Abstract

Electric Vehicles (EVs) are developing faster than ever before, and they could be key to transportation in the future. Using other reliable studies in this field, I looked at different factors of EV penetration into the global market, like carbon emissions, refueling time, safety and reliability, consumer preferences, advancements and challenges, etc. I compared these to similar data in gasoline vehicles. After analyzing the data, I found many interesting pieces of information. Gasoline vehicles produce 1.2 to 1.6 times the amount of CO2 as EVs. Soon, the cost of batteries and charging will rival the price of gasoline vehicles' engines and refueling. The development of Solid State Batteries (SSBs) will reduce the recharging time to less than a minute once perfected. These findings mean that while gasoline vehicles still hold the advantage over EVs at the moment, EVs will be far more reliable and efficient than gasoline vehicles in the future.

Introduction

Electric Vehicles (EVs) are automobiles that run mainly or completely on electricity. There are many types of electric vehicles, including Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs), and Plug-in Hybrid Electric Vehicles (PHEVs).

The BEV is an EV that runs fully on a battery and is charged by an external power source.

The HEV mainly runs on gasoline, however, it uses electricity under lighter loads. An external power source like the BEV cannot charge the HEV. Instead, the HEV uses heat, generated by braking, to make electricity in a process called regenerative braking. The HEV can also convert gasoline directly into electricity using an electric generator.

The PHEV combines the methods of both the HEV and the BEV. It has all the functions of an HEV and can be charged by an external power source. BEVs are the greenest EVs as they do not use gasoline. Though PHEVs and HEVs are less green, they are still more eco-friendly than Internal Combustion Engine Vehicles (ICEVs).

IEEE Xplore states, “Currently, there are several types of electric vehicles (EVs) in the market. Hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), plug-in electric vehicles (PEVs), and battery electric vehicles (BEVs) are the main types of EVs. In HEVs, the batteries cannot be charged by the power grid. There are two energy resources for battery charging which include gasoline and regenerative braking. The energy of the braking system is converted to heat in combustion engine vehicles to charge the battery of HEVs. Also, the gasoline can be converted directly to electric

energy to charge the battery using an electricity generator. Under the light load and low-speed conditions, the electric motor is used to drive the wheels, while both electric and gasoline motors are used under the heavy load and high-speed conditions. The PHEVs can be powered by both gasoline and electric energies. A regenerative braking system, similar to HEVs, and the external power grid, can charge the battery of PHEVs. The PHEVs can be plugged into the power grid and charged completely. The use of both energy resources extends the driving range of PHEVs. The PEVs or BEVs are powered fully by electricity. They can be plugged into an external power grid to charge the batteries. This type of EV can drive about 200 km using one or more electric motors." (https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8967190, Page 1).

Background on Electric Vehicles

Electric Vehicles are generally considered very eco-friendly. While this is true, many people want to understand exactly how much better EVs are than Gasoline Vehicles.

Mining the resources needed to make EVs leaves a large carbon and water footprint. The process of making the EV itself is also water and carbon-intensive. The main benefit of EVs is that they have a reduced carbon footprint over an extended period. Unless EVs are used for longer periods of time, they are more harmful to the environment than ICEVs.

Carbon dioxide is the leading cause of global warming. Carbon dioxide mainly comes from the current largest mode of transportation, gasoline vehicles. When the earth warms up, ice from the north and south poles will melt significantly. When these ice caps start melting, the melted water will flood many places and will soon run off into the oceans. This runoff will cause the global sea level to rise, and many coastal cities will get flooded. This leads to the residents of the affected areas needing to move inland, causing more population density. More population density will lead to more crime, disease, and many other things. So, essentially, ICEVs are indirectly influencing the future of our world. If we began extensively using EVs now, we could delay this inevitable future and even take steps to prevent it.

Andrew Nickischer states, “Overall, internal combustion engines create from 1.2 - 1.6 times the CO2 that electric battery vehicles create over the vehicles’ entire lifespan. This is considering the vehicles’ production, operation, and disposal. This data shows that electric cars are better for the environment, but they still contribute to pollution and

are not perfect." (https://dsc.duq.edu/cgi/viewcontent.cgi?article=1068&context=duquark, Page 2).

While EVs don't fully solve the issue of global warming, they significantly reduce emissions, prolonging the onset of further climate change stemming from gasoline vehicle transportation.

