The Future of Electric Vehicles: A Comprehensive Review of Technological Advancements, Market Trends, and Environmental Impacts

Priyadarshan Patil
The University of Texas at Austin

RECEIVED
17 September 2017
REVISED
18 October 2017

Keywords: autonomous driving, electric vehicles, environmental impacts, market trends, technological advancements, renewable energy.

ACCEPTED FOR PUBLICATION
20 January 2018
PUBLISHED
21 January 2018

Abstract

This study examines the technological advancements, market trends, and environmental impacts of electric vehicles (EVs). Through an analysis of current research and industry reports, several key findings were identified. Technological advancements in the EV industry, including battery technology, charging infrastructure, and autonomous driving, have made EVs more efficient, affordable, and practical. Battery technology has improved the range and reduced the cost of EVs, while charging infrastructure has reduced range anxiety for EV drivers. Autonomous driving technology has the potential to make EVs even more convenient and efficient. Market trends in the EV industry are driven by government incentives, environmental regulations, and technological advancements. EV adoption is increasing rapidly, with EV sales projected to reach 145 million by 2030. EV manufacturers are diversifying their product portfolios to meet the diverse needs of consumers, and collaboration between EV manufacturers, technology companies, and governments is increasing. The environmental impacts of EVs are complex, but overall, they are considered to be a more environmentally friendly option than internal combustion engine vehicles. EVs emit significantly less greenhouse gases and air pollutants than internal combustion engine vehicles, particularly in regions where the electricity grid is powered by renewable energy sources. However, the production of EVs requires significant amounts of energy and resources, including metals, minerals, and water, and the disposal of EV batteries is a concern. This study provides insight into the current state of the EV industry and its potential to address global environmental challenges. Continued innovation and collaboration will be necessary to maximize the potential of EVs as a solution to these challenges.

Introduction

Electric vehicles (EVs) have a rich history dating back to the late 19th century when inventors first began experimenting with electric power for transportation. In 1832, Scottish inventor Robert Anderson built the first crude electric carriage, and in 1835, American Thomas Davenport built a small locomotive powered by a primitive electric motor. However, it wasn't until the 1890s that the first practical electric vehicles were developed. During this period, electric vehicles were popular among wealthy urbanites because they were quiet and didn't produce smoke or smell. In 1899, the electric taxi was introduced in New York City, and by 1900, electric vehicles accounted for one-third of all cars on the road in the United States.

Table 1. A timeline of electric vehicle development

Year	Milestone
1832	Robert Anderson built the first crude electric carriage
1835	Thomas Davenport built a small locomotive powered by electric motor
1890s	First practical electric vehicles developed
1899	Electric taxi introduced in New York City
1900	Electric vehicles accounted for one-third of all cars on the road in the United States
1920s	Electric vehicles mostly used for commercial and industrial purposes
1966	General Motors introduced the first modern electric vehicle, the Electrovair
1990s	General Motors EV1 and Toyota Prius introduced
2003	Tesla Motors was founded
2018	More than 2 million electric vehicles sold worldwide

Despite their popularity, electric vehicles were soon overshadowed by gasoline-powered vehicles, which were cheaper and had longer driving ranges. By the 1920s, electric vehicles were mostly used for commercial and industrial purposes, such as delivery trucks and golf carts. It wasn't until the 1960s and 1970s, during the energy crisis, that electric vehicles experienced a resurgence in popularity. In 1966, General Motors introduced the first modern electric vehicle, the Electrovair. However, the vehicle was not successful due to its limited range and high cost.

The modern electric vehicle era began in the 1990s with the introduction of the General Motors EV1 and the Toyota Prius. The EV1 was the first mass-produced electric vehicle of the modern era, and it was only available for lease to customers in California. The Prius, which was a hybrid vehicle that combined electric and gasoline power, was introduced in Japan in 1997 and in the United States in 2000. In 2003, Tesla Motors was founded, and the company's Roadster became the first highway-capable electric vehicle to use lithium-ion batteries. Since then, the electric vehicle market has grown rapidly, with more than 2 million electric vehicles sold worldwide in 2018. Electric vehicles are seen as a key component of the transition to a low-carbon future and are a rapidly growing segment of the global automotive market.

