ePROPELLED™

DRIVING EVS TO PROFITABILITY

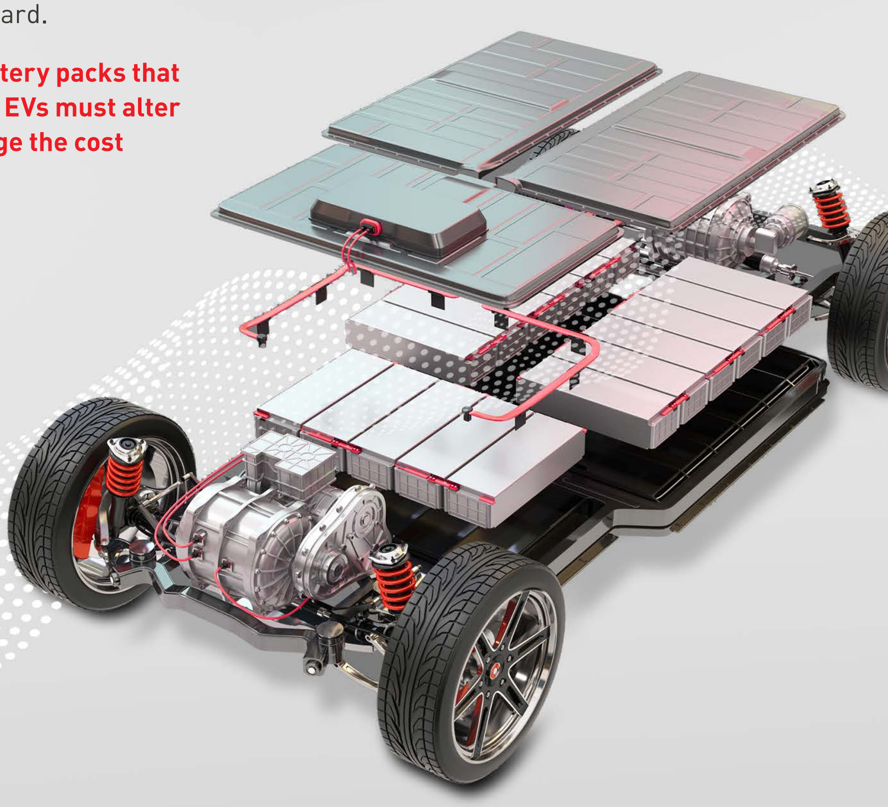
eMobility has become an imperative, with governments setting dates to end internal combustion engine (ICE) sales and expanding financial support for initiatives ranging from charging stations to consumer incentives. The transportation industry is on the cusp of a societal and technological change. New solutions, government support, and consumer attitudes are all contributing to a trend of electric mobility.

Consumer preferences are shifting as more people embrace electric vehicles. In response, manufacturers are investing billions of dollars in new plants, platforms, and vehicles. However, these new vehicles cost more to manufacture than their ICE counterparts. If it wasn't for government subsidies, they would not be price competitive despite the lower cost of ownership.

The industry needs to maintain the appeal of EVs while reducing cost to make them profitable.
This paper analyzes trends and suggests a way forward.

The EV cost structure is driven by the cost of the battery packs that are necessary to meet consumer preference. Thus, EVs must alter the energy equation to become more efficient, change the cost structure, and become profitable.