Advancement in Battery Technology

Currently, most electric vehicles use the Lithium-ion battery (LIB) for power. LIBs have seen major technological advancements recently. For example, IOPscience states that “Over the last 10 years, the price of a lithium-ion battery pack has dropped by almost 90% from over $1000 kWh−1 in 2010 to $156 kWh−1 at the end of 2019 (BloombergNEF 2020). Meanwhile, the specific energy of a lithium-ion battery cell has almost doubled from 140 Wh kg−1 to 240 Wh kg−1 during that same window of time (BloombergNEF 2020). These advancements mainly come from engineering improvements, using materials with higher capacities and voltages, and developing methods to increase stability for longer life and improved safety. Cell, module, and pack design improvements also help to strengthen performance and lower costs. Increases in manufacturing volume due to EV sales contribute significantly to cost reductions (Nykvist and Nilsson 2015, Nykvist et al 2019); however, further reductions in battery costs, electric machines, and power electronics are needed for EVs to achieve purchase-price parity with ICEVs. This parity is estimated to be achieved by the U.S. Department of Energy (DOE) at battery costs of ~$100 kWh−1 (preferably less than $80 kWh−1) (VTO, 2020). At that price point, EVs should have both a purchase and lifetime-operating-cost benefit over ICEVs.” (https://iopscience.iop.org/article/10.1088/2516-1083/abe0ad/meta, Page 11).

In our evolving society, battery technology has advanced like never before. One example is the new solid-state battery (SSB), which will power electric vehicles soon. Currently, we are using the Lithium-ion Battery (LIB), to power electric automobiles. While they have worked very well for the past few years, they have many issues,

including flammability, stability, and safety. LIBs have been known to explode when overworked and have a long charging time. SSBs are the solution- while they aren't perfect, they solve the issues of the LIB. They are more stable, charge faster, and are safer overall due to how the battery is built. Wiley Online Library states, "There is considerable interest in the development of solid-state batteries (SSBs), which use solid electrolytes (SE) to supplant liquid electrolytes (LE). The motivation for this is the expectation of improved cell properties in terms of energy density, operating temperature range, stability, and safety—depending on the specific type of SSB."(https://onlinelibrary.wiley.com/doi/full/10.1002/aenm.202201939).

The liquid electrolyte (LE) is the root of the issues of the LIB. The LE is made out of organic material and, therefore, is precarious. SSBs remedy this problem by replacing this component with a very stable solid electrolyte (SE). ACS Publication states, "The liquid organic electrolyte (LE) is the component of a LIB primarily responsible for any combustion risk because of its high volatility and flammability. In this regard, all-solid-state batteries (ASSBs), in which solid electrolytes (SEs) are used as substitutes for LEs, are increasingly regarded as very promising next-generation battery systems."(https://pubs.acs.org/doi/full/10.1021/acsenergylett.0c01977).

Global Sustainability Initiatives

To understand the benefits of EVs, we must first examine a glaring disadvantage of Internal Combustion Engine Vehicles (ICEVs): pollution.

ICEVs are efficient in range and stability, yet their Carbon Dioxide emissions outweigh this pro. This is one benefit of EVs over ICEVs. EVs don't have tailpipe emissions and, therefore, do not emit Carbon Dioxide. While Carbon Dioxide is used in EVs for charging and manufacturing, it is not used nearly as much as the amount produced by ICEVs during their lifetime.

Global Warming is a major worldwide concern; if left unchecked, it can lead to many other problems like animal extinction, rising sea levels, climate change, and more. Transportation is one of the leading causes of global warming. The amount of CO2 released from combustion engines across all the different types of vehicles is huge. A way to reduce this massive amount of CO2 is to switch from gasoline to electric vehicles. ESCI-KSP states, "Vehicles powered by electricity have the potential to reduce many of these problems. In most places, electric drive lowers the smog-forming and global warming pollution associated with vehicle use, and when powered by renewable resources, electric vehicles can nearly eliminate such pollution from vehicular operation. Electric vehicles powered by a clean electricity grid offer a key pathway to achieving the greater than 80 percent reduction in global warming pollution we need by mid-century to avoid the worst consequences of climate change. Powered by domestically produced electricity, electric vehicles (EVs) could be a significant part of reducing our oil dependence." (https://esci-ksp.org/wp/wp-content/uploads/2012/04/State-of-Charge.pdf, Page 1).

Andrew Nickischer states, "The bulk of an internal combustion engine's air pollution comes from its day-to-day operation. Comparing many internal combustion

engine mid-sized vehicles, they create, on average, 150.4 grams of carbon dioxide equivalent per kilometer (g CO2 eq per kilometer). Comparing many SUV class internal combustion engine vehicles, they create, on average, 269.2 g CO2 eq per kilometer. This would mean that a mid-sized car with 100,000 miles would've produced approximately 24 million g CO2 over its entire operation. An SUV class vehicle with 100,000 miles would've produced approximately 43 million g CO2 over its entire operation." (https://dsc.duq.edu/duquark/vol4/iss2/3/, Page 5). Nickischer includes this chart as well:

		Operation		Production / Decomposition	
		CO_2 Per kilometer driven (g)	CO_2 Produced from 100k miles (Mg)	CO_2 produced from the mechanical production / decomposition (Mg)	CO_2 Produced from Lithium Ion battery (Mg)
Electric Battery Vehicle	Mid-sized Electric Vehicle	73.9 - 131.5	12 – 21 AVG = 16.5	7.425	2.2
	SUV class Electric Vehicle	119.3 - 196.45	19 – 32 AVG = 25.5	11.475	3.4
Internal Combustion Vehicles	Mid-sized Combustion Vehicle	150.4	24	4.32	N/A
	SUV class Combustion Vehicle	269.2	43	7.74	

*Results were computed based on averages of relatively new vehicles (2010-present) using two sources (6,9) also assuming that each of these vehicles has traveled one hundred thousand miles [6,9].