Unlike conventional vehicles that rely on gasoline or diesel fuel, EVs use batteries and electric motors to power their engines. The batteries in electric vehicles are rechargeable, which means they can be recharged by plugging them into an electrical outlet or charging station. The electric motor in an EV converts the electrical energy from the battery into mechanical energy that drives the wheels of the vehicle. This is achieved by sending a current through a set of coils in the motor, which creates a magnetic field that interacts with the permanent magnets in the motor to produce torque. The amount of torque produced by the motor determines the speed of the vehicle.

The batteries used in EVs are typically lithium-ion batteries, which are the same type of batteries used in cell phones, laptops, and other portable electronic devices. These batteries are made up of cells that contain lithium ions, which are charged and discharged to store and release energy. The cells in a lithium-ion battery are connected in series to create a battery pack that can store a large amount of energy. The size of the battery pack in an EV determines the range of the vehicle, or how far it can travel on a single charge. EVs typically have a range of 100-300 miles per charge, although this can vary depending on the type of vehicle and the conditions under which it is driven.

Technological Advancements

The advent of electric vehicles has led to increased interest in the development of advanced battery technology. Lithium-ion batteries have emerged as the leading technology for powering EVs. The energy density of lithium-ion batteries has increased significantly over the years, resulting in longer driving ranges for electric vehicles. In addition, the cost of producing lithium-ion batteries has decreased, making them more affordable for consumers.

Moreover, there is increasing interest in the development of solid-state batteries. Unlike traditional lithium-ion batteries that use a liquid electrolyte, solid-state batteries use a solid electrolyte. This feature allows for the potential of higher energy density, longer battery life, and improved safety. Solid-state batteries could also provide a reduction in battery size and weight, which would further improve the performance and efficiency of electric vehicles. Although still in the research and development phase, solid-state batteries hold great promise for the future of electric vehicles.

One of the biggest challenges is the limited availability of raw materials, particularly cobalt and lithium. The production of lithium-ion batteries requires large amounts of these materials, and their extraction can have negative environmental impacts. Another challenge is the recycling of batteries at the end of their life. The recycling process can be expensive and complicated, and many batteries end up in landfills, posing a potential environmental hazard. Addressing these challenges will be critical for the future of battery technology and the growth of the electric vehicle market.

Despite the challenges, the development of battery technology has made significant progress in recent years. Researchers are exploring new materials and manufacturing processes that could further improve the performance and efficiency of batteries. For example, the use of silicon as an anode material in lithium-ion batteries has shown promising results in increasing energy density. Graphene, a material with excellent conductivity and strength, is also being studied for its potential use in batteries.

Another area of research is the development of battery management systems that can optimize the performance and lifespan of batteries. These systems use algorithms and machine learning to monitor the state of the battery and adjust charging and discharging accordingly. By optimizing the use of the battery, these systems can extend its lifespan and reduce the likelihood of failure.

The development and expansion of charging infrastructure has been one of the most significant developments in the electric vehicle (EV) market. For many years, range anxiety was a major concern for EV drivers, as the limited range of their vehicles often made it difficult to travel long distances. However, with the increasing installation of public charging stations, this issue has been significantly reduced. The installation of public charging stations in various locations, including commercial areas, public parking lots, and highways, has made it easier for EV drivers to find a convenient location to charge their vehicles. As a result, EV drivers no longer need to worry about running out of charge and being stranded on the road.

Moreover, advancements in fast-charging technology have further reduced charging times, making it possible to charge an EV in just a matter of minutes. In the past, charging an EV could take several hours, which was a significant barrier to the widespread adoption of electric vehicles. However, fast-charging technology has made it possible to charge an EV in a matter of minutes, which is much more convenient for drivers. This technology has been made possible by the development of new charging protocols, such as the CCS and CHAdeMO standards. These protocols allow for high-power charging, which can deliver up to 350 kW of power, allowing for rapid charging times.

In addition to reducing range anxiety and improving charging times, the installation of public charging infrastructure has also helped to address other challenges in the EV market. One of the most significant challenges is the issue of charging access for those who do not have access to a personal charging station. Public charging infrastructure has made it possible for drivers who live in apartments or other multi-unit dwellings to charge their vehicles conveniently. This has helped to democratize access to electric vehicles, making them more accessible to a wider range of people. Additionally, the installation of public charging infrastructure has helped to reduce the carbon footprint of electric vehicles by enabling the use of renewable energy sources, such as solar or wind power, to power the charging stations.