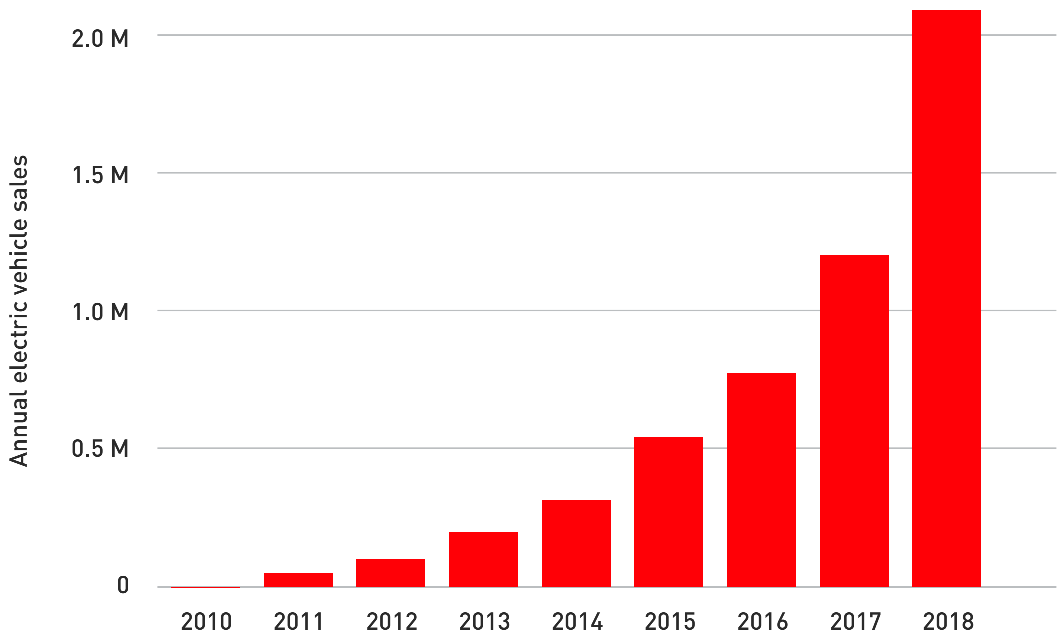
This will allow manufacturers to thrive in this rapidly changing landscape.



The Marketplace Is Shifting Into Overdrive

According to the International Energy Agency (IEA), "While the COVID-19 pandemic drove global car sales down 16% in 2020, EV sales jumped 41% to around 3 million vehicles."[1]
More specifically, BloombergNEF reports that the size of the passenger EV market increased four times compared to 2016, reaching an estimated $118 billion.[2]

Global light-duty EV sales 2010-2018[3]



IHS Markit's global passenger car forecast sees battery electric vehicles (BEVs) growing to 15% market share in 2025, and 23% in 2030. UBS[4] is even more aggressive by increasing their forecasts of EV market share to 20% of global new car sales in 2025, and a 50% market share in 2030.

They stated, "By 2040, we dare to say, 100% EV could already be a reality. Owning an ICE car will become a true luxury. Carmakers will stop investing in this technology, and "laggard" emerging markets with low car penetration will just leapfrog the ICE technology, like they did with phone landlines, in our view."

The cost-to-revenue ratio remains a serious challenge for manufacturers. It would seem that with over 100 years to perfect the idea of electric propulsion, the current EVs would be more efficient, but the lack of past overall interest in the technology means that it lagged behind and didn't use the century it had to the extent it could have.

1 Nick Carey, "(OFFICIAL) Global EV Sales Accelerating, but Government Help Needed–IEA", last modified April 29, 2021, https://www.reuters.com/business/autos-transportation/global-ev-sales-accelerating-government-help-needed-iea-2021-04-29
2 *Energy Transition Investment Trends*, BloombergNEF, 2021
3 Adapted from: *Update on Electric Vehicle Costs in the United States Through 2030*, Nic Lutsey, Michael Nicholas, 2019, ICCT.
4 "The Electric Vehicle Revolution Is Shifting Into Overdrive", last modified March 3, 2021, https://www.ubs.com/global/en/investment-bank/in-focus/2021/electric-vehicle-revolution.html

The Two Challenges

To make mass market EVs a success, there are many variables that must be addressed. Among them is the infrastructure challenge. After all, EVs can't yet readily stop at the corner gas station. Thus, charging infrastructure becomes important and this is currently being addressed by various governments across the world.

The U.S. government's infrastructure plan includes billions for charging stations and consumer subsidies in the form of tax credits to individuals.[5] The U.K.'s Transport Decarbonization Plan is the first zero emissions transport plan for a major economy, addressing everything from aviation and maritime transport to roads and rails, including charging stations.[6] The U.S. plan for 500,000 charging stations would more than double the current count. And the ban on ICE sales by governments like Britain's is a strong message to go electric.

The other challenge is the fact that consumers don't want to change their driving habits or preferred type of vehicles when switching to electric cars. If they're used to driving a pickup truck and need to use it to transport or tow heavy loads, they need to be sure that their EV will meet those needs just as well (if not better) as a gas car would.

Driving experience and performance also have to meet expectations. Good acceleration, ability to pass cars at highway speeds, responsiveness, low charge loss in very cold weather, etc. all matter to consumers.