-

Consumer Preferences and Market Dynamics

EVs have many advantages and disadvantages, including their prices. While upfront costs are quite high compared to ICEVs, EVs have an operating cost benefit, as customers don't need to spend as much on gas and vehicle maintenance. One downside of ICEVs is their volatile gas prices, as they constantly fluctuate based on the supply of fossil fuels. On the other hand, EVs have a reliable, renewable energy source with steady prices. Duzce University Journal of Science and Technology states, "Additionally, ICEs have operated in high-vibration, and they are actually high noise sources. Also, it has constantly decreasing and limited reserves, and price increases due to particularly the transportation of fossil fuels and depending on the dollar exchange rate, especially for countries like Turkey. Owing to these reasons, almost all of the automobile industry has turned again its route to electric and hybrid vehicles [9]. In parallel with this, the biggest step to take is undoubtedly possible by a new and renewable energy source that can replace internal combustion engines to reduce dependence on fossil fuels." (https://dergipark.org.tr/en/pub/dubited/issue/43004/457914?publisher=duzce, Page 4).

Another benefit of EVs is that as they penetrate the market, their prices will become less and less expensive. The used vehicles entering the market make it easier for low-earning families to buy EVs than ICEVs. EVs have been in production for some time, meaning many cars are now sold secondhand. Since used cars are not as costly as new ones, they are sold at a lower price point, making them more accessible. Unlike ICEVs, EVs do not lose their efficiency as easily throughout their lifetime. All this results in EVs being less pricey and more consumer-friendly than ICEVs.

Lindseyresearch.com states, “As the U.S. EV market expands over time, especially for used vehicles, EVs will likely become more attractive to lower-income households. There have been roughly 1.6 million cumulative electric vehicle sales in the United States as of September 2020 (U.S. Department of Energy, 2020), and many of these are now entering the used car market. Already, in disadvantaged communities in California, used EVs are purchased at higher rates than new EVs (Canepa et al., 2019). In addition, improving electric vehicle technology, increasing electric range, and declining electric vehicle costs will continue making electric vehicles more attractive to more consumers. As both purchase price and total cost of ownership for EVs decline in coming years, EV cost savings will become significant, and it will be critical to ensure equal access to disadvantaged groups.” (https://lindseyresearch.com/wp-content/uploads/2021/12/NHTSA-2021-0053-1578-Exhibit-86-Bauer-et-al-2021.pdf, Page 3).

EVs do have economic downfalls as well. One issue is the upfront prices of many EVs. Their expensive batteries mainly cause these prices. Batteries account for about 30% of the cost of the whole EV. Many low-income families cannot afford these high upfront prices. For EVs to succeed in the market, their batteries must be cheaper. Once they are more affordable, EVs will have a clear-cut advantage against ICEVs. SSBs are becoming more realistic and less imaginative. Scientists are perfecting the technology to engineer cheaper, safer batteries, and once they succeed, this will factor into more affordable vehicles.

Challenges Facing Electric Vehicles

While EVs are increasingly becoming more popular, they still have their issues. For example, a major consumer concern is the vehicle's range, also known as range anxiety. Like regular batteries, EV batteries have a limited range and must be charged periodically. This is an issue from the buyers' perspective as they want to get the best range they can from an EV. They do not want low EV charges to interfere with long trips. Since EVs are relatively new, the infrastructure for charging stations hasn't been fully developed, unlike gas stations. Many areas do not have charging stations for miles, leaving EVs with nowhere to charge. Cell.com states, "Driving range is one of the major concerns of customers regarding EVs, and it is mainly determined by the battery energy densities (the amount of energy stored per unit volume or weight). As space and weight in EVs are limited, the batteries with higher energy densities can drive vehicles a longer distance." (https://www.cell.com/joule/pdf/S2542-4351(20)30043-X.pdf, Page 2). Science Direct also states, "The main concern of EV users is the range anxiety determined by the battery. At present, the battery technologies are not at a mature level. Many batteries have a limited life cycle and high initial cost and are not flexible with the varying temperature." (https://www.sciencedirect.com/science/article/pii/S2090447922002490#s0010).