Furthermore, the expansion of public charging infrastructure has been driven in part by government incentives and regulations aimed at reducing greenhouse gas emissions and promoting the adoption of electric vehicles. In many countries, governments have implemented programs to support the installation of public charging infrastructure, including funding for charging stations and tax incentives for EV owners. These initiatives have helped to accelerate the growth of the EV market and reduce the environmental impact of transportation.

The development of autonomous driving technology has been one of the most significant advancements in recent years. With the emergence of electric vehicles (EVs), this technology has the potential to revolutionize the way people travel. Autonomous driving technology enables vehicles to operate without human intervention, allowing passengers to relax and enjoy their journey without worrying about steering, accelerating, or braking. This technology has the potential to make EVs even more convenient and efficient, as they can be charged and operated without the need for a human driver.

As autonomous driving technology continues to improve, it is expected that EVs will play an increasingly significant role in the future of transportation. This is because EVs are more energy-efficient than traditional gas-powered vehicles, and they emit fewer greenhouse gases. With the growing concern about climate change, many governments around the world are encouraging the use of EVs to reduce carbon emissions. Autonomous driving technology can further enhance the appeal of EVs by making them more accessible and convenient for consumers. As a result, the combination of EVs and autonomous driving technology has the potential to revolutionize the way people travel and reduce the negative impact of transportation on the environment.

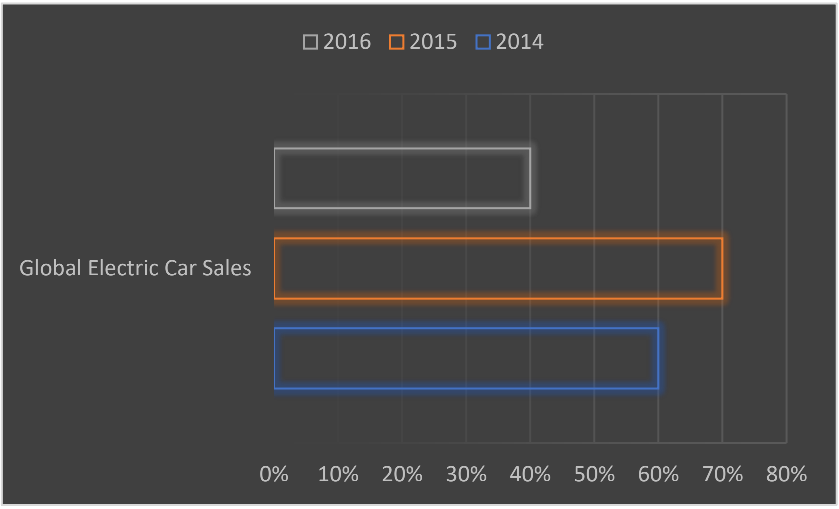
Moreover, the development of autonomous driving technology has already had a significant impact on the automotive industry. Many major automakers are investing heavily in autonomous driving technology, and some have already released vehicles with autonomous features. In addition, a number of technology companies have entered the market, offering innovative solutions for autonomous driving. This competition has driven rapid innovation in the field, leading to improvements in safety, reliability, and efficiency. As more companies invest in autonomous driving technology, the cost of these systems is likely to decrease, making them more accessible to consumers. This, in turn, will lead to increased adoption of EVs and autonomous vehicles, further driving innovation and improving the efficiency of transportation systems.

Market Trends

The figure 1 shows the percentage of global electric car sales in three consecutive years: 2014, 2015, and 2016. In 2014, electric car sales accounted for 60% of the total global car sales. This means that 60% of all cars sold globally in 2014 were electric.

In 2015, the percentage of electric car sales increased to 70%, indicating that there was a significant growth in the adoption of electric cars between 2014 and 2015. However, in 2016, the percentage of electric car sales decreased to 40%, indicating a decline in the adoption of electric cars. This may be due to various reasons such as the lower oil prices and the higher costs of electric cars compared to traditional gasoline-powered cars.

