Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 47 No. 02 (2026)

Comprehensive Review of Electric Vehicle Technologies: Battery Advancements, Charging Infrastructure and Future Prospects

Vinay Lomte[1*], R R Deshmukh[2], Somila Hashunao[3], Prem Kumar[4], Ngayaiwon Hashunao[5], Khushbu Ramesh Khandait[6], Mohammad Ashique Azad[7]

[*1]Department of Mechanical Engineering, Dr Babasaheb Ambedkar Marathwada University, Chhatrapati Sambhajinagar, Maharashtra

[2]Department of Mechanical Engineering, JNEC, MGM University, Chhatrapati Sambhajinagar, Maharashtra

[3]Department of Electrical Engineering, NERIST, Arunachal Pradesh

[4]Department of Computer Science and Engineering (CS&DS), Brainware University, West Bengal

[5]Department of Electrical Engineering, Manipur Technical University, Manipur

[6]Department of Computer Engineering, Trinity Academy of Engineering, Pune

[7]Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Guntur, Andhra Pradesh

Abstract

Electric vehicles (EVs) constitute a revolutionary change in the field of transportation technology, which is associated with important environmental and financial benefits when compared to traditional vehicles with internal combustion engines (ICE). This is due to the fact that this review focuses on a thorough analysis of the present and future of the electric vehicle technologies with specific attention given to battery technologies, charging infrastructure, and the market trends. Recent advancements since 2021 to 2026 have been synthesized in the paper to examine several architectures of EVs such as Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Fuel Cell Electric Vehicles (FCEVs). Emerging battery technologies which include solid-state batteries, sodium-ion batteries, lithium-sulfur batteries and metal-air batteries are given particular attention. The update on the charge infrastructure advancement between AC Level 1 and DC Fast charging is explained and the recent advancement on ultra-fast charging networks. The prevailing market trends indicate that the global battery technology market of EV is estimated to be 98.65 billion dollars in 2025, and will be 156.95 billion dollars in 2031[1]. In this paper, the author has named the main technological obstacles as range constraints, charge time, battery prices, and infrastructure shortages and provided the hopeful solutions as solid-state batteries designed by Toyota to achieve 750-mile range and 10-minute charge time by 2027-2028[2].

The conclusion of the analysis is that further development of battery chemistry, the extension of charging systems, and the relevant governmental policies will stimulate EV adoption and fundamentally transform the automotive industry in the world.

Keywords: Electric Vehicle, Battery Technology, Charging Infrastructure, Solid-State Batteries, Sodium-Ion Batteries, Lithium-Ion Batteries, Sustainable Transportation

1. Introduction

The transport sector is among the most important sources of greenhouse gas (GHG) emissions and contributes to the overall effect of 29 percent of all greenhouse gas emissions as of 2019[3]. As the environmental issues are swirling and climate change is going to happen, electric vehicles have proved as an option that is viable and on the rise in popularity as an alternative to the traditional internal combustion engine vehicles. The shift of transportation relying on fossil fuel to the electric mobility is not just a technological change, but a reconsideration of the idea of sustainable development of cities and the integration of energy systems.

EVs have strong benefits as compared to their counterparts in ICEs. They also generate no tail pipe emissions which hugely minimize air pollution at the local level in cities. EVs are also more energy efficient with up to 59-62 percent of electric grid energy entering the locomotor being converted to power at the wheels versus a low 17-21 percent in conventional gasoline powered vehicles[4]. Also, the simplicity of the operation of electric drives, the reduction in moving components, and the absence of complex transmissions, cooling systems, and exhaust systems, mean that the cost of maintenance and the overall reliability of the vehicle throughout its life will be lower.

Nevertheless, among all these merits, EVs have continued to experience a series of challenges that have traditionally hindered their market penetration. The main ones include low driving range as compared to gasoline powered vehicles, takes a longer time to charge, more expensive to purchase initially, and the lack of effective charging infrastructure in most locations. The limited battery capacity of the early EVs limited the range of the vehicles to 150-200 kilometers and the potential buyers had serious range anxiety. Moreover, there is the time-old chicken-and-egg problem: consumers are afraid to buy EVs, as there is not a strong network of charging stations, and infrastructure developers are waiting until EVs are widely adopted to make a step.

The history of electric vehicles turns out to have a much longer history than expected. The first electrically operated vehicles were developed in 1834 and by 1918, electric cars were quite popular, making 38 percent of the vehicles on the road (62 percent of the vehicles were steam operated vehicles and 22 percent were gasoline powered vehicles) [5]. Nonetheless, the use of EV had fallen drastically by the 1930s since they were slow, expensive and had limited range in comparison to the rapidly advancing internal combustion engines. The electric car revived interest in the 1970s as a by-product of the power shortage crisis, but sustainable commercial viability had still not been achieved before the 21st century.

