TECHNICAL AND ENVIRONMENTAL ANALYSIS OF THE ADVANTAGES AND DISADVANTAGES OF ELECTRIC VEHICLES

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Abstract: The rapid development of electric vehicles has become one of the most important technological transformations in the modern automotive industry. The transition from internal combustion engine vehicles to electric vehicles is being driven by the need to reduce greenhouse gas emissions, improve urban air quality, decrease dependence on petroleum fuels, and introduce more efficient transport technologies. This article presents a technical and environmental analysis of the advantages and disadvantages of electric vehicles. The study examines the main structural differences between electric vehicles and conventional vehicles, including the role of the traction battery, electric motor, power electronics, regenerative braking system, thermal management system, and charging equipment. The environmental advantages of electric vehicles are analyzed from the viewpoint of zero tailpipe emissions, higher energy efficiency, reduced urban noise, and the possibility of integrating transport with renewable energy systems. At the same time, the article discusses the limitations and disadvantages of electric vehicles, such as battery production emissions, dependence on the electricity generation mix, charging infrastructure requirements, driving range limitations, battery degradation, cold-weather performance reduction, recycling challenges, and critical mineral supply risks. The results show that electric vehicles have clear environmental and technical advantages over conventional internal combustion engine vehicles during operation, but their overall sustainability depends on the energy source used for charging, battery production technology, responsible raw material extraction, and end-of-life battery management. The article concludes that electric vehicles should be evaluated not only as individual vehicles but also as part of a wider transport-energy system that includes electricity generation, charging infrastructure, service networks, recycling systems, and state policy mechanisms.
Keywords: electric vehicle, internal combustion engine, battery, energy efficiency, emissions, charging infrastructure, life-cycle assessment, regenerative braking, sustainable transport.

1. Introduction

The automotive industry has entered a period of deep technological transformation. For more than a century, internal combustion engine vehicles were the dominant form of road transport. Their development was based on liquid fossil fuels, mechanical transmission systems, exhaust systems, and a large number of moving components. This technology enabled the rapid expansion of personal mobility, goods transportation, and industrial development. However, the environmental and energy consequences of this transport model have become increasingly serious. Road vehicles contribute to greenhouse gas emissions, urban air pollution, noise pollution, and dependence on petroleum resources. In large cities, the concentration of vehicles with internal combustion engines leads to the accumulation of nitrogen oxides, carbon monoxide, particulate matter, unburned hydrocarbons, and carbon dioxide. These emissions affect public health, climate change, and the quality of life in urban areas.

Electric vehicles are considered one of the most promising alternatives to conventional vehicles. An electric vehicle uses one or more electric motors for propulsion and stores energy in a rechargeable battery pack. Unlike an internal combustion engine vehicle, a battery electric vehicle has no tailpipe emissions during operation because it does not burn gasoline or diesel fuel inside the vehicle. This feature gives electric vehicles an important advantage in cities where air quality is a major concern. In addition, electric motors are highly efficient and can convert a large portion of electrical energy into mechanical motion. This makes electric vehicles more energy-efficient than vehicles powered by internal combustion engines, in which a significant part of fuel energy is lost as heat through the exhaust and cooling system.

The global electric vehicle market has grown rapidly during the last decade. Governments, automotive manufacturers, energy companies, and consumers are increasingly paying attention to electrified transport. Many countries have introduced incentives for electric vehicles, invested in charging infrastructure, and adopted policies aimed at reducing emissions from road transport. At the same time, automotive companies are expanding their electric model lines, improving battery technologies, and developing new platforms designed specifically for electric propulsion. This process shows that electric vehicles are not a short-term trend but a strategic direction in the future of mobility.

However, the transition to electric vehicles is not simple. Electric vehicles have many advantages, but they also have technical, economic, environmental, and infrastructural limitations. Their environmental performance depends not only on the absence of tailpipe emissions but also on how electricity is generated, how batteries are produced, how raw materials are extracted, and how used batteries are recycled. A vehicle charged with electricity produced from renewable energy has a much lower environmental impact than a vehicle charged with electricity produced mainly from coal. Similarly, the production of lithium-ion batteries requires energy and raw materials, and this stage can create significant environmental impacts before the vehicle even begins operation.

For this reason, a balanced scientific analysis is necessary. Electric vehicles should not be described only as completely clean or completely problematic. They must be evaluated through a comprehensive approach that includes technical structure, energy efficiency, operating conditions, environmental impact, service requirements, charging infrastructure, battery life, and life-cycle emissions. Such an analysis is especially important for countries where electric mobility is still developing and where decisions about infrastructure, education, service systems, and policy support must be made carefully.