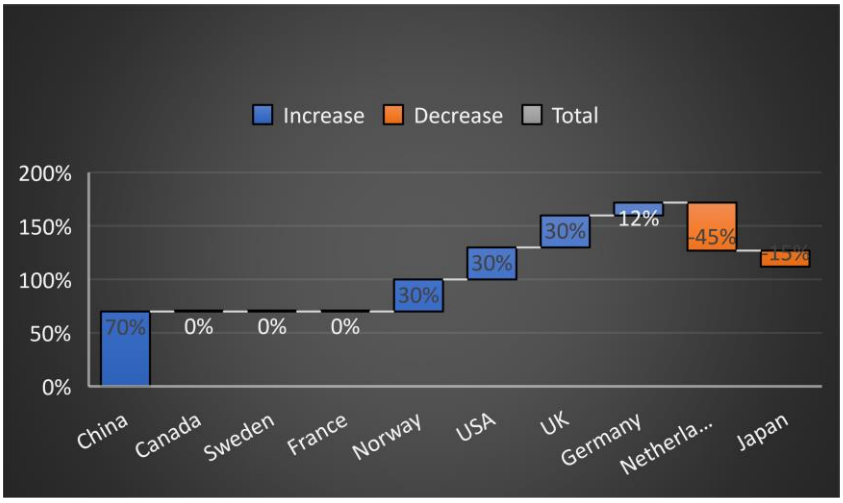
Figure 1. Global Electric Car Sales



The figure 2 shows the annual growth rates of electric car sales for various countries in 2016, expressed as percentages. China had the highest annual growth rate in electric car sales at 70%, indicating a significant increase in the adoption of electric vehicles in the country. Canada, Sweden, and France all had annual growth rates of 50%-70%, indicating strong growth in the adoption of electric cars in these countries. Norway, the USA, and the UK all had growth rates of 30%, indicating moderate growth in electric car sales.

Germany had a growth rate of 12%, indicating a slower rate of adoption of electric cars compared to the other countries in the table. Netherlands had a negative growth rate of -45%, indicating a decline in electric car sales in 2016 compared to the previous year. Japan had a negative growth rate of -15%, indicating a decline in electric car sales, but to a lesser extent compared to the Netherlands.

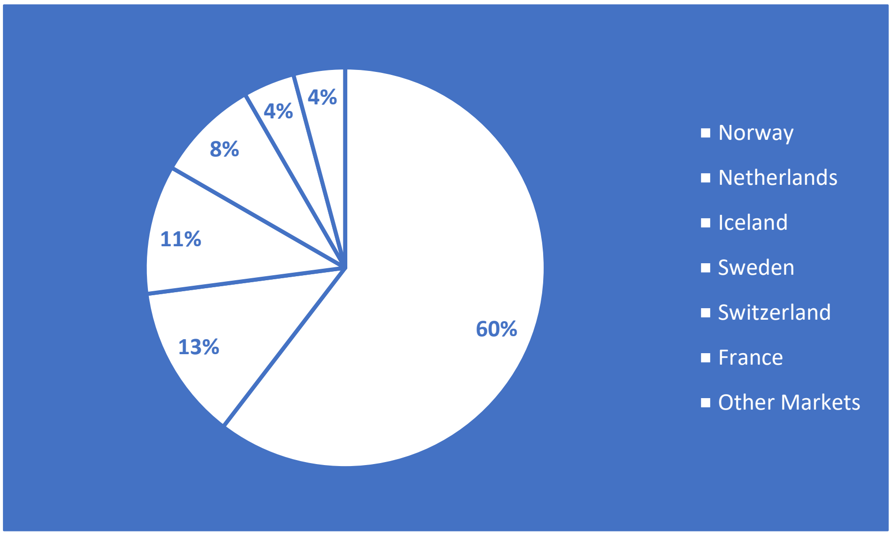
Figure 1. Annual Growth in 2016



The data in figure 3 provides the electric sales share of different markets in the year 2016. Norway had the highest share of electric sales with 29%, indicating that almost one-third of the electric cars sold in 2016 were in Norway. Following Norway, the Netherlands had a 6% share of electric sales, which was considerably lower than Norway but still a significant portion of the market. Iceland had a 5% share, whereas Sweden and Switzerland had 4% and 2% shares, respectively. France had a 2% share, similar to Switzerland. Finally, other markets combined had an electric sales share of around 1%, which indicates that they were relatively small markets for electric vehicles in 2016.

Norway's high share indicates that the country had a favorable environment for electric vehicles, which can be attributed to incentives and initiatives from the government, such as tax exemptions and infrastructure development. On the other hand, the relatively low share of some countries like France and Switzerland suggests that these markets were not as welcoming towards electric vehicles at that time.