Modern revival of electric cars which started at the beginning of the 2000s has been triggered by a combination of convergent forces: increased oil prices, strict regulations on emissions, radical advances in battery technology (especially the lithium-ion batteries), increased environmental awareness, and massive government subsidies. In the period between 2002 and 2012, there were more than 350 models of the electric vehicles in the automotive industry [6]. Large producers such as Toyota, Honda, Nissan, Chevrolet, and Tesla have invested billions of vehicles in EV development, and a prototype such as the Tesla Model S proved in 2012 that electric cars might not only be able to travel great distances (270 miles), but also perform well.

By the year 2026, the electric vehicle situation has changed significantly. The price of lithium-ion batteries has reduced to $568 per kilowatt-hour down to around 100 per kilowatt-hour in 2025[7], which also makes EVs a more affordable alternative to ICE vehicles. There is a move towards solid-state battery technology, which has been the long-held holy grail of EV batteries, and which Toyota, Samsung, and other companies are aiming to produce by 2027-2028[2][8]. Meanwhile, other battery chemistries, including sodium-ion batteries, are commercially being used, especially in China, and are cheaper and better-handling in cold weather conditions [9].

2. Advantages and Disadvantages of Electric Vehicles

2.1 Advantages Over Conventional Vehicles

The use of electric cars has a variety of strong selling points that are contributing to their growing popularity in the world:

- Zero Tailpipe Emissions: EVs have no direct emissions of carbon monoxide (CO), carbon dioxide (CO 2), nitrogen oxides (NO 0 -NO3), or particulate matter. Although the manufacturing processes and electricity generation can lead to emissions, the well-to-wheel (WTW) of EVs with renewable energy can be up to70 percent, whereas the gasoline and diesel vehicles have well-to-wheel (WTW) of 11-27 percent and 25-37 percent, respectively[10].
- Excellent Energy Efficacy: Electric motors are more efficient in nature as compared to internal combustion engines. EVs use 59-62% of electrical energy to generate mechanical energy, where gasoline cars only use 17-21% efficiency[4]. This basic thermodynamic benefit is directly converted to the reduction of the energy used in each kilometer covered.
- Lower Operating Costs: Electricity price per kilometer is significantly low in comparison with gasoline, diesel, or other types of fuel. Relative studies reveal that the fuel price per kilometer of any kind of electric vehicle is the lowest of all. Moreover, regenerative braking systems will capture kinetic energy during deceleration and increase the range, as well as decrease the wear of brakes.
- Reduced Moving parts: There are few moving parts in electric vehicles as compared to ICE cars: no pistons, no valves, no transmissions or clutches, no exhausts, no complex cooling systems. It is a mechanical simplicity that leads to decreased maintenance requirements, decreased maintenance costs and increased reliability.
- Better Reliability: EVs have less breakdown as there are fewer items that require wear and tear. The stresses of combustion, vibrations, and corrosion byproducts of combustion are not seen in electrical motors, resulting in longer lifespan of the drive tract.

• Demand: Vehicle-to-Grid (V2G) technology can be used to make EVs be a distributed energy source to provide grid stability and allow variable renewable energy to be incorporated into the grid.

Table 1: Relative fuel economy comparison showing electric vehicles offer substantially lower operating costs than all conventional alternatives

Fuel Type	Cost per Kilometer (relative)
Electricity	1.0 (lowest)
Natural Gas Vehicles (NGV)	1.2
Liquefied Petroleum Gas (LPG)	2.0
Biodiesel	2.3
Diesel	2.7
Hybrid	3.3
Ethanol (E85)	3.8
Gasoline	7.5 (highest)

2.2 Disadvantages and Challenges

• Electric vehicles have a number of serious problems, although they are beneficial, such obstacles still exist:

• Poor Driving Range: EV range is currently limited, but it is on the way to getting better than what gasoline-powered cars have. The majority of BEVs have 60-400 kilometers of charge range, but the higher-end models go way beyond this. The range anxiety remains one of the key consumer adoption barriers.

• Long Charging Duration: The recharge of a EV battery takes so long to complete charging as compared to a gasoline car, despite the fast-charging technology. AC Level 2 charging takes 4-8 hours to charge fully and DC Fast Charging may require 30 minutes to charge 80 percent, but is costlier and may reduce battery life[11].

• Increased Starting price: EVs usually incur higher prices of purchase compared to other similar ICE cars, even with rising battery prices. The cost of battery packs (30-40% of total vehicle cost) is the main driving force. Nevertheless, lifetime cost of ownership of the vehicle is gradually becoming competitive in terms of reduced operating and maintenance costs.

• Battery Weight and Volume: High capacity battery packs increase the weight of the vehicle and take up a lot of space, which affects its overall efficiency, handling, and cargo space. The current lithium-ion batteries are significantly lower in energy density than gasoline, and so require larger and heavier battery packs to achieve the same range.

- Temperature Sensitivity: The battery works poorly in high and low temperatures, specifically cold weather. Cold weather also decreases the battery capacity and efficiency and the heating of the cabin uses power in the battery decreasing range further. On the same note, a battery can wear out when it is overheated.

