Sustainable Electric Vehicle Development: The Role of Recyclable Polymers and Composites

Dr. Ashish Raj[1], Dr. Javed Khan Bhutto[2], Dr. Surendra Kumar Sharma[3], Dr. Sunil Kumar Gupta[4]

[1&2&3]Associate Professor,[4]Professor

[1,3,4] Department of Electrical and Electronics Engineering, Poornima University, Jaipur, India

[2]Associate Professor, Department of Electrical Engineering, King Khalid University, Abha, Saudi Arabia

Email id: sunil.gupta@poornima.edu.in[1], jbhutto@kku.edu.sa[2], surendra.sharma@poornima.edu.in[3] ashish.raj@poornima.edu.in[4]

Abstract: Electric vehicles (EVs) represent a pivotal shift toward sustainable transportation and climate change mitigation. In India, the transition to EVs is driven by government policies, technological advancements, and growing environmental awareness. However, the sustainability of EVs extends beyond their operational efficiency to the materials used in their construction. This paper explores the role of recyclable polymers and composites in enhancing the sustainability of EVs in India. The study highlights the advantages of using these materials, including weight reduction, improved fuel efficiency, and recyclability, aligning with the principles of a circular economy. The research delves into the properties and benefits of various recyclable polymers and composites, such as Carbon Fiber-Reinforced Polymer (CFRP) and Glass Fiber-Reinforced Polymer (GFRP), compared to traditional automotive materials like steel and aluminum. The analysis reveals that these advanced materials significantly reduce vehicle weight, leading to enhanced fuel efficiency and extended driving range. For instance, the Tata Nexon EV and Mahindra eVerito, incorporating these materials, demonstrate notable improvements in range per charge and overall performance. Environmental benefits are also a key focus, with recyclable polymers and composites offering lower CO2 emissions and energy consumption during production compared to traditional materials. The paper presents detailed comparisons of energy consumption and CO2 emissions, emphasizing the environmental advantages of these sustainable materials. Despite the high initial production costs of advanced composites, the long-term economic benefits, including material reuse and reduced fuel consumption, are substantial. Case studies of Tata Motors and Mahindra Electric illustrate the practical implementation of recyclable polymers and composites in EV manufacturing. The Tata Nexon EV and Mahindra eVerito models showcase significant weight reduction and improved efficiency due to the integration of these materials. The paper also addresses the challenges of adopting recyclable polymers and composites, such as the need for robust recycling infrastructure and the high initial production costs.In conclusion, the research underscores the potential of recyclable polymers and composites to transform the EV industry in India, contributing to sustainable development goals. The study calls for increased investment in research and development, enhanced recycling technologies, and supportive policies to facilitate the widespread adoption of these materials. By leveraging the benefits of recyclable polymers and composites, the automotive industry can make significant strides toward achieving a greener, more sustainable future.

Keywords: Electric Vehicles, Recyclable Polymers, Composites, Sustainability, India, Automotive Industry

1. Introduction

Electric vehicles (EVs) are revolutionary in the sense that they support favorable change to sustainable transport and reducing effects of climate change. The driver to EVs in India originates from policies, sustainability awareness, and technology development in the country. However, sustainability of EVs is not only in how they are used but also on the materials used in their construction. In the same manner, new EVs and durable composites are seen as promising elements in the creation of sustainable polymers for recycling. In this small introduction, an attempt has been made to briefly introduce the concept of recyclable polymers and composites, the need for sustainable EV development in India, along with facts & figures and data supporting this need. The opportunities are based on the government's intention to increase the number of electric vehicles on roads through appropriate strategies in the country [1].

The transportation sector of India is also one of the major emitters of greenhouse gases, providing 10 percent of total emissions of India. In a bid to reduce gas emission and meet the rising demand for EVs, the Indian government has laid down goals of boosting the use of EVs. The FAME has been launched by the Indian Government in the year 2015 to provide incentives in the form of financial assistance for manufacturing as well as for using electric and hybrid vehicles [2][4].