The purpose of this article is to analyze the main advantages and disadvantages of electric vehicles from technical and environmental perspectives. The study aims to identify the strengths of electric propulsion technology, explain the environmental benefits of electric vehicles, and examine the practical limitations that must be solved for wider adoption. The article also discusses the relevance of electric vehicles for modern automotive engineering education and for the development of sustainable transport systems.

2. Literature Review

The scientific literature on electric vehicles covers several major directions. The first direction is related to energy efficiency and vehicle technology. Studies in this area compare electric motors and internal combustion engines in terms of energy conversion, drivetrain design, power electronics, and control systems. Electric motors are widely recognized for their high efficiency, fast torque response, compact structure, and ability to operate with regenerative braking. Unlike internal combustion engines, electric motors do not require fuel injection systems, exhaust systems, spark plugs, engine oil circulation, or complex multi-speed transmission in the same form as conventional vehicles. These features make electric vehicles simpler in several mechanical aspects, although they introduce new complexity in battery management, high-voltage safety, software control, and thermal regulation.

The second direction concerns environmental assessment. Many studies evaluate electric vehicles by using life-cycle assessment methods. A life-cycle assessment considers not only vehicle operation but also raw material extraction, vehicle production, battery manufacturing, electricity generation, maintenance, and end-of-life treatment. Such studies often show that electric vehicles produce higher emissions during manufacturing, mainly because of battery production, but lower emissions during the use phase. Over the full life cycle, electric vehicles usually provide lower greenhouse gas emissions than comparable gasoline or diesel vehicles, especially when the electricity mix includes a significant share of low-carbon energy sources. The environmental advantage of electric vehicles becomes stronger as the electricity grid becomes cleaner.

The third direction focuses on batteries. The lithium-ion battery is the most important and most expensive component of a modern electric vehicle. Battery research includes energy density, charging speed, safety, degradation, thermal management, recycling, and material supply. Battery performance directly affects vehicle range, cost, charging time, weight, safety, and consumer acceptance. Improvements in battery technology have significantly increased the driving range of electric vehicles and reduced battery cost over time. Nevertheless, battery production remains one of the most critical environmental and economic issues in electric mobility. Mining and processing of lithium, cobalt, nickel, graphite, and other materials can create ecological and social challenges if not managed responsibly.

The fourth direction is related to charging infrastructure. Electric vehicles require access to charging points at home, at workplaces, in public parking areas, and along highways. The convenience of charging is one of the key factors that determines consumer confidence. Slow charging is suitable for overnight charging, while fast charging is needed for long-distance travel and commercial use. However, fast charging requires high-power equipment, grid capacity, appropriate safety systems, and investment. In regions where charging infrastructure is insufficient, electric vehicle adoption may be limited even if vehicles themselves are technologically advanced.

The fifth direction examines the economic and social effects of electric vehicles. Electric vehicles can reduce fuel costs and maintenance expenses, but they often have a higher initial purchase price due to the battery. Governments may support adoption through tax incentives, import benefits, charging infrastructure programs, and emission regulations. For consumers, the economic attractiveness of an electric vehicle depends on electricity prices, fuel prices, driving distance, maintenance costs, battery warranty, resale value, and availability of charging. For society, the benefits include reduced local pollution, lower oil dependence, and potential integration with renewable energy systems.

The existing literature shows that electric vehicles have strong potential but must be analyzed in a systemic way. It is not enough to compare only fuel and electricity costs or only tailpipe emissions. A comprehensive approach is required to understand both advantages and disadvantages. This article follows that approach by combining technical and environmental analysis.

3. Research Methodology

The research uses an analytical and comparative method. The main object of the study is the battery electric vehicle, while the conventional internal combustion engine vehicle is used as the main comparison category. The comparison is carried out according to technical, operational, environmental, and infrastructural criteria. The technical criteria include drivetrain structure, energy efficiency, traction characteristics, maintenance requirements, braking system, and battery performance. The environmental criteria include tailpipe emissions, life-cycle emissions, air pollution, noise, electricity source, battery production, and recycling. The operational criteria include driving range, charging time, cold-weather performance, battery degradation, and user convenience.

The article is based on secondary data from international energy and environmental organizations, automotive technology publications, life-cycle assessment studies, and electric mobility reports. The analysis does not focus on one specific electric vehicle model but considers electric vehicles as a general vehicle category. This allows the results to be used for educational and analytical purposes in a diploma project related to the advantages and disadvantages of electric vehicles.