- Charging Infrastructure Gaps: Even with the rapid growth, charging infrastructure is still underdeveloped in most areas especially in rural locations and developing countries. The lack of charging stations makes long-distance travel and the ownership of an EV practically less convenient to the uneven distribution of such stations, unlike to multi-unit dwelling residents.

- Battery Degradation: The battery capacity decreases progressively with charge-discharge cycles and age, and will normally have 70-80 percent of the original capacity after 8-10 years. The cost of replacement, which is on the decrease, is still large.

- Environmental Impact of the Battery Production: EVs have zero tailpipe emissions, but the production of batteries has serious effects on the environment, such as the mining of lithium, cobalt, and nickel, energy-intensive processing, and the lack of efficient end-of-life recycling.

- Strain on the Electricity grid: EV adoption will experience a significant rise in electricity demand, which is likely to overburden more electricity grid infrastructure and necessitate substantial investing in generation and distribution capacity unless charging is done intelligently.

3. Types of Electric Vehicles

There are multiple different architectures of electric vehicles, each having its own different characteristics, benefits, and uses. These various types must be understood in order to determine their appropriateness to the different applications and market segments.

3.1 Battery Electric Vehicles (BEVs)

Pure electric vehicles or all-electric vehicles, also referred to as battery electric vehicles, run on nothing but electrical power, which is stored in battery packs mounted on the car. BEVs have no internal combustion engine and have zero tailpipe emission.

Battery Electric Vehicles (BEVs) run solely on the electrical energy in the form of batteries installed in the car, and all of them rely on the size of the battery pack to drive range. BEVs normally have a range of between 60 and 400 kilometers on a charge and the state of the art products have been able to reach more than 500 kilometers. These cars have built-in generative braking systems, which retrieve the kinetic energy during deceleration hence enhancing the overall energy efficiency. The charge time is different according to the charging mode and AC Level 2 charging mode takes around 4 -8 hours to fully charge the battery where as DC fast charging can be charged to around 80 percent in 30 minutes. BEVs have zero direct tailpipe emissions when operating and their operating costs and maintenance are less complex than conventional vehicles. The examples of modern BEVs are Tesla Model S (with a range of more than 600 kilometers), Nissan Leaf, Chevrolet Bolt, and many models by traditional and new manufacturers entering the market. The BEV architecture is the most sustainable example of an electric vehicle and is viewed as the final aim of sustainable transportation, especially with renewable electricity being used.

3.2 Hybrid Electric Vehicles (HEVs)

Hybrid Electric Vehicles are vehicles with an electric motor and a battery system with a built in internal combustion engine in which they can be powered by either an internal combustion engine or an electric motor and battery system. HEVs were designed to overcome the range constraints of the early BEV but offer better fuel efficiency and fewer emissions than the traditional ICE cars.

The inner combustion engine is not directly coupled to the wheels in series hybrids (sometimes known as range extenders). Rather, the ICE actually powers the electric generator to charge the battery and drives the electric motor which, in turn, solely propels the wheels. This design enables the ICE to work with the maximum efficiency speed irrespective of the vehicle speed.

In parallel hybrids, the ICE and the electric motor are both directly and physically linked to the transmission and can act independently or even in simultaneity in order to drive the wheels. The main power source is the ICE with the electric motor acting as the supplementary power source in cases of acceleration and during low speed operation, the electric motor can operate separately.

3.3 Plug-in Hybrid Electric Vehicles (PHEVs)

Plug-in Hybrid Electric Vehicles also build on the concept of hybrids further by adding bigger battery packs capable of being charged outside the car. PHEVs are generally provided with a range of 30-80 kilometers of all-electric range, after which the ICE kicks in to provide a total range that is similar to that of standard vehicles.

PHEVs are a transition technology, and they deal with range anxiety with the ability to operate a significant portion of the time on electricity, particularly in daily commuting. They provide flexibility to users who require long-range occasionally and can meet most of daily commuter requirements using electricity.

Table 2: Comparison of representative PHEV models showing electric-only and total driving ranges

Vehicle Model	Electric Range	Total Range	Price (USD)
BMW i3 REX	160 km	300+ km	48,950
GM Chevy Volt	60 km	560 km	36,895
Ford C-Max Energy	34 km	591 km	36,999

3.4 Fuel Cell Electric Vehicles (FCEVs)

Fuel Cell Electric Vehicles refer to vehicles that utilize hydrogen fuel cells to produce electricity in cars that in turn powers electric motors. Contrary to the BEVs, which can store electricity in batteries, the FCEVs can store gas hydrogen in high-pressure tanks and generate electricity under the effect of the electrochemical interaction between hydrogen and oxygen of the ambient air.

FCEV is also a potentially significant long-term solution especially in heavy-duty transport, long-haul trucking, and where rapid refueling is necessary. Nevertheless, there are still serious issues, such as the process of hydrogen generation (the largest share of hydrogen is generated on the basis of fossil fuels), distribution networks, the safety of storage, and the price of fuel cells.

4. Battery Technologies for Electric Vehicles

The most important aspect that defines the performance of EV, its cost, and marketability is battery technology. This part looks at the existing and new battery technologies, both the lithium-ion and new generation ones.