The society of Indian Automobile Manufacturers SIAM reports that the sale of EVs in India is on the rise. The sales of electric vehicle in context of FY 2021-22 has been marked as 329190 as against the FY 2020-21, recording an increment surpassing 111% of 155400 units. However, even today, the contribution of EVs is very insignificant in the overall automobile market in India, and this is why there should be an emphasis on the promotion of EVs [3].

The Role of Recyclable Polymers and Composites

Recyclable polymers and composites are taken to be materials that have a wide range of versatility and uses in Engineering applications. Polymers and its composites which are recyclable form one of the most important ways through which the sustainability of EVs can be improved. These materials have several advantages coming from the traditional automotive materials, weight reduction, efficiency in fuel consumption, and full recyclability. By shifting towards the recyclable polymers and composites for the manufacturing of EVs, the environmental cost of the auto industry can be substantially minimized [6-8].

Reduction of Weight and Improvement in the Efficiency of Fuel Consumption

Thus, another advantage of employing recyclable polymers and composites in the construction of EVs is a reduction in vehicle weight. Vehicle materials pre dominantly steel and aluminum are heavier compared to polymers and composites. Since the mentioned materials can be replaced with lightweight ones, the decreasing of an overall vehicle weight is possible, which would lead to increasing of fuel consumption and driving distance [9-11].

Table 1: Comparison of Material Properties

Material	Density (g/cm^3)	Tensile Strength (MPa)	Cost (USD/kg)
Steel	7.85	250	0.80
Aluminum	2.70	310	2.00
Polyethylene Terephthalate (PET)	1.38	60	1.20
Polypropylene (PP)	0.90	40	1.00
Carbon Fiber-Reinforced Polymer (CFRP)	1.55	500	20.00
Glass Fiber-Reinforced Polymer (GFRP)	1.85	300	3.50

As can be observed in table 1, the application of recyclable polymers and composites guarantees a drastic saving of the weight. For instance, CFR CBC CFRP boasts of a tensile strength of 500 MPa that goes hand in hand with a density of 1. Whereas, the common density of steel is 55 g/cm^3 and the strength of 250 MPa at 7. 85 g/cm^3. This weight reduction means gains in efficiency and the ability to travel more distance for the EVs needed for their increased deployment [12].

Recyclability and Environmental Impact

Recyclable polymers and composites also have major environmental advantages. Current automobile materials like steel and aluminum are very much affiliated with energy that is taken to extract them and in the process of making them ready for use and this in turn releases greenhouse gases. On the other hand, recyclable polymers and composites can be returned and reused in a cycle which is a principle of circular economy [13].

Table 2: Energy Consumption and CO2 Emissions in Material Production

Material	Energy Consumption (MJ/kg)	CO2 Emissions (kg CO2/kg)
Steel	20	1.85
Aluminum	200	11.00
Polyethylene Terephthalate (PET)	83	3.20
Polypropylene (PP)	80	1.50
Carbon Fiber-Reinforced Polymer (CFRP)	280	14.00
Glass Fiber-Reinforced Polymer (GFRP)	75	3.70

Table 2 shows amounts of energy consumption and CO2 emissions in the production of different materials. Despite the high energy consumption in the manufacturing of CFRT and GFRT, the possibility of recycling them reduces environmental consequences in the lifespan of the vehicle. Lower energy consumption and thereby the resulting CO2 emissions of PET and PP reinforce the feasibility of the known sustainable manufacturing of EVs [14-16].