The research method includes four main stages. In the first stage, the main technical differences between electric vehicles and conventional vehicles are identified. In the second stage, the advantages of electric vehicles are grouped into environmental, technical, and operational categories. In the third stage, the disadvantages and limitations are analyzed according to battery, infrastructure, climate, cost, and recycling issues. In the fourth stage, the results are discussed from the perspective of sustainable transport development and automotive engineering.

4. Technical Structure of Electric Vehicles

A battery electric vehicle consists of several key systems that differ significantly from the systems of an internal combustion engine vehicle. The most important component is the traction battery pack. The battery stores electrical energy and supplies power to the electric motor through power electronics. Modern electric vehicles usually use lithium-ion battery technology because it provides relatively high energy density, acceptable weight, long cycle life, and good power performance. The battery pack includes many cells connected in modules, cooling channels, sensors, safety devices, and a battery management system. The battery management system monitors voltage, current, temperature, state of charge, state of health, and cell balance. It is essential for safety, performance, and battery life.

The electric motor converts electrical energy into mechanical torque. Electric motors provide instant torque, which improves acceleration and driving response. Many electric vehicles use permanent magnet synchronous motors, induction motors, or other motor types depending on design requirements. The electric motor is controlled by an inverter, which converts direct current from the battery into alternating current suitable for motor operation. The inverter and motor control system regulate torque, speed, power, and energy recovery.

Another important component is the charging system. Electric vehicles may use alternating current charging through an onboard charger or direct current fast charging through external charging equipment. The onboard charger converts AC electricity from the grid into DC electricity for the battery. In DC fast charging, the charger is outside the vehicle and supplies DC power directly to the battery through controlled communication between the vehicle and charging station. Charging speed depends on battery capacity, charger power, battery temperature, state of charge, and vehicle charging limits.

Electric vehicles also require a thermal management system. The battery, motor, inverter, and cabin must be kept within safe and efficient temperature ranges. Battery performance is sensitive to temperature. If the battery becomes too cold, chemical reactions slow down and available power may decrease. If the battery becomes too hot, degradation and safety risks may increase. Therefore, cooling and heating systems are necessary, especially in regions with hot summers or cold winters.

The braking system of an electric vehicle includes regenerative braking. During deceleration, the electric motor can operate as a generator and convert part of the vehicle's kinetic energy back into electrical energy. This energy is returned to the battery instead of being lost as heat in the brake discs. Regenerative braking improves energy efficiency and reduces mechanical brake wear. However, the amount of recovered energy depends on driving conditions, battery state of charge, speed, and control strategy.

Compared with internal combustion engine vehicles, electric vehicles have fewer mechanical systems related to fuel combustion. They do not require a fuel tank, exhaust pipe, catalytic converter, engine oil system, spark plugs, or traditional engine cooling in the same way. However, this does not mean that electric vehicles are technically simple in every respect. They require advanced software, high-voltage safety systems, battery diagnostics, charging communication, and thermal control. Therefore, electric mobility changes the focus of automotive engineering from mechanical combustion systems to electrical, electronic, and software-controlled systems.

5. Environmental Advantages of Electric Vehicles

The most visible environmental advantage of an electric vehicle is the absence of tailpipe emissions. During driving, a battery electric vehicle does not emit carbon dioxide, nitrogen oxides, carbon monoxide, hydrocarbons, or particulate matter from fuel combustion. This is especially important in cities because road transport emissions directly affect the air that people breathe. In dense urban areas, replacing internal combustion engine vehicles with electric vehicles can reduce local air pollution and improve public health conditions.

The reduction of local pollutants is different from the reduction of greenhouse gas emissions. Local pollutants affect human health near roads, while greenhouse gases contribute to climate change globally. Electric vehicles help reduce both types of environmental impact, but in different ways. Local emissions are reduced immediately because there is no exhaust pipe. Greenhouse gas reductions depend on electricity generation. If electricity comes from renewable energy, nuclear energy, or other low-carbon sources, the climate benefit is high. If electricity comes from coal, the benefit is smaller but may still exist because electric drivetrains are more efficient than internal combustion drivetrains.

Another environmental advantage is higher energy efficiency. Internal combustion engines lose a large part of fuel energy as heat. Electric motors have much higher efficiency and can use energy more effectively. In urban driving, where frequent acceleration and braking occur, regenerative braking further improves efficiency. This means that electric vehicles can travel the same distance with less primary energy, especially when electricity is produced efficiently.

Electric vehicles also reduce noise pollution. Internal combustion engine vehicles generate noise from engine combustion, exhaust flow, vibration, and mechanical components. Electric motors are quieter, especially at low speeds. In urban areas, lower vehicle noise can improve comfort, reduce stress, and contribute to a better living environment. At higher speeds, tire and aerodynamic noise become more important, but in city driving electric vehicles are usually quieter than conventional vehicles.