Figure 3. Electric Sales Share 2016



The diversification of EV models represents a significant shift in the automotive industry towards sustainable and eco-friendly transportation solutions. With the increasing demand for electric vehicles, manufacturers are investing heavily in research and development to offer a wide range of models that cater to the diverse needs of consumers. This trend is driven by the need to address the growing concerns about environmental pollution and the depletion of fossil fuels. As a result, we are witnessing a proliferation of EV models that range from small city cars to luxury SUVs, providing consumers with a range of options that suit their budget, lifestyle, and preferences.

The diversification of EV models is not only limited to passenger cars but also extends to other modes of transportation such as trucks, buses, and motorcycles. This expansion of the EV market is due to the growing awareness among consumers and businesses about the benefits of electrification, including lower operating costs, reduced emissions, and improved performance. As a result, EV manufacturers are partnering with other companies to develop new models that are tailored to specific needs, such as last-mile delivery, ride-sharing, and public transportation. This trend is also driving innovation in battery technology, charging infrastructure, and autonomous driving, as manufacturers seek to offer more advanced and efficient solutions to meet the evolving needs of their customers.

EV manufacturers are recognizing the importance of offering a wide range of EV models that meet the specific needs of their target customers. This approach involves developing vehicles that are tailored to different consumer segments, such as families, young professionals, and adventure seekers. For example, some EV manufacturers are offering models with longer range capabilities, while others are focusing on delivering high-performance sports cars. Similarly, some are developing EVs that are more affordable, while others are offering luxury models that cater to the high-end market.

In addition to catering to specific consumer segments, the diversification of EV models is also driven by the need to address the challenges of range anxiety and charging infrastructure. To overcome these challenges, EV manufacturers are developing models with longer range capabilities and faster charging times. They are also partnering with charging infrastructure companies to expand the network of charging stations and make them more accessible to consumers. This focus on improving range and charging infrastructure is crucial for the wider adoption of EVs, as it helps to alleviate the concerns of consumers who may be hesitant to switch to electric vehicles.

Collaboration and partnerships have become a key strategy for EV manufacturers, technology companies, and governments to accelerate the growth of the EV industry. The EV market has been rapidly expanding in recent years, and collaboration has become essential to meet the increasing demand for sustainable transportation solutions. EV manufacturers are collaborating with technology companies to develop advanced technologies, such as battery management systems, electric drivetrains, and charging infrastructure. This collaboration has resulted in the development of more efficient, reliable, and affordable EVs, which have helped to increase consumer adoption.

In addition to collaboration between EV manufacturers and technology companies, governments have also played a significant role in the growth of the EV industry. Many governments are now offering incentives and subsidies to promote the adoption of EVs, which has encouraged collaboration between the public and private sectors. Governments are collaborating with EV manufacturers to create policies that promote sustainable transportation solutions, such as increasing the availability of charging infrastructure and promoting the use of renewable energy sources. This collaboration has created a favorable environment for innovation and growth in the EV industry.

Moreover, collaboration between EV manufacturers, technology companies, and governments has also led to the development of new business models and revenue streams. For example, some EV manufacturers have partnered with utility companies to provide grid services, such as energy storage and demand response, using the batteries of their EVs. This collaboration has created a new revenue stream for EV manufacturers, while also helping to stabilize the grid and reduce carbon emissions. Furthermore, some governments have collaborated with technology companies to develop smart charging infrastructure, which allows EV owners to charge their vehicles during off-peak hours when electricity is cheaper. This collaboration has helped to reduce the strain on the grid and lower the cost of electricity for consumers. Overall, collaboration and partnerships have become essential for the growth of the EV industry, creating opportunities for innovation, sustainability, and economic development.

Collaboration and partnerships have also led to increased research and development in the EV industry. EV manufacturers, technology companies, and governments are working together to develop new and innovative technologies that can improve the performance and efficiency of EVs. For example, some technology companies are developing artificial intelligence (AI) algorithms to optimize battery performance and extend the range of EVs. This collaboration has resulted in the development of more efficient, reliable, and affordable EVs, which have helped to increase consumer adoption.