Another challenge in EVs is the cost of the battery. The battery cost is about 30% of the cost of the whole vehicle. The costlier the battery, the costlier the vehicle. Potential customers may avoid buying an EV due to the costly battery. Scientists are working toward making batteries cheaper and safer, yet they still have a long way to go. The unpredictable stability of batteries is also a concern. Science Direct states, "From

an economic point of view, the cost is an important parameter that restricts EV penetration in the market. The cost involved with the individual charging point, battery replacement cost, the cost of communication, and charger cost are high, and they are not suitable for an average-earning family." (https://www.sciencedirect.com/science/article/pii/S2090447922002490#s0010).
Cell.com states, "One benefit of EVs is their lower operating costs relative to those of ICE vehicles. Nevertheless, their high upfront purchase price remains one major obstacle for wide EV adoption. As the battery cost determines the EV price, it needs to be reduced to make EVs more affordable." (https://www.cell.com/joule/pdf/S2542-4351(20)30043-X.pdf, Page 2).

Another challenge in EVs is their inability to match the competition in Internal Combustion Engine Vehicles (ICEVs). For example, elements like speed, range, safety, and fueling time are difficult to match, as ICEV manufacturers have had more time and experience to perfect their cars. If EVs fail to match the competition given by ICEVs, they will fail in the market. ACS Energy Letters states, "A variety of challenges and opportunities exist for automotive LIBs in the present day. Further advancements in energy storage efficiency (by both weight and volume) are necessary to improve the competitiveness of electric vehicles. The ability to quickly and accurately validate and predict long battery life is an important area of development. Likewise, continued cost reduction of LIBs on a $/kWh basis is both challenging and necessary to increase the opportunity for wide-scale adoption of electric transportation. Automotive LIBs are also expected to meet or exceed the safety performance of existing gasoline-powered internal combustion engine (ICE) vehicles. ICE-powered vehicles have also created a customer expectation of fast refueling, which is a large challenge for LIB technology to match. Although the overall performance of automotive LIBs has improved greatly in recent years, major challenges and opportunities remain." (https://pubs.acs.org/doi/full/10.1021/acsenergylett.0c02584, Pages 1 & 2).

Potential Solutions and the Way Forward

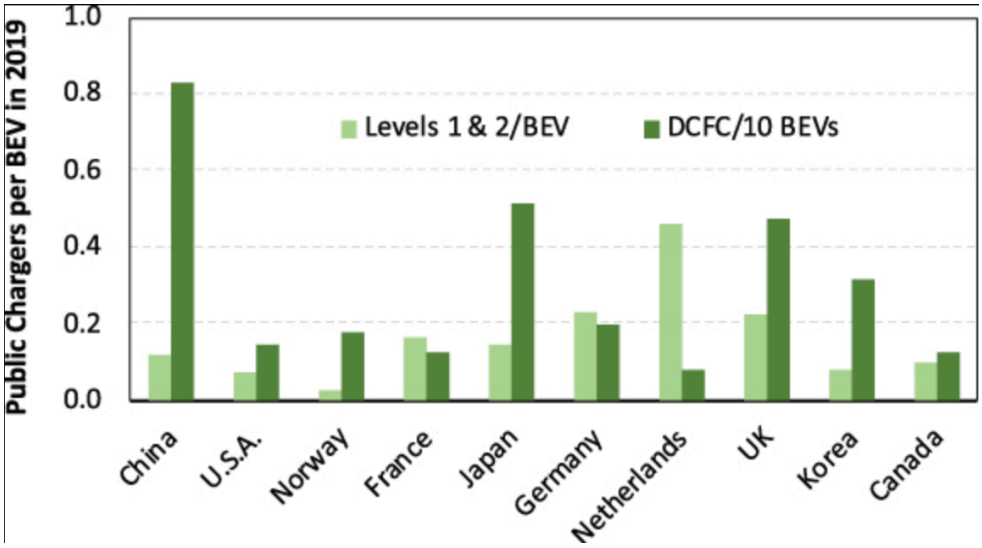
While challenges exist, EVs' penetration of the automobile market is almost inevitable. As previously stated, SSBs will be very helpful as fast-charging technology improves.

We are finding ways to power renewable electricity to address the nonrenewable energy issue. Though we still use fossil fuels such as coal to generate electricity, substitutes like solar, wind, and hydroelectricity are now being employed. Jocet.org states, “Due to technological advancement vehicles are made with improved fuel efficiency and also perfect hybrid vehicles are made. Also, improvements are needed so that wind, solar, and hydrogen can be more valuable sources in the energy field. The many types of renewable energy resources - such as wind and solar energy - are constantly replenished and will never run out. That is one benefit.” (https://jocet.org/papers/092-J30008.pdf, Page 1).

Another recent breakthrough is the newly developed Vehicle-to-grid(V2G) system. This system is where many cars charge using other people's electricity. First, the EV owner charges their vehicle in a charging port connected to the V2G system. Then, they set a time by which they want their car to be above a given percentage. Then, the car gives electricity to charge other cars connected to the system. However, the system ensures that this given car will have enough electricity by the time specified by the owner. This is helpful because it saves electricity and stops electricity from being produced inefficiently. This system is truly revolutionary. IOPscience states, “V2G directs the charging and discharging of EV batteries based on users’ needs and the

grid's electricity supply, it allows the electricity grid to optimize the supply of local renewable energy and reduce infrastructure costs, while the EV owner can enjoy greener, more economical consumption of electricity and be financially rewarded for serving the electricity grid." (https://www.evenergi.com/vehicle-to-grid-an-overview/).