Electric vehicles create opportunities for integration with renewable energy. If charging is coordinated with solar, wind, or other renewable electricity generation, transport emissions can be reduced significantly. In the future, smart charging and vehicle-to-grid technologies may allow electric vehicles to support the electrical grid by charging when electricity demand is low and renewable energy supply is high. This could transform electric vehicles from simple energy consumers into flexible elements of the energy system.

6. Technical Advantages of Electric Vehicles

Electric vehicles have several technical advantages that make them attractive for modern transport. One of the most important is the instant torque characteristic of electric motors. Unlike internal combustion engines, which need to reach a certain engine speed to produce maximum torque, electric motors can deliver strong torque from very low speeds. This improves acceleration and makes the vehicle responsive in city traffic. It also simplifies transmission design because many electric vehicles can operate effectively with a single-speed reduction gear.

Another advantage is smooth operation. Electric motors do not have combustion cycles, pistons, valves, and crankshaft vibration in the same form as internal combustion engines. As a result, electric vehicles provide smoother acceleration and lower vibration levels. This improves driving comfort and reduces mechanical stress on some components.

Maintenance requirements are generally lower. All-electric vehicles have fewer moving parts and fewer fluids to change. There is no engine oil, no oil filter, no exhaust system, no timing belt, and no fuel injection system. This can reduce routine maintenance time and cost. The braking system may also last longer because regenerative braking reduces the use of friction brakes. For fleet operators, lower maintenance can be a significant advantage because vehicles spend less time out of service.

Electric vehicles also offer better compatibility with digital control systems. Because propulsion is controlled electronically, electric vehicles can be integrated easily with advanced driver assistance systems, energy management algorithms, traction control, and software updates. The electric drivetrain responds quickly to control signals, which improves vehicle stability and performance control.

Packaging flexibility is another technical advantage. An electric vehicle platform can place the battery pack under the floor, lowering the center of gravity and improving stability. Without a large engine and transmission tunnel, designers can create more interior space and new body layouts. This is why many modern electric vehicles have flat floors, compact front compartments, and efficient cabin design.

7. Environmental and Technical Disadvantages

Despite the advantages, electric vehicles also have important disadvantages. The first major issue is battery production. Lithium-ion battery manufacturing requires energy, water, and raw materials such as lithium, nickel, cobalt, manganese, and graphite. Mining and processing these materials can create environmental damage, land disturbance, water use, and social concerns. If battery production uses electricity from high-carbon sources, the manufacturing emissions of an electric vehicle can be higher than those of a conventional vehicle.

The second issue is dependence on the electricity mix. Electric vehicles do not emit pollutants from the tailpipe, but electricity generation may produce emissions elsewhere. If the grid is based mainly on fossil fuels, part of the environmental burden is shifted from the road to the power plant. Therefore, the environmental benefit of electric vehicles is strongest when the electricity grid becomes cleaner. This means that transport electrification and energy sector decarbonization should be developed together.

The third issue is driving range. Although modern electric vehicles have improved significantly, range anxiety remains a concern for many users. The real driving range depends on battery capacity, driving speed, road conditions, temperature, air conditioning or heating use, vehicle load, and driving style. Highway driving at high speed can reduce range because aerodynamic drag increases strongly with speed. Cold weather can also reduce range because the battery works less efficiently and cabin heating consumes energy.

Charging time is another limitation. Refueling a gasoline or diesel vehicle takes only a few minutes, while charging an electric vehicle may take from several hours to less than an hour depending on charger type and battery capacity. Fast charging reduces waiting time, but it requires expensive infrastructure and can place stress on the electrical grid. Frequent fast charging may also affect battery degradation if thermal management is not adequate.

Battery degradation is a long-term technical concern. Over time, lithium-ion batteries lose capacity due to chemical and physical processes inside cells. Capacity loss reduces driving range and may affect vehicle value. Degradation depends on temperature, charging speed, depth of discharge, driving patterns, and battery management strategy. Manufacturers provide battery warranties, but replacement can be expensive after warranty expiration.

Recycling is also a challenge. Used electric vehicle batteries contain valuable materials, but recycling them requires specialized technology, collection systems, safety procedures, and economic viability. If battery recycling is not developed, waste management problems may appear in the future as the number of old electric vehicles increases. Effective recycling can reduce demand for new raw materials and decrease environmental impacts.

