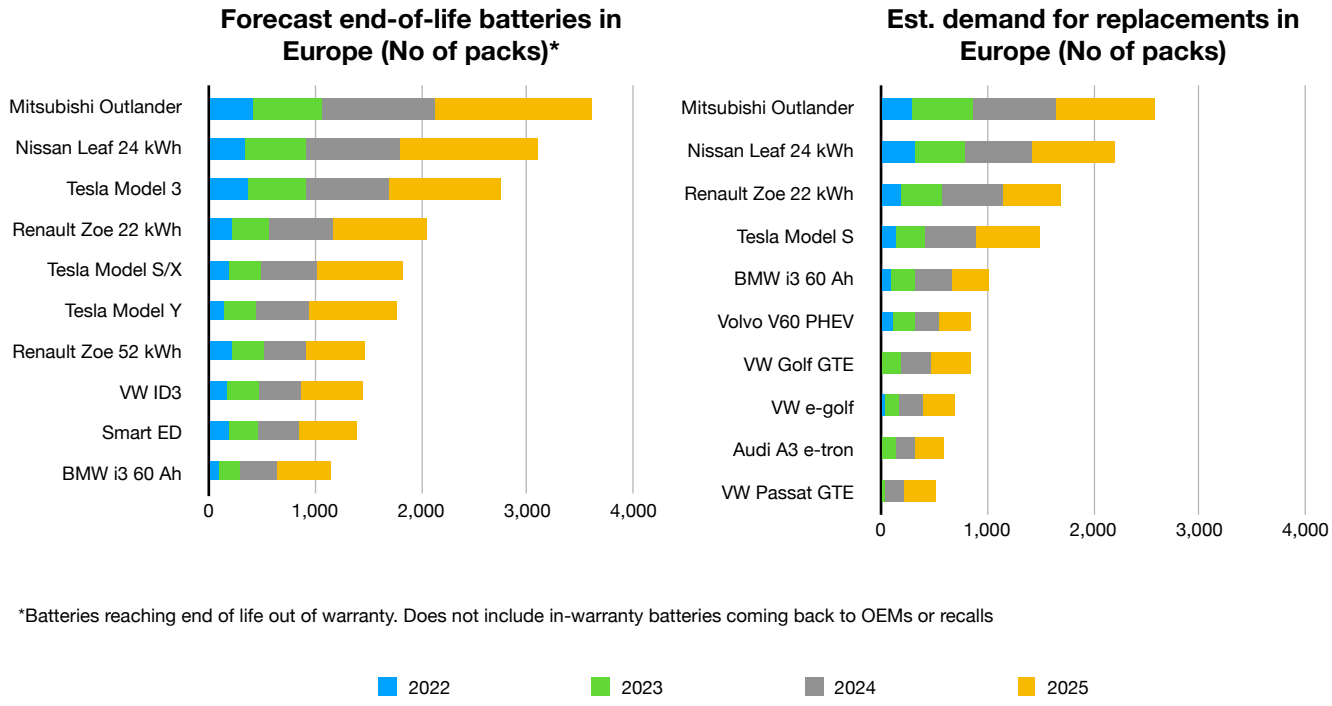
Outlook for 2023

During 2022 we have seen falling prices for several categories while some specific EV packs have increased in value mainly connected to demand for replacement packs. There have also been disruptions in the automotive value chain causing lower volumes of electric vehicles placed on the market than expected, especially in Europe, which has driven up prices of used vehicles. This has a direct effect on both availability and prices of used batteries. With higher prices of used vehicles the threshold for when a damaged car is deemed end of life is raised. Likewise it fuels a higher demand for replacement batteries as the increased value of the vehicles make it worthwhile to invest in, and upgrade the vehicles.

We believe it is likely that this development will continue in 2023, leading to an even higher demand of used vehicles.

In the same time the demand from countries with no original EV market is still high. In our report from February 2022 on the likely effects on the war in Ukraine we estimated that the import of used electric vehicles to Ukraine would decrease significantly during 2022. This was proven incorrect. Instead the amount of cars exported from both EU and the US to Ukraine has increased with 150% since last year, with more than 10,000 vehicles registered in Ukraine this year as of October. Other markets in Middle East, South America and the Caribbean are also importing EVs from Europe and North America. This does not only additionally drive up the prices of the vehicles but also limit the amount of end-of-life batteries as many of these vehicles in several cases would have been deemed end-of-life in their home market but are now exported instead. The use of the vehicles in these markets also increase the demand for replacement batteries which can be sourced from wrecks that might not be placed back on the road.

All in all there will be fewer batteries available due to fewer end-of-life vehicles and the need for replacement batteries will only increase. This might mean that the high prices for both BEV and PHEV batteries the car dismantlers today announce may be accepted by a larger and larger market which are happy to pay far less than what new batteries, or even a new car, would cost. In the charts below is a comparison between our estimated amount of batteries reaching end of life in Europe and how large the demand would be if 1% of the fleet which is out of warranty would need a replacement battery. Likely the need is very different depending on car model but already today there is clear evidence that replacements are done for vehicles such as Mitsubishi Outlander, Nissan Leaf, BMW i3 and Volvo V60.



*Batteries reaching end of life out of warranty. Does not include in-warranty batteries coming back to OEMs or recalls

In certain local markets, such as London, United Kingdom or Amsterdam, Netherlands, where there are large fleets of electric vehicles operated by private hire companies, taxi companies or by individual car-hailing drivers, there may also be several vehicles such as Hyundai Kona, MG EV5, VW ID4, Tesla Model 3, and Kia Niro which will see batteries lose their warranty cover earlier than normal vehicles due to their heavy use. This might increase the demand for replacement packs also among vehicles that otherwise wouldn't be a particularly large market.

What's special with replacements is of course that they not only use batteries that otherwise would have been repurposed or recycled. They also generate batteries for replacement and reuse. Despite that these batteries ought to be less valuable and fit for purpose (as they needed replacement) they may still find their way to the reuse market, most often as modules. The precursor to this development is the ecosystem around Toyota Prius in which modules are harvested from packs that have been deemed as end of life only to be tested, graded and put back into packs in a remanufacturing process. This represents an opportunity for both reuse companies and recyclers to capture these batteries which otherwise might end up in a box in a garage after both one or two times on Ebay. These modules will also contribute to the lower end of the price spectrum and may make the market look more saturated than it actually is.

It is however also clear that some models, due to large number of vehicles placed on the market, will reach end of life in large volumes without having a matching replacement market. Tesla Model 3 and Model Y are already an example of this, followed by VW ID3 and ID4, Skoda Enyaq and Peugeot e-208. These models will need to find their way to the repurposing market if the values shouldn't fall in the same way they have done for Tesla Model 3 already.

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