EV manufacturers, technology companies, and governments are working together to increase the availability of charging stations and improve the speed and convenience of charging. Some governments are investing in the development of charging infrastructure, while some technology companies are developing new charging technologies, such as wireless charging, to make it easier for consumers to charge their EVs. This collaboration has helped to address one of the major barriers to the adoption of EVs, which is the lack of charging infrastructure. Collaboration and partnerships have also played a significant role in the global effort to reduce greenhouse gas emissions and combat climate change. Collaboration between EV manufacturers, technology companies, and governments has created a favorable environment for the development and adoption of EVs, which can help to reduce emissions and combat climate change. Some governments are setting targets for the adoption of EVs, and some are even mandating the phase-out of internal combustion engines. This collaboration has helped to create a sense of urgency and importance around the adoption of EVs, which can have a significant impact on global emissions and climate change.

Environmental Impacts

Two essential components of a sustainable future are electric cars and renewable energy sources. Electric vehicles are crucial to the worldwide effort to cut carbon emissions and battle climate change since they are powered by electricity and emit no pollutants. While lowering dependency on fossil fuels, renewable energy sources like solar and wind power can supply the electricity required to power electric automobiles. The fact that electric cars are environmentally friendly is one of their most important features. Electric cars create no pollutants, in contrast to conventional automobiles, making them a great option for those who care about the environment. Furthermore, the environmental impact of electric vehicles can be further reduced by charging them with sustainable energy sources like solar or wind energy.

Electric vehicles (EVs) have gained significant attention in recent years due to their potential to reduce greenhouse gas emissions and improve air quality. One of the most significant advantages of EVs is their ability to emit significantly fewer greenhouse gases and air pollutants compared to internal combustion engine vehicles (ICEVs). The shift from ICEVs to EVs is seen as a key strategy in reducing the carbon footprint of the transportation sector, which is one of the largest sources of greenhouse gas emissions globally. In addition, the reduction in air pollutants such as nitrogen oxides (NOx) and particulate matter (PM) can have significant health benefits, particularly in urban areas where air pollution levels are high.

The environmental benefits of EVs are not uniform and are dependent on the source of electricity used to charge the vehicles. In regions where the electricity grid is powered by renewable energy sources, such as wind, solar, and hydroelectric power, the benefits of EVs are amplified. Renewable energy sources produce little to no emissions during operation and have a much lower carbon footprint than fossil fuel-based electricity generation. Thus, using renewable energy to power EVs results in a significant reduction in greenhouse gas emissions and helps to combat climate change. The transition to renewable energy sources in the electricity sector is a critical step towards achieving net-zero emissions goals and building a sustainable future.

The production of electric vehicles (EVs) requires significant amounts of energy and resources, making them a complex product from an environmental standpoint. EVs rely on a complex network of materials, ranging from metals and minerals to plastics and rare earth elements. The mining and extraction of these resources often comes with an environmental cost, including water usage and land degradation. The use of these resources in the production of EVs requires an extensive amount of energy, which is primarily sourced from non-renewable energy sources such as fossil fuels. Therefore, the environmental impact of resource consumption is an essential aspect of the EV production process, and efforts must be made to reduce its impact.

Recycling materials used in the production of EVs reduces the demand for new resources, which in turn reduces the environmental impact of their extraction. Another way is through responsible sourcing of materials. This approach ensures that the materials used in the production of EVs are obtained from sustainable sources, minimizing the environmental impact of resource extraction. This approach also supports the development of sustainable supply chains, ensuring that the production of EVs does not come at the cost of the environment.

Recycling and responsible sourcing of materials are crucial to reducing the environmental impact of resource consumption in the production of EVs. These approaches help reduce the amount of waste generated during the production process, which in turn reduces the amount of energy required for production. Additionally, responsible sourcing of materials reduces the environmental impact of resource extraction, ensuring that the resources used in the production of EVs are obtained sustainably. By incorporating these approaches, EV manufacturers can make significant strides in reducing the environmental impact of their production processes.

It is important to note that the environmental impact of resource consumption in EV production is not limited to the production process alone. The end-of-life disposal of EVs also poses significant environmental challenges, particularly in the disposal of the battery. Batteries used in EVs are made up of a variety of materials, including lithium, cobalt, and nickel, which can pose environmental risks if not disposed of correctly. Therefore, it is essential to consider the full life cycle of EVs, from production to disposal, when assessing their environmental impact.

With the increasing adoption of these vehicles comes the responsibility of managing their batteries at the end of their lifespan. In addition to the environmental and health hazards posed by improper disposal, these batteries are also expensive to manufacture, making recycling a more economical option. Recycling not only reduces the environmental impact of battery disposal but also conserves natural resources by recovering materials such as lithium, cobalt, and nickel.