There are more charging stations being built worldwide. Most countries are working on their charging infrastructure, which is paying off. IOPscience includes this chart:



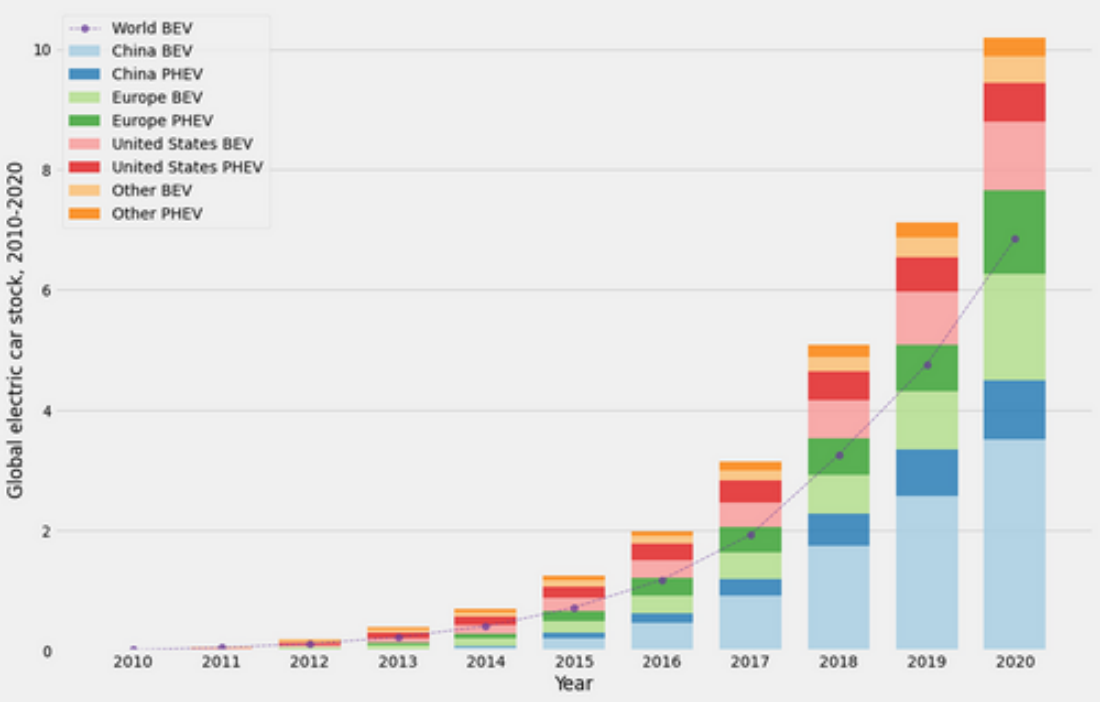
Case Studies

In many countries, EVs have reached varying stages of penetration in the automobile market. In some countries, EVs are lagging; in others, EV development has advanced far more than average.

A major reason for this discrepancy is the role of the government. In countries like the US, France, and Japan, the government plays a small role in the development of EVs. They invest in private companies, but the private companies themselves manage the market. However, the government controls the EV market in countries like China, leading to faster integration but less variety in the vehicles. While this is faster in the short-term gain, more diversity is important in newly developed inventions. Mdpi.com states, “America, Japan, and France are under the modes of public-private partnership. In these countries, the governments are usually the investors, but the managers can be other stakeholders, which means that the market for constructing and managing charging stations is open to all companies. These companies can enter this area through fair competition. Besides, the electricity or battery suppliers can be state-owned enterprises or privately owned companies. However, in China, the market is monopolized by the State Grid Corporation of China (SGCC) or the China Southern Power Grid (CSPG). SGCC is not only the manager, but also the supplier, and it had already built 400 charging stations and 19,000 charging outlets by the end of 2013 [62]. The advantage of this mode is that it is simple and easy to manage. However, it may hinder the development of the EV market because of there being no competition.” (https://www.mdpi.com/2071-1050/6/11/8056).