8. Discussion

The analysis shows that electric vehicles provide strong technical and environmental advantages, but they are not an isolated solution. Their success depends on the development of a complete ecosystem. This ecosystem includes clean electricity generation, reliable charging infrastructure, battery manufacturing standards, service personnel training, battery recycling, and consumer education.

From a technical point of view, electric vehicles are highly suitable for urban transport. Their efficiency is high in stop-and-go driving, regenerative braking works effectively, and zero tailpipe emissions improve air quality. Their quiet operation is also beneficial in city environments. For daily commuting, taxis, delivery vehicles, public fleets, and short-distance transport, electric vehicles can be especially effective.

For long-distance travel, the situation is more complex. Electric vehicles require planning around charging points, and charging time is longer than refueling. However, as fast charging networks expand and battery energy density improves, this disadvantage is gradually decreasing. The development of charging corridors along highways is important for wider acceptance.

From an environmental viewpoint, the largest advantage of electric vehicles appears during operation. However, the battery production stage must not be ignored. The higher manufacturing footprint of electric vehicles can be compensated during use, especially if electricity is low-carbon. This means that the environmental value of an electric vehicle increases over its lifetime. Vehicles used more frequently may recover their manufacturing emissions earlier because they replace more gasoline or diesel consumption.

For developing countries, including countries where the electric vehicle market is still emerging, the key issue is preparation. It is not enough to import electric vehicles. Charging infrastructure, technical service centers, high-voltage safety training, spare parts supply, emergency response procedures, and battery recycling regulations are also necessary. Universities and technical institutes should prepare specialists who understand both automotive engineering and electrical engineering.

Electric vehicles also create new research opportunities. Students can study battery thermal management, charging station design, energy consumption modeling, life-cycle emissions, electric motor control, regenerative braking efficiency, and economic feasibility. Therefore, the topic of electric vehicle advantages and disadvantages is highly relevant for diploma projects in automotive engineering.

9. Recommendations

Based on the analysis, several practical recommendations can be proposed. First, electric vehicle adoption should be supported by the gradual development of charging infrastructure. Public charging stations should be installed not only in city centers but also near residential areas, universities, service stations, shopping centers, and intercity roads. Second, the electricity generation mix should be improved by increasing the share of renewable and low-carbon sources. This will strengthen the environmental advantage of electric vehicles.

Third, technical education should include high-voltage safety, battery diagnostics, charging systems, and electric drivetrain maintenance. Traditional automotive education focused mainly on internal combustion engines, but electric mobility requires new competencies. Fourth, battery recycling and second-life applications should be developed. Used vehicle batteries may still be suitable for stationary energy storage before final recycling.

Fifth, consumers should be informed about realistic driving range, charging time, battery care, and maintenance features. Misunderstandings about electric vehicles can reduce trust. Clear technical information helps users choose the right vehicle for their needs.

10. Conclusion

Electric vehicles represent one of the most important directions in the modernization of road transport. Their main advantages include zero tailpipe emissions, high energy efficiency, low noise, instant torque, smoother operation, reduced maintenance needs, regenerative braking, and the possibility of integration with renewable energy. These features make electric vehicles especially suitable for urban mobility and sustainable transport development.

At the same time, electric vehicles have disadvantages that must be carefully considered. Battery production creates environmental impacts, raw material extraction requires responsible management, charging infrastructure must be developed, driving range can be affected by climate and speed, charging takes longer than refueling, and battery recycling remains an important future challenge. The environmental benefit of electric vehicles also depends on how electricity is produced.

The main conclusion is that electric vehicles are technically and environmentally superior to conventional vehicles in many operational aspects, but they should be evaluated through a life-cycle and system-based approach. The vehicle itself, the battery, electricity generation, charging infrastructure, service system, and recycling process are all connected. Therefore, the transition to electric mobility should be planned as a comprehensive technological, environmental, and infrastructural transformation.

For automotive engineering education, electric vehicles are an important research object because they combine mechanics, electrical engineering, electronics, software, energy systems, and environmental analysis. The study of their advantages and disadvantages helps students understand the future direction of the automotive industry and prepares them for new professional requirements in sustainable transport.

References

1. International Energy Agency. Global EV Outlook 2026. Paris: IEA, 2026.
2. International Energy Agency. Global EV Outlook 2025. Paris: IEA, 2025.
3. U.S. Environmental Protection Agency. Electric Vehicle Myths. Washington, DC: EPA.
4. U.S. Department of Energy, Alternative Fuels Data Center. Electric Vehicle Benefits and Considerations.
5. U.S. Department of Energy, Alternative Fuels Data Center. Maintenance and Safety of Electric Vehicles.
6. U.S. Department of Energy. R&D GREET Life Cycle Assessment Model.