4.1 Lithium-Ion Batteries

Since the beginning of the 2000s, lithium-ion batteries (LIB) have taken over the EV market and can be considered as the default choice of electric vehicles in 2026, too. The fairly high power density, relatively acceptable cycle life, and a consistently dropping cost of them have made the present surge of EV adoption possible.

Lithium-ion batteries work, when lithium ions are transported between positive and negative electrodes by means of electrolyte. When the vehicle is put into action (turning the switch off), the lithium ions move off the negative electrode (anode) through the electrolyte to the positive electrode (cathode), and the electrons proceed through the external circuit so as to generate electrical current. In the charging process, this process is reversed.

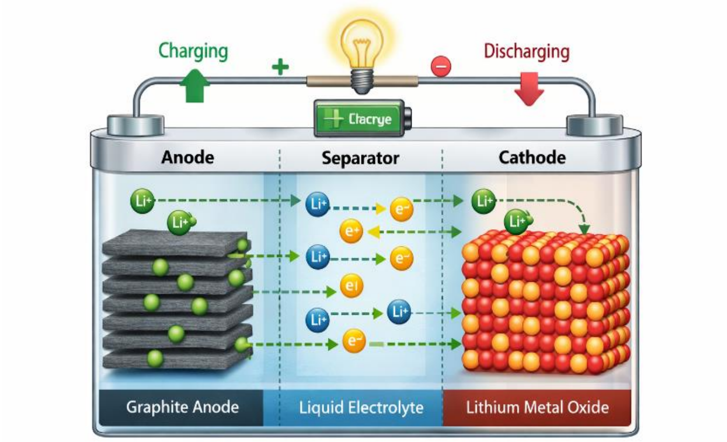

Fig. 1: Schematic diagram of lithium-ion battery operation showing ion movement during charge and discharge cycles, with graphite anode, lithium metal oxide cathode, and liquid electrolyte separator

4.2 Solid-State Batteries

One of the most likely future technologies is solid-state batteries which will be using solid materials in place of liquid. The underlying change has solutions to several drawbacks of traditional lithium-ion batteries and could potentially allow significant performance enhancement.

In solid state batteries, the electrolyte is not a liquid organic material but rather a solid polymers, glass or ceramic material. This allows the use of lithium metal anodes, with a much higher energy density than graphite anodes in the traditional LIBs.

Solid-state battery technology is expected to become commercially viable as of March 2026, with a number of companies publicly declaring plans to produce them:

- Toyota: By 2027-2028, focused on manufacturing solid-state battery EVs, with a range of 750-mile (1,200 km), and 10-minute charging [2] [8].
- Samsung SDI: Proven prototypes (800 km range and more than 1,000 charge cycles) were done by using silver-carbon composite anodes to avoid dendrite formation. Mass production is intended in 2027[8].
- QuantumScape: Making anode-free ceramic-separator-based solid-state lithium-metal batteries with less than 15-minute charge times to 80 percent capacity.
- Factorial Energy: The company would provide solid-state batteries to Stellantis, Mercedes-Benz, Hyundai, and Kia. Mercedes showed a modified EQS with a 750 miles (1,205 km) on one charge[12].
- Against this background, Nissan has been planning to introduce solid-state batteries into vehicles by the end of 2028, even in hybrid use.
- Honda: Solid-state technology: Honda is developing solid-state technology that is aimed at achieving 620-mile range, but the company is experiencing difficulty with the scaling of cell sizes.
- The technology is maturing and is soon to be commercialized as China released standards on solid-state EV batteries in 2026 [13].

4.3 Sodium-Ion Batteries

The use of sodium-ion batteries has become a potentially disruptive technology, which is less expensive compared to lithium-ion batteries, as it utilizes a more plentiful source of sodium, rather than a limited source of lithium. Na + batteries may have a lower energy density than that of a lithium-ion, but they are cheaper and safer in use in certain applications.

Sodium-ion batteries propagate on the same principles as the lithium-ion batteries, except that sodium ions are used in place of lithium ions. Cost and supply chain benefits include the fact that sodium is more accessible (sea water can be used as a source) and is spread across a broader geographical area.

According to the global EV battery technology market report, sodium-ion batteries are the new trend in the market motivated by low costs, safety, and availability of raw materials[1]. Although the cost of lithium-ion battery has decreased significantly to about 100/kWh in

2025[7], this makes it hard to be beaten by sodium-ion battery. However, when cost considerations are more important, e.g. in urban cars, two-wheelers, stationary storage, sodium-ion batteries have strong points.

4.4 Lithium-Sulfur Batteries

Another potential alternative is the lithium-sulfur (LiS) batteries, which have a theoretical higher energy density than regular lithium-ion batteries, and at comparatively lower cost. LiS batteries have lithium metal and sulfur-carbon composite cathode.

Lately LiS battery cycle life has been extended, and some of the prototypes have reached 1,000 cycles. NASA is investing in solid-state LiS batteries in space exploration; and Oxis Energy is preparing to be commercialized. The Zephyr-6 unmanned aircraft was able to fly three days on LiS batteries with the combination of solar panels, which proved that the technology can be used in weight sensitive applications.