Recycling of lithium-ion batteries involves a complex process of disassembly, separation, and extraction of valuable materials. The process requires significant energy and resources, making it crucial to implement efficient and sustainable recycling practices. Despite the challenges, several initiatives and innovations have emerged to address the issue of battery disposal. These include the development of new recycling technologies that use less energy and recover a higher percentage of valuable materials. Additionally, there are efforts to establish a circular economy for battery materials, where materials are recycled and reused in new batteries, reducing the need for mining and production of new materials.

Conclusion

The development of advanced battery technology is crucial for the growth of the electric vehicle market and the transition to a more sustainable energy system. Lithium-ion batteries have already made significant progress in increasing energy density and reducing costs. Solid-state batteries hold great promise for even further improvements in energy density, battery life, and safety. However, addressing the challenges of raw material availability and battery recycling will be critical for the long-term viability of battery technology. With continued research and innovation, battery technology could revolutionize the way we power our vehicles and homes, leading to a cleaner and more sustainable future.

The installation of public charging infrastructure and the development of fast-charging technology have been critical to the success and growth of the electric vehicle market. These developments have helped to address some of the key challenges of EV ownership, including range anxiety and charging access. They have also helped to reduce the carbon footprint of electric vehicles and promote the use of renewable energy sources. As the demand for electric vehicles continues to grow, it is essential that we continue to invest in charging infrastructure and continue to innovate to make electric vehicles an even more attractive and convenient option for drivers.

As the technology continues to improve, it is expected that EVs will play an increasingly significant role in the future of autonomous driving. With the rapid innovation and competition in the industry, the cost of autonomous driving technology is likely to decrease, making it more accessible to consumers. This will lead to increased adoption of EVs and autonomous vehicles, further driving innovation and improving the efficiency of transportation systems.

The diversification of EV models is a positive development for the automotive industry and the environment. As more consumers switch to electric vehicles, manufacturers will be under increasing pressure to deliver a wider range of models that meet their specific needs. This will not only provide consumers with more choice but will also spur innovation in battery technology, charging infrastructure, and autonomous driving. As a result, we can expect to see a more sustainable and cleaner future, where electric vehicles play a significant role in reducing emissions and preserving the environment.

Collaboration and partnerships between EV manufacturers, technology companies, and governments have become essential for the growth and success of the EV industry. This collaboration has created opportunities for innovation, sustainability, and economic development, while also addressing some of the major challenges facing the industry, such as the lack of charging infrastructure and consumer adoption. As the world continues to transition towards a more sustainable future, collaboration and partnerships will play an increasingly important role in the global effort to reduce greenhouse gas emissions and combat climate change.

Widespread adoption of EVs presents significant opportunities to mitigate climate change, reduce air pollution, and promote sustainable development. To maximize the environmental benefits of EVs, it is essential to increase the share of renewable energy sources in the electricity grid, promote energy efficiency measures, and incentivize the deployment of EV charging infrastructure. Governments, the private sector, and individuals all have a role to play in facilitating the transition to a cleaner and more sustainable transportation sector.

The production of EVs requires significant amounts of energy and resources, including metals, minerals, and water. However, the environmental impact of resource consumption can be mitigated by recycling and responsible sourcing of materials. These approaches help reduce the amount of waste generated during the production process, ensuring that the resources used in the production of EVs are obtained sustainably. It is also important to consider the full life cycle of EVs, from production to disposal, when assessing their environmental impact. By incorporating sustainable practices into their production processes, EV manufacturers can make significant strides in reducing the environmental impact of their products.

Battery disposal is a critical issue that needs to be addressed urgently. The increasing adoption of EVs necessitates the development of sustainable and efficient battery recycling practices. By implementing innovative recycling technologies and establishing a circular economy for battery materials, we can reduce the environmental and health hazards of battery disposal, conserve natural resources, and ensure the long-term sustainability of EVs. It is essential to recognize the significance of this issue and take necessary actions to mitigate its impact.

As a result of market trends and technological breakthroughs, the future of EVs appears optimistic. EVs are typically seen as a more environmentally benign option than cars with internal combustion engines, despite the complexity of their environmental effects. However, in order to address the challenges that the EV industry is facing and to realize its full potential as a response to the current environmental problems on a worldwide scale, more innovation and cooperation will be required.