The countries currently controlling the EV market are China, South Korea, and Japan. This is not good for the world as it weakens trade due to the power imbalance. Benjamin Jones states, “China, South Korea, and Japan currently dominate battery and components manufacturing as well as associated chemicals refining. The market concentration of this type risks weakening the terms of trade for developing

country exporters, particularly where producers are small in scale or lack understanding and awareness of the broader international markets." (https://onlinelibrary.wiley.com/doi/full/10.1111/twec.13345). He also includes this chart showing how each of these groups compares to the rest of the world:

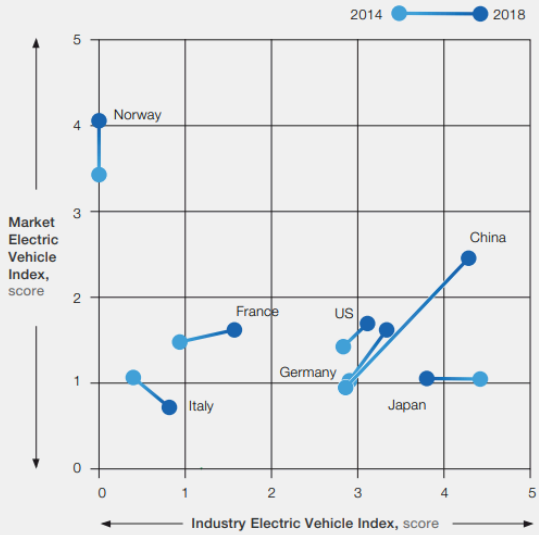


Mckinsey.com(https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/The%20global%20electric%20vehicle%20market%20is%20amped%20up%20and%20on%20the%20rise/The-global-electric-vehicle-market-is-amped-up-and-on-the-rise-web-final.pdf) also adds a few charts describing the growth of EVs in certain countries while some countries lag:

Exhibit 3

China's positive performance put the country in a strong position in McKinsey's latest overall Electric Vehicle Index rankings.

Electric Vehicle Index (EVI) development of selected countries, score out of five



Examining the details

China is outperforming other countries on both market side (EV penetration rose from 0.3% to 2.2%, available models number almost 100, intense investment in charging infrastructure) and industry side (higher EV and component share)

France's EV market increased slowly, from 0.7% to 1.7% adoption rate; gains on industry side driven by insourcing of EV components

Germany had equal though slow improvement on both market and industry side as a result of higher sales (from to 0.4% to 1.5%) and vehicle production

Italy's market-side performance decreased because of stagnant market; missing industry focus on e-mobility slowed progress on supply side

Japan lost ground on industry side because of falling market share in EV and component production; slight improvement on market side given slow sales development (from 0.6% to 1.1%)

Norway increased EV penetration from 11% to 32% in 4 years, thanks mainly to significant monetary and nonmonetary incentives and larger choice of EV models

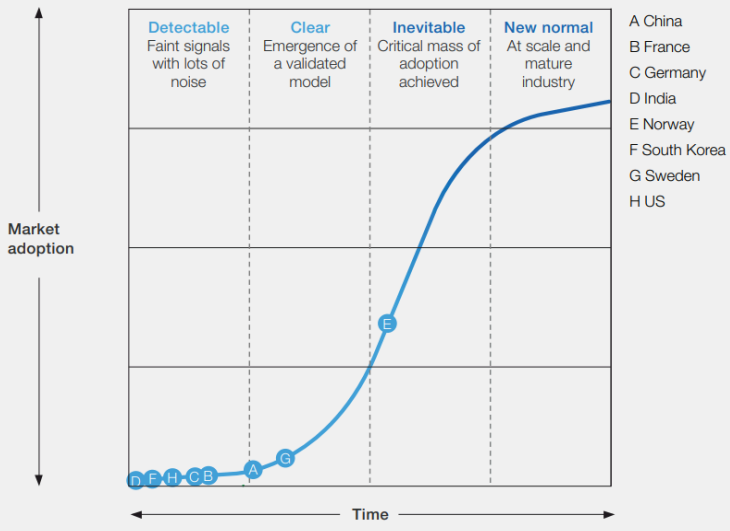
The **US** had few positive dynamics on both market and industry side; while EV model availability and market share (from 0.7% to 1.2%) rose slightly, vehicle and component production share decreased

McKinsey&Company | **Source:** McKinsey analysis

Exhibit 4

In Norway—which is clearly ahead of other countries—the electric-vehicle disruption is inevitable.

The 4 stages of a disruptive trend—focus on electric-vehicle market adoption

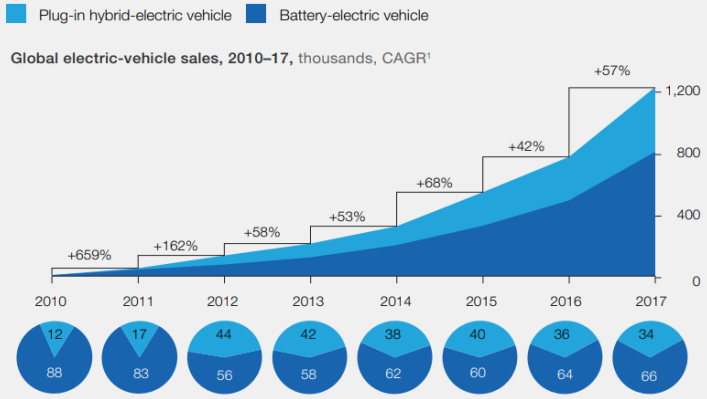


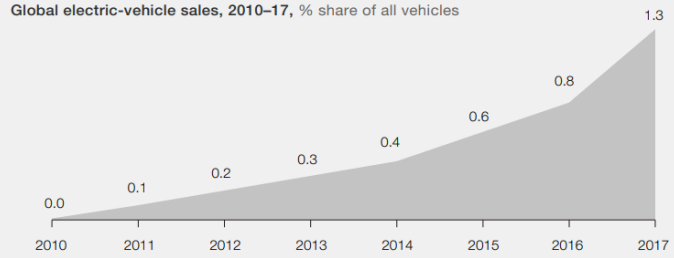
Source: Chris Bradley, Martin Hirt, and Sven Smit, Strategy Beyond the Hockey Stick, McKinsey, 2018