In the case of automotive, LiS batteries would allow much longer ranges to be achieved with lighter battery packs. Cycle life and longevity however need to be improved significantly before LiS batteries can compete with those of lithium-ion in mainstream EVs.

4.5 Aluminum-Ion Batteries

Batteries made of aluminum metal include anodes made of aluminum ions, which may prove to be more advantageous in terms of cost, safety, and sustainability. Aluminum is found in the most quantity in the crust of the earth and thus it is a good alternative to lithium.

The Stanford University researchers made a breakthrough as they developed aluminum-ion batteries with the graphite cathode that can be charged within a matter of one minute and that can be used over 7,500 times without the decrease of the performance. No other institutions have stopped research into aluminum-ion technology, with Oak Ridge National Laboratory doing research on it. Aluminum-ion batteries are still at the early stage of development, but might provide ultra-fast charging and enhanced safety of EVs in the future.

4.6 Metal-Air Batteries

Metal-air batteries are batteries that have a pure metal anode (usually lithium, aluminum, zinc or sodium) and ambient air cathode. Oxygen in the atmosphere was used as the cathode material, which allows metal-air batteries to reach very high theoretical energy densities of the order of gasoline.

Metal-air batteries in general are still in very early development phases, and useful, rechargeable metal-air batteries to power EVs are probably decades away. To ensure that contamination is not a problem, most experimental systems utilize pure oxygen instead of ambient air, and to store the onboard oxygen in this case, it would have to store it onboard, cancelling the weight benefits.

4.7 Lithium Iron Phosphate (LFP) Batteries

Although technically it is a set of lithium-ion technology, LFP batteries should be mentioned separately as they capture an increasing market share in the year 2026. LFP batteries incorporate lithium iron phosphate (LiFePO 4) cathodes rather than nickel-manganese- cobalt or lithium cobalt oxide cathodes.

The LFP batteries have made considerable market share especially in China where they drive most BYD and Tesla cars. Cost benefits and better safety have made them more appealing to standard-range EVs, but more energetically-dense NMC batteries are still popular on long-range high-end automobiles.

5. Charging Infrastructure and Standards

The emergence of effective and convenient charging systems is needed in order to face the faster adoption of electric vehicles (EVs). There are, broadly speaking, three levels of EV charging technologies depending on voltage, current, and the speed of charge. AC Level 1 charges are provided on 120 V household receptacles with a current of between 1216 A, providing between 2 and 5 miles per hour of driving range. Though it does not require any further installation, it has a slow charge rate hence full charging takes 20-40 hours which is only applicable in case of emergency or low distance. AC Level 2 charging has a power supply of 240 V and a typical output of 37kW to 7kW to enable a 10-20 mile range per hour and in 4-8 hours to charge completely. It finds a wide application as a residential, workplace, and public charging. DC Fast Charging (DCFC) is the quickest charging with high power stations (50350 kW), which allows charging to 1080% in approximately 2040 minutes, and therefore, when used in long-distance travel, it requires more infrastructure but lowers the cost.

Table 3: Comparison of EV charging levels showing voltage, power, and practical charging rates

Charging Type	Voltage Input	Charging Rate	Range per Hour
AC Level 1	120V AC	1.4-1.9 kW	2-5 miles
AC Level 2	240V AC	3-19.2 kW	10-20 miles
DC Fast Charging	480V+ DC	50-350 kW	150-1,000 miles

The latest technology in charging electric vehicles is ultra-fast charging which provides very high-power levels to shorten charging time dramatically. Current solutions like Tesla Supercharger V3 (250 kW), Tesla Supercharger V4 (up to 350 kW), Electrify America, and IONITY networks offer the charge capacity of up to 350 kW. The particular technologies can increase the driving range of compatible vehicles by almost 200 miles in about 15 minutes. Very few existing EVs, however, charge faster than 150 kW, and at that power level, the battery should be thermally managed. There are a number of charging standards worldwide, such as SAE J1772, Type 2, CCS, CHAdeMO, Tesla NACS and GB/T, but there has been slow industry progress in interoperability and standardisation.

The electric vehicle charging infrastructure has developed at an impressive rate over the past few years, as more people switch to EVs and the government tends to support the development of this problem. Charging stations of electric cars have been proliferated in some areas. In the United States, the Alternative Fuels Data Center has noted that there is a steep rise in the years 2024, as a total of 4.6% and 6.3% of the total charging ports are on the rise in Q1 and Q2 respectively. The number of public charging infrastructure increased compared to the individual ones, and DC fast-charging ports increased by over 7 percent every quarter. The Northeast area had the best growth and California has remained on the forefront with respect to public charging. The government schemes in India like FAME Phase II scheme are promoting a massive installation of charging points in the city, highways, and expressways.