Finally, a reasonable range is a significant factor in purchasing choices, too. Consumers expect their EVs to drive long distances, and not only in cities, where charging stations are available.

And although at least two-thirds of American drivers are open to buying an EV,[7] various surveys show that an EV's purchase price and driving range are the biggest hurdles for consumers (with the current scarcity of charging stations also a significant influence on purchasing decisions).[8,9] Both these challenges are linked to battery economics. If vehicle energy efficiency could increase and extend driving range by at least 15%, it would impact the so-called "range anxiety" and help consumers chose EVs more readily.

These are the two main challenges to EVs' widespread adoption: the ability to easily charge a vehicle and the performance requirements. Government action can jumpstart charging infrastructure and even address the needs of the electric grid to support it. Consumer preferences are harder to handle because legitimate needs drive the type of vehicle consumers purchase. This determines the battery pack specifications for a given EV. And technology, raw material supply, and manufacturing scale determine the cost of the batteries.

Therefore, with the many changes necessary to make the inevitable transition to electric propulsion meaningful and successful, one main problem needs to be addressed because it affects efficiency, costs, and longevity of the vehicles. And that problem is battery packs. Energy storage is a constraint on profitability.

5 *Biden, in a Push to Phase Out Gas Cars, Tightens Pollution Rules*, Coral Davenport, The New York Times, August 2021
6 Brian Gemmell, Graeme Cooper, "Commentary: The United Kingdom's electric vehicle plans could be a blueprint for the U.S.", last modified August 10, 2021, https://energynews.us/2021/08/10/commentary-the-united-kingdoms-electric-vehicle-plans-could-be-a-blueprint-for-the-u-s
7 Benjamin Preston, "Consumer Reports Survey Shows Strong Interest in Electric Cars", last updated December 18, 2020, https://www.consumerreports.org/hybrids-evs/cr-survey-shows-strong-interest-in-evs
8 *Electrifying Insights: How Automakers Can Drive Electrified Vehicle Sales and Profitability*, Russell Hensley, Patrick Hertzke, Stefan M. Knupfer, Nicolaas Kramer, Nicholas Laverty, and Patrick Schaufuss, 2017, McKinsey & Company
9 *Electric Vehicles and Fuel Economy: A Nationally Representative Multi-Mode Survey*, CR Survey Research Department, December 2020

Profitability

According to BloombergNEF 2021 analysis, continuing acceleration of electric vehicle adoption is driven by "generous subsidies, tighter fuel economy/CO_2 regulations, fleet purchases, and a growing number of competitive models."[10]

However, most OEMs do not make a profit from the sale of EVs.[11] Producers break even because of subsidies tied to the global push to move away from internal combustion engines.

According to Reuters, consumers spent around $120 billion on EVs in 2020, globally. At the same time, governments provided around $13 billion in subsidies, which was "equivalent to around 10% of total spending, down from 20% of total spending in 2015."[12]

From an end-user perspective, EVs are more appealing by paying for themselves over time and even making it worthwhile for consumers to invest in a home charger (whose cost is often also subsidized). But the production costs need significant improvements that would enable manufacturers to stop relying on subsidies and rebates and start making profits.

The public interest and government support can't outweigh the main problem: the price of manufacturing an EV is significantly higher than the cost of manufacturing a gas car.

$120B
spending on EVs in 2020, globally

$13B
in government subsidies

≈10%
of total spending, down from 20% in 2015

10 Angus McCrone "Energy, Transport, Sustainability – 10 Predictions for 2021", last modified January 19, 2021, https://about.bnef.com/blog/energy-transport-sustainability-10-predictions-for-2021
11 *The Future of Mobility Is at Our Doorstep*, McKinsey Center for Future Mobility, 2019
12 Nick Carey, "(OFFICIAL) Global EV Sales Accelerating, but Government Help Needed–IEA", last modified April 29, 2021, https://www.reuters.com/business/autos-transportation/global-ev-sales-accelerating-government-help-needed-iea-2021-04-29