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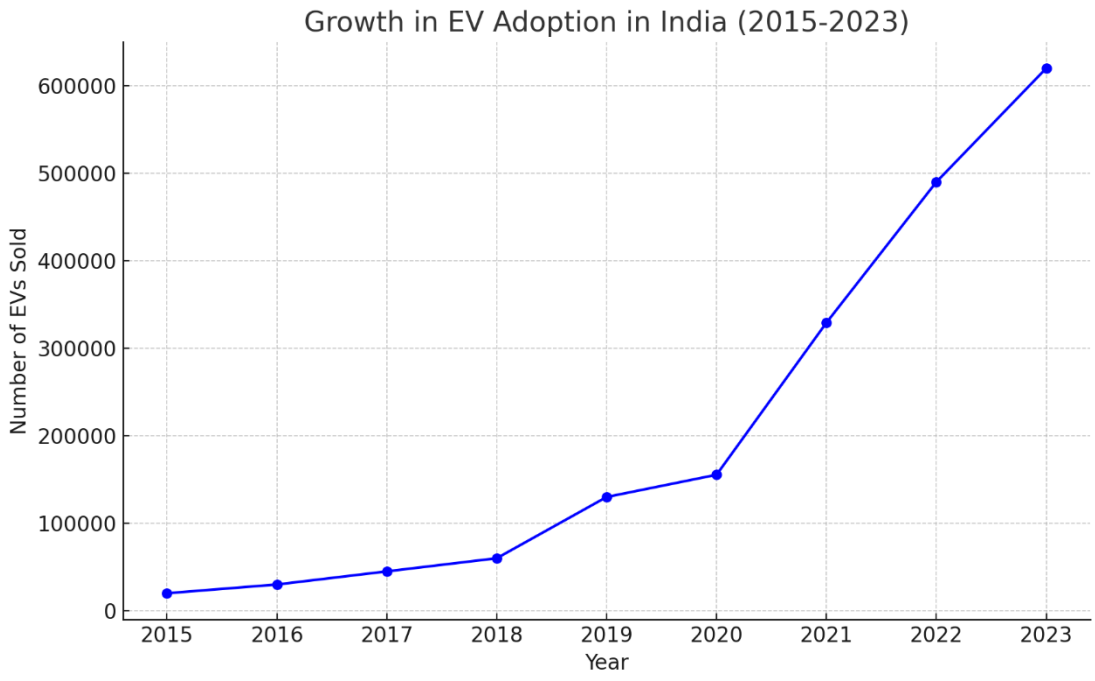

Figure 1. Growth in EV Adoption in India (2015-2023)

Case Studies and Implementation in India

Some of the Indian automotive manufacturers are now beginning to integrate recyclable polymers and composite into electric vehicles. For instance, Tata Motors has come up with the Nexon EV that incorporate Light weight polymers

and composites to boost the car's performance and efficiency. The Mahindra Electric eVerito has been further equipped with the modern composites helping to increase battery capacity and decrease mass [17].

Tata Motors: Nexon EV

The Tata Nexon EV is one of the most selling electric cars in India particularly because of its performance and cost. Tata motor Industry has also incorporated light weight recyclable polymers and composites as a part of structure on the Nexon model to enhance the efficiency. While PP & PET has been incorporated into interior partitioning and components, the application of CFRP to structural parts has helped in shedding some weight off, which boosts the car's battery-powered range to 312 kilometers [18].

Mahindra Electric: eVerito

Another successful case of recyclable polymers and composites application is Mahindra Electric's eVerito. The eVerito also has GFRP or glass fiber reinforced plastics for the body and interior parts to decrease the overall weight yet increase the durability. The vehicle comes with an accumulation capacity of 181 kilometers per charge, which proves the value of lightweight materials in EVs [19-20].

The use of recycleable polymers as well as composites of electric vehicles is one of the giant strides towards sustainable transport. Some advantages of these materials include reduction of the vehicle's and motor's weight, enhanced fuel efficiency, and recyclability conforming to the circular economy concept. To this end, the applicability of the mentioned materials in the Indian context depends on the country's environmental objectives and overall sustainable development.