6. Market Trends and Future Outlook of Electric Vehicles

The industry of electric vehicles (EV) is changing rapidly because of the improvement in battery technology, the governmental policies that favor it, and the growing environmental awareness. The EV battery technology market is estimated to be nearly $98.65 billion in the year 2025 and will reach 156.95 billion in 2031 with a compound annual growth rate (CAGR) of approximately 8.05. The increase is influenced by growing the use of EVs, governmental support, reduced battery prices, and the ongoing building of the charging network. Today, the Asian companies are the leaders in battery market, and the companies like BYD, CATL, LG Energy Solution, Samsung SDI, and Panasonic are the major producers on the world market.

EVs are also being influenced by technological advances with regard to the future. Solid-state batteries will be commercialized sometime in 202728, with a higher energy density, quicker charge, and enhanced safety. Also, sodium-ion batteries are becoming an alternative that is cost-effective especially in the case of urban vehicles and stationary storage systems. Other alternative chemistries like the lithium-sulfur and metal-air batteries are also being developed in the industry.

Although all these are true, there are still a number of challenges such as battery material supply chain shortages, grid capacity issues, range and cost concerns by consumers among others. Solving these problems is the key to the global adoption of EVs.

7. Results and Discussions

Electric cars are a paradigm shift in the transportation technology with impressive environmental, economic and performance benefits over the traditional vehicles powered by internal combustion engines. This overall analysis has discussed the present and future of EV technologies, including battery chemistries and charging infrastructure, market trends and policy drivers.

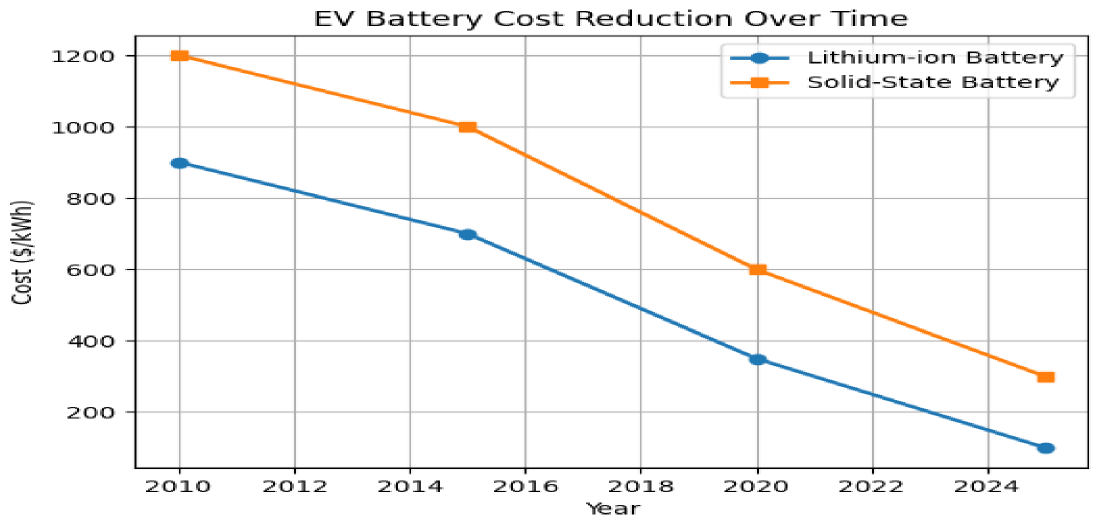

Fig. 2:

Fig. 2 represents the trend in costs of electric vehicle (EV) batteries as the technologies of lithium-ion and solid-state battery became more affordable as the years progressed. The horizontal axis is the year 2010-2025 whereas the vertical axis is the cost of the battery in terms of dollars per kilowatt-hour (/kWh). Lithium-ion battery price also reduces drastically, by 2025 it will be reduced to about 100/kWh compared to the year 2010, which was about 900/ kWh. This steep decree indicates the enhancement of the manufacturing efficiency, technological advancement, economies of scale, and global production. On the same note, solid-state batteries are increasingly becoming cheaper by an average of 1200 to almost 300/ kWh between 2010 and 2025 respectively. Solid-state batteries are more expensive than lithium-ion batteries, but their cost trend shows that it is steadily making progress towards commercialization. The general trend of decreasing battery costs is important in enhancing the affordability of electric vehicles. Reduced battery cost decreases the total cost of the vehicle and thus the EV adoption is faster than ever and it aids in the shift to sustainable transportation systems across the globe.