Estimated Costs: ICE vs EV

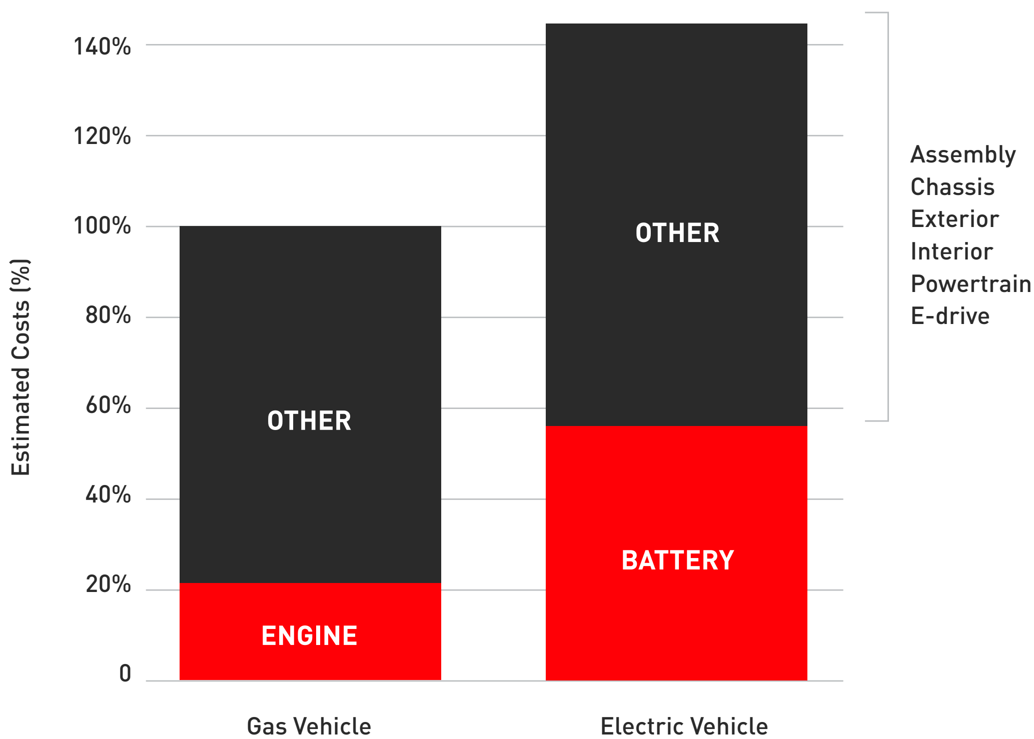
Today, EVs cost much more to manufacture than comparable ICE vehicles. A recent study by BloombergNEF noted:

"The cost difference between average BEVs and equivalent ICEs varies widely by segment. Light and heavy battery electric vans are for now about 50% more expensive, as they have modest performance requirements and medium ranges. In contrast, smaller battery vehicles in segments A and B can cost more than twice as much compared to ICEs. Powertrain costs in these segments tend to be low compared to total manufacturing costs at the moment, due to the wide use of smaller and cheaper gasoline engines. Even low-capacity batteries—around 55 kWh[13] for B-segment BEVs—may cost more than three times the total ICE drivetrain today."[14]

According to a study by consultancy Oliver Wyman for the *Financial Times*, EVs were 40% more expensive than the average ICE vehicle in 2020 and "electric cars will remain significantly more expensive for European carmakers to produce than combustion engine models for at least a decade."[15]

According to the study, the total cost of manufacturing an EV will likely drop to $19,000—a reduction of more than a fifth—by 2030, but there will still be a 9% gap when compared with petrol or diesel models.

Estimated vehicle cost[16]