McKinsey&Company

Exhibit 1

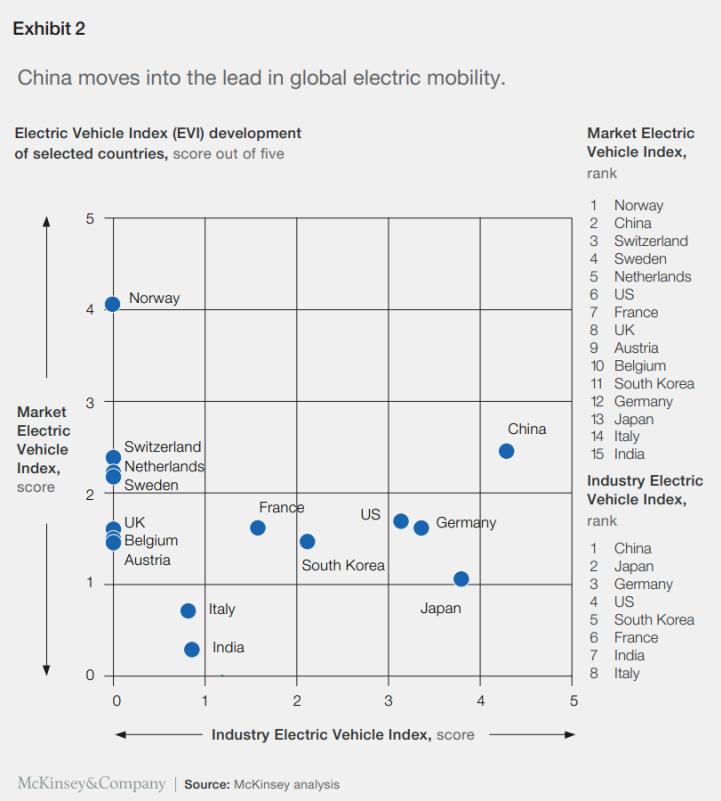
Last year, for the first time, global sales of new electric vehicles passed a million units.





[1]Compound annual growth rate.

McKinsey&Company | **Source:** EV-volumes.com; McKinsey analysis



These charts show that the US is behind in the EV market. Mckinsey.com also states, “The rollout of more attractive, better-performing EVs in key high-demand segments is another major driver for sales uptake, both in Europe and the United States. Nevertheless, at 27 percent, US growth lagged behind that of China and the European Union, since fuel prices remain low, reducing the operating-cost advantage of EVs.”
(https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/The%20global%20electric%20vehicle%20market%20is%20amped%20up%20and%20on%20the%20rise/The-global-electric-vehicle-market-is-amped-up-and-on-the-rise-web-final.pdf, Page 6).

In the US, however, there is one company that shines above the rest, leading the way in the EV revolution: Tesla Motors. Tesla is one of the first companies in the US to make a few successful models of EVs and lead the market. Researchgate.net states, “It is with this background that Tesla Motors operates, leading the world into a revolution by mass-producing a line of all-electric cars. Tesla has taken the idea of an electric future beyond theory. In doing so, the company has activated the real-world implications of fundamentally changing one of the most significant aspects of our lives.”(Page 5).

Conclusion

In conclusion, EVs have come a long way in the past few decades, though they still have a long way to go. They have evolved from simple motors to complex batteries. They limit their CO2 emissions, preventing worsening climate change. They are user-friendly and are becoming more affordable every year. They have already penetrated the market in many countries like Norway and China.

While EVs need to improve on a few aspects, including battery range and recharging time, scientists and researchers are finding ways around these problems. New batteries like the SSB are being invented, and new charging methods like V2G have been implemented. Many companies are finding ways to harness renewable energy. Once this new technology has been implemented, EVs will conquer the market. EVs are the future.