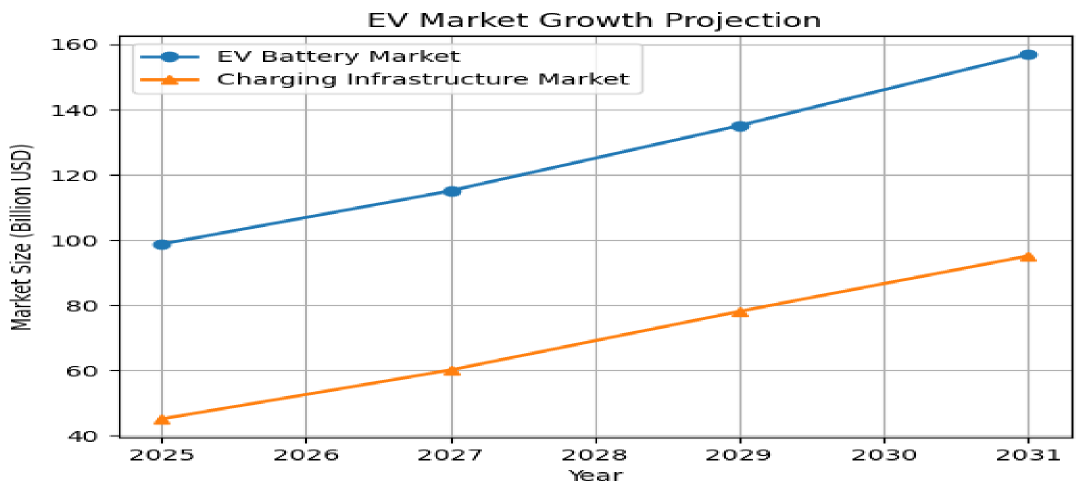

Fig. 3:

Fig. 3 estimates the market size of EV battery technology and charging infrastructure between 2025 and 2031. The EV battery market line begins at $98.65 billion in 2025, increases to approximately 115billion in 2027, 135billion in 2029, and 156.95billion in 2031 with a constant CAGR growth of approximately 8. The market of charging infrastructure will start at a lower level of 45 billion dollars in 2025, which then grows to 60, 78, and 95 billion dollars respectively, which points to a faster relative growth because of the necessity of infrastructures. Combined, they emphasize how EV adoption and battery cost reductions motivate the parallel sector advancement, which makes EVs more profitable in the global context.

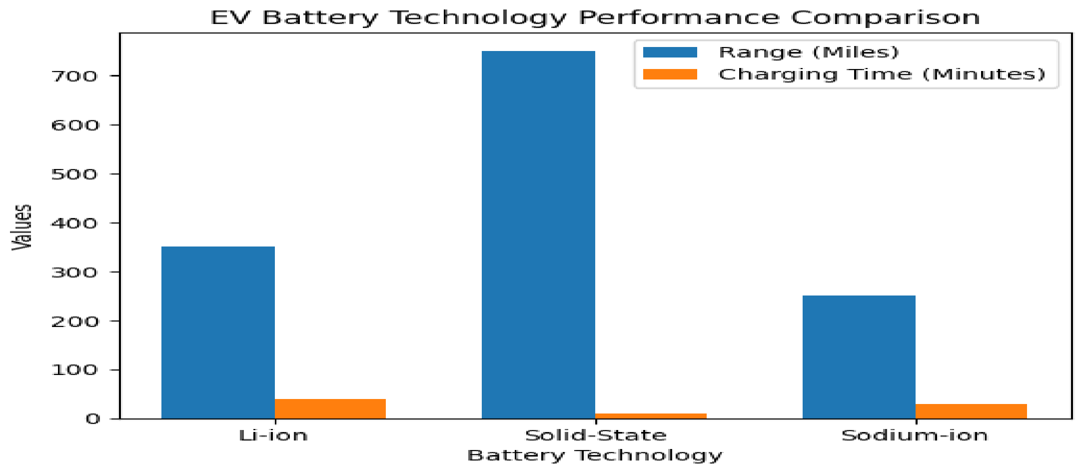

Fig. 4:

Fig. 4 compares three battery technologies; Li-ion, Solid-State and Sodium-ion based on range (miles) and charging-time (minutes). Li-ion demonstrates range of 350 miles under 40 minutes charge (blue bars left); Solid-State demonstrates 750 miles under 10 minutes charge (blue bars center); Sodium-ion demonstrates only 250 miles under 30 minutes charge (blue bars right). The technologies are labeled on the X-axis, scale of values on Y-axis, and a legend is used to differentiate metrics. The image highlights that Solid-State is better suited to long-range EVs, which solves major challenges, such as range anxiety, whereas Sodium-ion is cost-effective in short-range applications, which contributes to the wide market adoption.