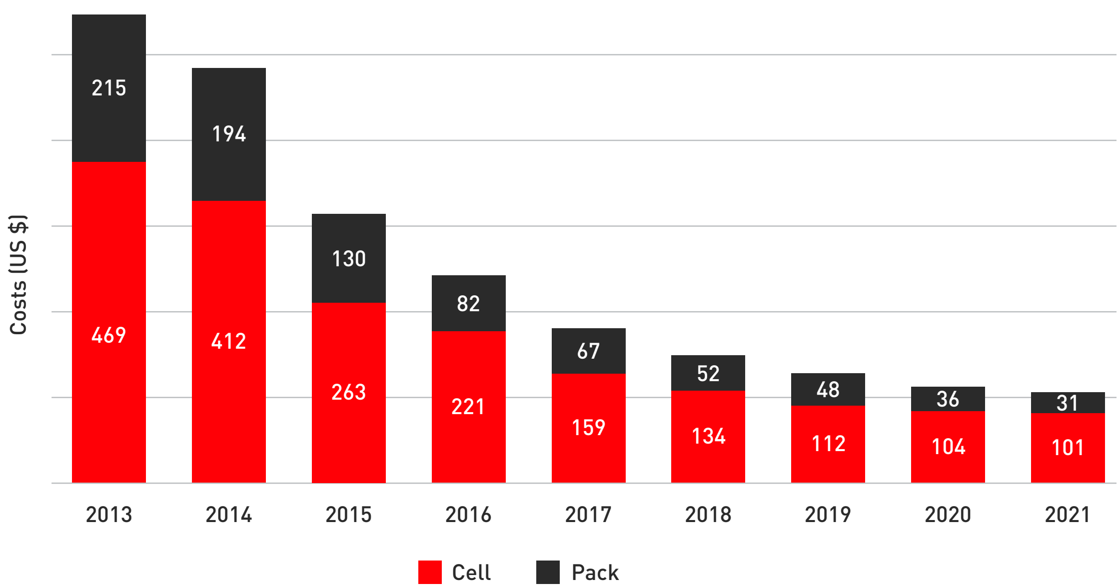
13 While BloombergNEF defines low capacity as 55 kWh, we set it at 25-30 kWh
14 *Hitting the EV Inflection Point*, BloombergNEF, May 2021
15 Joe Miller, "Electric Car Costs to Remain Higher than Traditional Engines", last modified August 31, 2020, https://www.ft.com/content/a7e58ce7-4fab-424a-b1fa-f833ce948cb7
16 Adapted from: Joe Miller, "Electric Car Costs to Remain Higher than Traditional Engines" last modified August 31, 2020, https://www.ft.com/content/a7e58ce7-4fab-424a-b1fa-f833ce948cb7

The Big Ticket

The battery pack is the most expensive component of the whole vehicle. According to BloombergNEF, the average cost was $137/kWh at the end of 2020.[17] Although the estimates can vary, averaging 30% of the total cost of the vehicle, even moderate savings to this component would have a huge impact on the overall cost of the car manufacture and price.

According to McKinsey Center for Future Mobility, "Apart from a few premium models, OEMs stand to lose money on almost every EV sold, which is clearly unsustainable. (...) Battery costs represent the largest single factor in this price differential. As industry battery prices decline, perhaps five to seven years from now, the economics of EVs should shift from red to green."[18]

Battery cost reductions are flattening[19]



Currently, a significant proportion of EVs on sale find themselves in the luxury category of vehicles, so it is easier to "hide" high battery costs. Manufacturers need to alter the cost structure to make EVs profitable, especially as government subsidies start diminishing.

McKinsey reports that, "A reduction in battery capacity to 40 kWh, from 50 kWh, would save $1,900 to $2,100 today, while the range would still enable most consumers, especially those in urban environments, to complete trips without any sacrifice to their daily routines."[20]

17 "Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh" BloombergNEF, last updated December 2020, https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh

18 *The Future of Mobility Is at Our Doorstep*, McKinsey Center for Future Mobility, 2019

19 Adapted from: "Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh" BloombergNEF, last updated December 2020, https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/

20 *The Future of Mobility Is at Our Doorstep*, McKinsey Center for Future Mobility, 2019

Deterioration Over Time

Batteries don't all deteriorate in the same way. Higher usage doesn't seem to be statistically significant, unlike continuous use of a battery at maximum or minimum end, which can negatively affect it. In this situation, using a state-of-charge buffer can lower degradation rates as it prevents batteries from becoming completely depleted or fully charged (although this means the effective accessible range for the driver is further reduced).

Direct-current fast chargers can accelerate degradation if used frequently. Hot climates can also increase battery degradation, although the impact is small.

All this is necessary for consumers to know to make an informed decision. But mainstream EVs haven't been around long enough to provide enough reliable information about battery life. The technology may not be new, but its wide use certainly is, which means that it will take a few more years to ensure enough reliable information about battery life.