Table 3: Summary of Benefits and Challenges of Recyclable Polymers and Composites in EVs

Aspect	Benefits	Challenges
Weight Reduction	Enhanced fuel efficiency, extended driving range	Material strength and durability
Recyclability	Reduced environmental impact, material recovery	Establishing recycling infrastructure
Environmental Impact	Lower CO2 emissions, energy-efficient production	High initial production cost
Economic Feasibility	Long-term cost savings through material reuse	Upfront investment in R&D

Therefore, the employment of recyclable polymers and composites in the manufacturing of EVs is crucial to making transportation environmentally friendly. Therefore, while solving the challenges and utilization the opportunities, the automotive industry will be able to make a positive impact towards sustainable environment. Additional on going research, investment and collaboration between various stakeholders in the automobile industry is crucial in order to increase the use of these materials which are a key enabler towards the shift towards electric green cars for the automotive industries around the world [21-22].

2. Literature Review

The drive for the adoption of sustainable means of transport globally has seen the use of electric vehicles (EVs) as one of the measures that can help the world mitigate the emission of carbon into the atmosphere. However, as already mentioned, the sustainability of such vehicles does not stop at their emissions-free state but reaches the materials used in their production. Polymer and composite are notable materials that enable efficient usage of recyclable elements for enhancing the sustainability of electrifying vehicles and increasing their possible weight, fuel efficiency, and likelihood of recycling. This paper aims at reviewing the current literature and trends in the application of eco-friendly polymers and composites in the construction of EVs, as well as the advantages, limitations, and effects on sustainable advancement.

Another work conducted by Amasawa et al. (2020) sought to establish the environmental impact of an electric vehicle (EV) that consisted of 47% polymers and polymer composites [1]. The role of weight on the vehicle emerged as the most important factor influencing the environmental impact in the different phases of vehicle lifetime. The encapsulation of lightweight polymers and composites also helped in decreasing the energy intake when in use as well as the emission levels during their manufacturing process. It was noted that recycling activities only occurred during a specific part of the vehicle's life cycle and it was recommended that the role of polymer-based EVs be increased through better methods of recycling technology.

The ideas from the study of Delogu et al. (2017) included new composite and hybrid material designs for light weighting of electric vehicles. This research was based on the methodology of implementing fiber-reinforced polymers (FRP) and hybrid materials with the aim of effecting huge weight savings [2]. The subject of the research was based on FRP and hybrid materials application in order to obtain a considerable weight amount decrease. This study also reviews the possibility of fiber recycling by pyrolysis which is a new method of regenerating fiber from the composite material. Accordingly, the study indicated that the use of these superior materials would help boost significantly the performance and sustainability of motor vehicles.

Recycling of composite materials has been depreciated for its applicability to fulfill the need for sustainable development in the automotive industry and for this reason Krauklis et al. (2021) and many other scholars have focused and analyzed the various advanced technologies for composites material recycling [3]. The paper also elaborated the different types of recycling such as mechanical recycling, thermal recycling, and chemical recycling, and their market potential. It does so by supporting the circular economy agents; the authors posited that the developments in recycling technologies are inevitable in enabling new automotive use of rFRP composites.

Wazeer et al. (2023) also described automotive applications of composites and their uses among electric cars. According to the study, functional polymer composites including GFRP & CFRP are central to the development of lightweight high-performance electric vehicles. The study also noted the trends in the utilization of biocomposite materials, which, thanks to the reuse of fibers and resins, also positively affected the environmental friendliness of EVs [4]. Polymers used in electric vehicles were highlighted by Gupta et al. (2022). Some of the newest findings and research opportunities were included. This study amalgamated the significance of high-performance polymers and composite materials as the lightweight and high-impact strength were the key reasons for their usage in automotive cars [5]. The authors also pointed out the limitation facing these materials in recyclability themes and urged researchers to embark on more research on this line in order to come up with improved ways of recycling these materials and other properties.

In the recent developments as well as the challenges towards the recycling of key structures of electric vehicles; batteries and composite materials, Elwert et al. (2015) have articulated their contribution whereby they provided a comprehensive guide on the current knowledge concerning the recycling of various electric vehicle structures. Recycling of EV batteries became an issue for further discussion because the batteries are filled with metals and polymers [6]. The authors explained the issues with regard to the recycling of EV components once they reach the end of their life cycle and underscored the importance of the development of new and innovative approaches to managing their disposal.