Bibliography:

admin. (2021, July 8). *Vehicle to Grid - An Overview*. Evenergi. https://www.evenergi.com/vehicle-to-grid-an-overview/

Ağbulut, Ü., & Bakir, H. (2019). The Investigation on Economic and Ecological Impacts of Tendency to Electric Vehicles Instead of Internal Combustion Engines. *Düzce Üniversitesi Bilim ve Teknoloji Dergisi*, *7*(1), 25–36. https://doi.org/10.29130/dubited.457914

Ahmadian, A., Mohammadi-Ivatloo, B., & Elkamel, A. (2020). A Review on Plug-in Electric Vehicles: Introduction, Current Status, and Load Modeling Techniques. *Journal of Modern Power Systems and Clean Energy*, *8*(3), 412–425. https://doi.org/10.35833/mpce.2018.000802

Alrikabi, N. (2014). *Renewable energy types - journal of clean energy ...* Journal of Clean Energy Technologies. http://www.jocet.org/papers/092-J30008.pdf

Anair, D., & Mahmassani, A. (2012). *State of charge - ESCI KSP*. ESCI KSP. https://www.esci-ksp.org/wp/wp-content/uploads/2012/04/State-of-Charge.pdf

Bauer, G., Hsu, C.-W., & Lutsey, N. (2021). *When might lower-income drivers benefit from electric vehicles? Quantifying the economic equity implications of electric vehicle adoption*. https://lindseyresearch.com/wp-content/uploads/2021/12/NHTSA-2021-0053-1578-Exhibit-86-Bauer-et-al-2021.pdf

Deng, J., Miller, T., Denlinger, A., & Bae, C. (2020). *Electric vehicles batteries: Requirements and challenges - cell press*. Joule. https://www.cell.com/joule/pdf/S2542-4351(20)30043-X.pdf

Gebert, M. (n.d.). *Could Tesla Motors be the new Nokia for the automotive industry? Dr ...* ResearchGate. https://www.researchgate.net/profile/Michael-Gebert-2/publication/261356392_Could_Telsa_Motors_be_the_new_Nokia_for_the_automotive_industry/links/00463533eabd7263ec000000/Could-Telsa-Motors-be-the-new-Nokia-for-the-automotive-industry.pdf

Hertzke, P., Müller, N., Schenk, S., & Wu, T. (2018). *THE GLOBAL ELECTRIC-VEHICLE MARKET IS AMPED UP AND ON THE RISE*. https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/The%20global%20electric%20vehicle%20market%20is%20amped%20up%20and%20on%20the%20rise/The-global-electric-vehicle-market-is-amped-up-and-on-the-rise-web-final.pdf

Jones, B., Nguyen‐Tien, V., & Elliott, R. J. R. (2022). The electric vehicle revolution: Critical material supply chains, trade and development. *The World Economy*, *46*(1). https://doi.org/10.1111/twec.13345

Masias, A., Marcicki, J., & Paxton, W. A. (2021). Opportunities and Challenges of Lithium Ion Batteries in Automotive Applications. *ACS Energy Letters*, *6*(2), 621–630. https://doi.org/10.1021/acsenergylett.0c02584

Muratori, M., Alexander, M., Arent, D., Bazilian, M., Cazzola, P., Dede, E. M., Farrell, J., Gearhart, C., Greene, D., Jenn, A., Keyser, M., Lipman, T., Narumanchi, S.,

Pesaran, A., Sioshansi, R., Suomalainen, E., Tal, G., Walkowicz, K., & Ward, J. (2021). The rise of electric vehicles—2020 status and future expectations. *Progress in Energy*, *3*(2), 022002. https://doi.org/10.1088/2516-1083/abe0ad

Nickischer, A. (2020). Environmental Impacts of Internal Combustion Engines and Electric Battery Vehicles. *D.U.Quark*, *4*(2), 21–31. https://dsc.duq.edu/duquark/vol4/iss2/3/

Ren, Y., Danner, T., Moy, A. C., Finsterbusch, M., Hamann, T. R., Dippell, J., Fuchs, T., Marius Müller, Hoft, R., Weber, A., Curtiss, L. A., Zapol, P., Klenk, M., Ngo, A. T., Pallab Barai, Wood, B. C., Shi, R., Wan, L. F., Tae Wook Heo, & Engels, M. (2022). Oxide‐Based Solid‐State Batteries: A Perspective on Composite Cathode Architecture. *Advanced Energy Materials*, *13*(1), 2201939–2201939. https://doi.org/10.1002/aenm.202201939

Savari, G. F., Sathik, M. J., Raman, L. A., El-Shahat, A., Hasanien, H. M., Almakhles, D., Abdel Aleem, S. H. E., & Omar, A. I. (2022). Assessment of charging technologies, infrastructure and charging station recommendation schemes of electric vehicles: A review. *Ain Shams Engineering Journal*, *14*(4), 101938. https://doi.org/10.1016/j.asej.2022.101938

Sun, Y.-K. (2020). Promising All-Solid-State Batteries for Future Electric Vehicles. *ACS Energy Letters*, *5*(10), 3221–3223. https://doi.org/10.1021/acsenergylett.0c01977

Zhang, X., Xie, J., Rao, R., & Liang, Y. (2014). Policy Incentives for the Adoption of Electric Vehicles across Countries. *Sustainability*, *6*(11), 8056–8078. https://doi.org/10.3390/su6118056