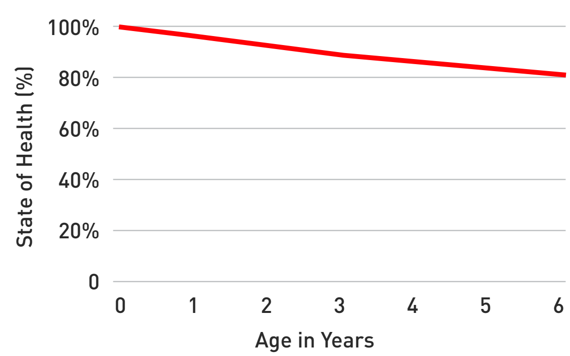
Research released in 2019 by Geotab Inc., analyzed data from 6,300 EVs (various makes and models) and found that in real-world use, an average capacity loss was 2.3% per year. In short, the batteries were exhibiting "high levels of sustained health."[21]

Batteries of native electric vehicles allow for greater range flexibility due to their larger size. However, their size doesn't solve the problem of their lifespan. Granted, the problem might not be perceived as significant, but for an end-user it's an important piece of data.

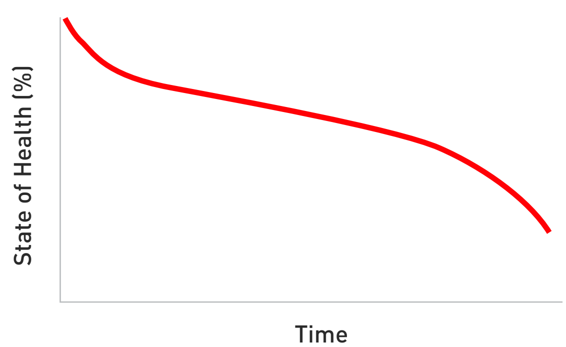
The deterioration noted above might be modest but for an average driver who wants 300 miles per charge, 75 miles lost over 10 years can be a significant loss. What's more, batteries decline non-linearly and the model above is an average degradation over time that doesn't show the initial drop. A typical degradation curve looks less linear and resembles the letter S.

It's worth noting, however, that most battery warranties allow a claim if the SOH falls below 70% of the new value, creating a safety net for consumers. Interestingly, automakers are developing secondary markets for ex-vehicle batteries, notably in the grid storage market where the energy density per volume (or mass) of the battery is less important than it is in a vehicle.

Average battery deterioration as shown by Geotab[21]



A typical degradation curve[21]

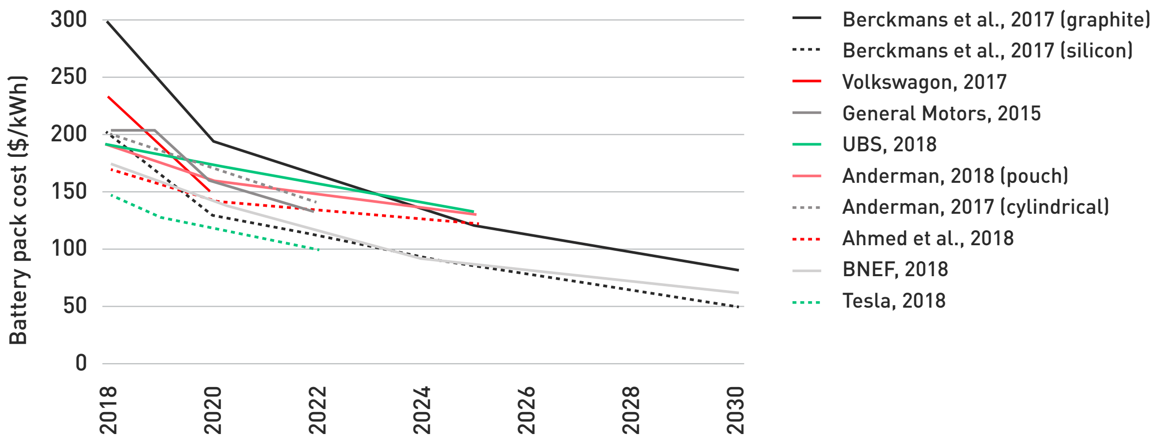


21 Charlotte Argue, "What Can 6,000 Electric Vehicles Tell Us About EV Battery Health?" last modified July 7, 2020, https://www.geotab.com/blog/ev-battery-health

Diminishing Returns

Most high-tech goods tend to get cheaper as they are manufactured at increasing volumes. This is also true for batteries but only up to a point.[22] The industry is growing, but its sudden and dramatic early growth means that matching earlier savings will be difficult, and the law of diminishing returns has set in as shown by the flattening curves.