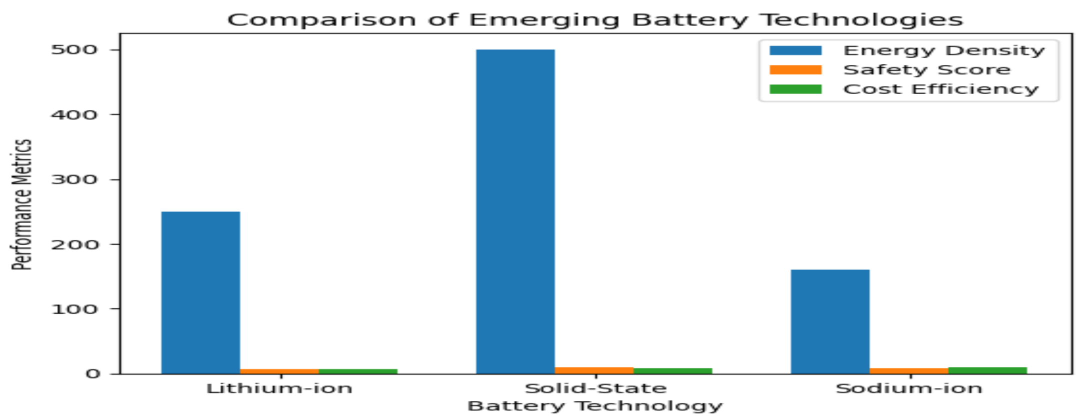

Fig. 5

Fig. 5 compares Lithium-ion, Solid-State and Sodium-ion in terms of energy density, safety score (1-10) and cost efficiency (1-10). Lithium-ion has a score of 250 (density of energy, left bars), safety of 7 (middle), cost 6 (right); Solid-State with highest density of 500, safety of 9, and cost efficiency 8; Sodium-Ion has the lowest density of 160, safety of 8 and cost efficiency of 9. Similar technologies can be immediately compared by side-by-side bars. It shows that Solid-State is a balanced high-performance premium EV manufacturer, but Sodium-ion is focused on affordability and safety in the mass-market market.

8. Concluding Remarks

EVs no longer belong to niche technology as they are currently mainstream transportation options, and their growth is expected to continue exponentially in the next several decades. The development of batteries, the growing charging networks, the favorable government policies, and the growth of the consumer acceptance are all colliding to drive this change faster. A potential inflection point that would be achieved by 2027-2028 is the successful commercialization of solid-state batteries, which contributes to the most significant limitations of existing EVs and could trigger a rapid change in its adoption. At the same time, other chemistries such as sodium-ion batteries are widening the market opportunity through lowering the entry-level vehicle prices. The problems persist, especially in areas of charging infrastructures coverage, battery materials chains and price parity in all the types of vehicles. The future of sustainable transportation systems is, nevertheless, evident: electric vehicles will be at the core of the energy systems, architectural layouts, and future environmental sustainability as it will redefine not only the automotive industry, but also energy systems, urban planning, and sustainability. Electric mobility is one of the most important technology and social shifts of the 21st century. To find out the rate at which this transition will take place and how well it will respond to the challenges posed by climate change, air quality and energy security to the global society, continued innovation, investment, and policy support will dictate the kind and speed with which the transition will be achieved.

References

[1] Finance Yahoo. (2026, February 17). Electric Vehicle Battery Technology Research Report 2026: A $156.95 Billion Market by 2031 from $98.65 Billion in 2025 with BYD, CATL, LG Energy, Panasonic, and Samsung Leading. https://finance.yahoo.com/news/electric-vehicle-battery-technology-research-090800884.html

[2] Monolith AI. (2026, March 5). Solid-State Battery News: Samsung & Toyota. https://www.monolithai.com/blog/solid-state-battery-news

[3] U.S. Environmental Protection Agency. (2019). Sources of Greenhouse Gas Emissions. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

[4] U.S. Department of Energy. All-electric cars. https://www.fueleconomy.gov/feg/evtech.shtml

[5] Yong, J.Y., Ramachandaramurthy, V.K., Tan, K.M., & Mithulananthan, N. (2015). A review on the state-of-the-art technologies of electric vehicle, its impacts and prospects. *Renewable and Sustainable Energy Reviews*, 49, 365-385.

[6] Frieske, B., Kloetzke, M., & Mauser, F. (2013). Trends in vehicle concept and key technology development for hybrid and battery electric vehicles. *World Electric Vehicle Symposium and Exhibition*, EVS 27.

[7] MIT Technology Review. (2026, February 2). What's next for EV batteries in 2026. https://www.technologyreview.com/2026/02/02/1132042/whats-next-for-ev-batteries-in-2026/

[8] CBT News. (2025, November 13). Solid-state batteries set to redefine EV performance, safety. https://www.cbtnews.com/solid-state-batteries-set-to-redefine-ev-performance-safety/

[9] Finance Yahoo. (2026, February 17). Electric Vehicle Battery Technology Research Report 2026: Sodium-Ion Batteries Gaining Traction. https://finance.yahoo.com/news/electric-vehicle-battery-technology-research-090800884.html

[10] Albatayneh, A., Assaf, M.N., Alterman, D., & Jaradat, M. (2020). Comparison of the Overall Energy Efficiency for Internal Combustion Engine Vehicles and Electric Vehicles. *Environmental and Climate Technologies*, 24, 669-680.

[11] Habib, S., Kamran, M., & Rashid, U. (2015). Impact analysis of vehicle-to-grid technology and charging strategies of electric vehicles on distribution networks: A review. *Journal of Power Sources*, 277, 205-214.

[12] Electrek. (2026, February 10). A solid-state EV battery standard will be released in China in 2026. https://electrek.co/2026/02/11/solid-state-ev-battery-standard-china-2026/

[13] Electrek. (2026, February 10). A solid-state EV battery standard will be released in China in 2026. https://electrek.co/2026/02/11/solid-state-ev-battery-standard-china-2026/