References

[1] T. R. Hawkins, O. M. Gausen, and A. H. Strømman, “Environmental impacts of hybrid and electric vehicles—a review,” *Int. J. Life Cycle Assess.*, vol. 17, no. 8, pp. 997–1014, Sep. 2012.
[2] F. Liao, E. Molin, and B. van Wee, “Consumer preferences for electric vehicles: a literature review,” *Transp. Rev.*, 2017.
[3] J. Du and D. Ouyang, “Progress of Chinese electric vehicles industrialization in 2015: A review,” *Appl. Energy*, 2017.
[4] M. Coffman, P. Bernstein, and S. Wee, “Electric vehicles revisited: a review of factors that affect adoption,” *Transp. Rev.*, vol. 37, no. 1, pp. 79–93, Jan. 2017.
[5] C. C. Chan and Y. S. Wong, “Electric vehicles charge forward,” *IEEE Power Energ. Mag.*, 2004.
[6] K. T. Chau, Y. S. Wong, and C. C. Chan, “An overview of energy sources for electric vehicles,” *Energy Convers. Manage.*, vol. 40, no. 10, pp. 1021–1039, Jul. 1999.

[7] C. C. Chan and K. T. Chau, “An overview of power electronics in electric vehicles,” *IEEE Trans. Ind. Electron.*, vol. 44, no. 1, pp. 3–13, Feb. 1997.
[8] N. Daina, A. Sivakumar, and J. W. Polak, “Modelling electric vehicles use: a survey on the methods,” *Renewable Sustainable Energy Rev.*, vol. 68, pp. 447–460, Feb. 2017.
[9] M. A. Hannan, F. A. Azidin, and A. Mohamed, “Hybrid electric vehicles and their challenges: A review,” *Renewable Sustainable Energy Rev.*, vol. 29, pp. 135–150, Jan. 2014.
[10] C. C. Chan and Y. S. Wong, “The state of the art of electric vehicles technology,” *The 4th International Power Electronics*, 2004.
[11] A. Sciarretta and L. Guzzella, “Control of hybrid electric vehicles,” *IEEE Control Syst. Mag.*, vol. 27, no. 2, pp. 60–70, Apr. 2007.
[12] S. F. Tie and C. W. Tan, “A review of energy sources and energy management system in electric vehicles,” *Renewable Sustainable Energy Rev.*, vol. 20, pp. 82–102, Apr. 2013.
[13] C. R. Bhat, S. Astroza, P. Patil, and Z. Zhang, “Corridor-Based Planning Tool for Transportation of Wind Turbine Components: Manual Guide (P1) Workshop Presentation (P2),” 2017. [Online]. Available: https://library.ctr.utexas.edu/ctr-publications/0-6850-p1p2.pdf. [Accessed: 12-Apr-2023].
[14] N. L. Panwar, S. C. Kaushik, and S. Kothari, “Role of renewable energy sources in environmental protection: A review,” *Renewable Sustainable Energy Rev.*, vol. 15, no. 3, pp. 1513–1524, Apr. 2011.
[15] S. Astroza *et al.*, “Texas transportation planning for future renewable energy projects,” University of Texas at Austin. Center for Transportation Research, 2017.
[16] P. Moriarty and D. Honnery, “What is the global potential for renewable energy?,” *Renewable Sustainable Energy Rev.*, 2012.
[17] J. Mohtasham, “Renewable energies,” *Energy Procedia*, 2015.
[18] S. Astroza, P. N. Patil, and K. I. Smith, “Transportation planning to accommodate needs of wind energy projects,” *Transp. Res.*, 2017.
[19] I. Dincer, “Renewable energy and sustainable development: a crucial review,” *Renewable Sustainable Energy Rev.*, 2000.
[20] A. Jäger-Waldau, “Photovoltaics and renewable energies in Europe,” *Renewable Sustainable Energy Rev.*, 2007.
[21] R. Gross, M. Leach, and A. Bauen, “Progress in renewable energy,” *Environ. Int.*, vol. 29, no. 1, pp. 105–122, Apr. 2003.
[22] C. R. Bhat, S. Astroza, P. N. Patil, K. I. Smith, and Z. Zhang, “Corridor-based planning tool for transportation of wind turbine components: manual guide: preliminary draft,” 2016.
[23] O. Ellabban, H. Abu-Rub, and F. Blaabjerg, “Renewable energy resources: Current status, future prospects and their enabling technology,” *Renewable Sustainable Energy Rev.*, 2014.