EV battery pack costs in the United States[23]



Looking at the industry trends, it's easy to notice that when it comes to the price per kWh of power, price reduction curves are going to flatten. It's not a question of whether the battery costs are going to stop declining, it's a question of when. The reductions are no longer as dramatic as they were 10 years ago and, each year, they get smaller by such small increments as to be almost insignificant.

Another problem affecting this curve is the technology itself. According to *The Times*, "A major technological breakthrough will be required to make electric cars much, much cheaper."[24] Normally, improvements in technology contribute to a lower price. But this takes time, and improvements to the batteries to make them more cost effective have not been dramatic enough to affect the price curve.

Interestingly, there has been a recent trend to revive one of the older battery types—the LFP[25] (lithium-iron phosphate)—in vehicles that are very cost sensitive. These batteries display lower energy density but have the advantage of a good life cycle and not being badly affected by higher temperatures (which makes a huge difference in geographical locations such as India). These batteries are also seen as more socially acceptable as they contain fewer "conflict minerals."

Batteries are hard to improve upon quickly. What's more, it will take time for innovations in battery technology to make it into viable products and then into vehicles. Therefore, it's important to keep redesigning the engines to make them more efficient, and to extend the battery life in smaller increments, while working on the "major breakthroughs."

22 Timoty B. Lee, "Battery Prices Have Fallen 88 Percent Over the Last Decade", last updated December 18, 2020, https://arstechnica.com/science/2020/12/battery-prices-have-fallen-88-percent-over-the-last-decade

23 Adapted from: "Update on Electric Vehicle Costs in the United States Through 2030", Nic Lutsey and Michael Nicholas, 2019, ICCT.

24 *Biden's Push for Electric Cars: $174 Billion, 10 Years and a Bit of Luck*, Niraj Chokshi, The New York Times, March 2021

25 "The Latest Trends in Lithium-Ion Batteries", BNamericas, last updated June 28, 2019, https://www.bnamericas.com/en/features/the-biggest-trends-in-lithium-ion-batteries

Summary

Current suggestions for optimizing EV costs include decontenting. This can include removing some displays, switches, buttons, wiring, some structural components, etc. Reducing design and feature complexity could also add to lowering the overall cost of EVs.[26]

However, features that simplify the overall design can make the vehicle seem less appealing and less impressive visually (and sometimes reduce the perceived value of the vehicle by more than the actual price reduction!), which can stand in stark contrast to the idea that EVs are the future and should therefore offer consumers some idea of a futuristic design. What's more, such savings would not be as substantial as those brought by improvements in battery prices and efficiencies.

Some other suggestions for cost savings include a reduction in battery capacity to still offer consumers the average optimal range (urban/suburban travel with occasional rural travel). However, if consumers know that they have just enough power to last them their routines, any unexpected changes to their habits or needs would cause range anxiety.

Manufacturers also have to address how their vehicles use energy to meet consumer needs and cut costs at the same time. EVs need to adopt better aerodynamic designs, use smaller tires, and lower overall weight to save energy.

However, as stated before, the main place for improvements is the battery pack. Unfortunately, the current solutions and the increase in LFP use are not really going to achieve the significant cost reductions that the industry needs.

Battery size, its energy density and life are the things to focus on to improve cost reduction and, therefore, profitability. Adopting new technologies that allow for reduced battery use would mean either smaller battery packs for the same range or an extended driving range with the same battery size. Solutions such as the **eDTS™** technology—an innovative system in which the speed and torque can be varied inside the motor in real time, delivering at least 15% in motor efficiency improvement—may not be widely used yet due to its very recent development, but they could be a huge step forward for the industry.[27]

Manufacturers shouldn't have to choose between sleek design and impressive interior and profit. With the right motor technology, they can reduce the costs of the most expensive component in their vehicles—the battery—meet consumer preferences for size and range, stop relying on subsidies, and start making profits.

26 *What a Teardown of the Latest Electric Vehicles Reveals About the Future of Mass-Market EVs*, Antoine Chatelain, Mauro Erriquez, Pierre-Yves Moulière, and Philip Schäfer, March 2018, McKinsey & Company
27 *Product Overview: Dynamic Torque Switching.* ePropelled, September 2021