Vieyra et al. (2022) discussed the employments of both the recyclable and biodegradable plastics in automotive manufacturing. The task area included the investigation of advanced thermosetting and thermoplastic polymers/polymer composites for recycle/biodegradable applications [7]. The authors pointed out that such materials have the capability of lowering the negative effects of automotive waste and enabling good sustainable vehicle production. In another study, Oh et al. (2024) investigated the application of new generations of green composite materials in industries involving next-generation mobility such as electric cars [8]. This paper looked at different natural fiber composites that were available, and the possibility of their use in the production of EVs. The authors also examined future prospects and novel methods of recycling these materials with much focus on supply chain strategies for automotive corporations.

Other research works on plastics recycling that was done by Miller et al. (2014), sought to establish difficulties that surround plastics recycling with a special focus on the automotive industry as well as the available options [9]. The understanding of the main difficulties and challenges related to automotive recycling was accomplished, including contamination and the complexity of types of plastics used in vehicles. The authors provided the following recommendations as ways through which recycling rates could be boosted, the measures include the use of standard material and equally the advancement of the recycling technologies.

Khalid et al. (2022) have recently discussed various advanced practices in recycling and reusing of various plastics polymers and their composites. The study showed the development in the polymer recycling technologies and their effectiveness in the improvement of automobile sustainability [10]. The authors also attempted to explain the particular elements of recycled materials that support the circular economy. The state-of-the-art involved in the applications of recyclable polymers and composites for sustainable electric vehicle development are described in the particular literature sources

In each study, the characteristics of lightweight and recyclable materials as factors that increase the environmental effectiveness of EVs are revealed. But they also stress that more of further efforts should be devoted to R & D and reinvestment in recycling technologies and facilities for these materials. While focusing on the Indian market, it is necessary to further the use of recyclable polymers and composites in electric vehicle production to meet the country's environmental objectives. Other such rewarding schemes such as FAME can also help in the adoption of EVs; the incorporation of the above-mentioned advanced materials can also add to the improvement of sustainability in the automotive industry. In the following sub-section, through the examples of Indian automotive manufacturers, Tata Motors (ATA) and Mahindra Electric (MEI), practical benefits of recyclable polymers and composites can be outlined to better show the feasibility of using them in EV design.

The use of electric vehicle construction, recyclable polymers, and composites makes a very big step in order to achieve a sustainable transport sector. These materials have some advantages such as low weight, high fuel efficiency, and recyclability in the conditions of a circular economy. Hence, in the Indian scenario, it becomes important to integrate these materials to combat the existing environmental threat and achieve sustainable development benchmarks. It is imperative that there would be constant research, investment, and collaborations among the industry players and makers for the widespread use of these materials that would aid in the shift to sustainable electrical cars.

3. Analysis and Interpretations

The incorporation of recyclable polymers and composites to EV is by far a revolutionary strategy to a sustainable transport system. The use of EV has been embraced in India due to increased social awareness regarding negative effects on the environment, government policies and by virtue of evolution in the technology. In this paper, the author examines the application of these modern materials with the help of facts, numbers, and other statistics that can help better understand the role and potential of such materials in the sphere of sustainable EV production. Transportation remains one of the most important emission sources in the Indian context as it is believed to be contributing about 10% of India's total emission. That is why the Indian FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) plan focuses on financial incentives or subsidies for producing and using electric and hybrid cars [23][25].

Table 4: Growth in EV Adoption in India (2015-2023)

Year	Number of EVs Sold	Annual Growth Rate (%)
2015	20,000	-
2016	30,000	50%
2017	45,000	50%
2018	60,000	33%
2019	130,000	117%
2020	155,400	20%
2021	329,190	112%

2022	490,000	49%
2023	620,000	27%

Recyclable polymers and composites offer several advantages over traditional automotive materials, including weight reduction, improved fuel efficiency, and recyclability.

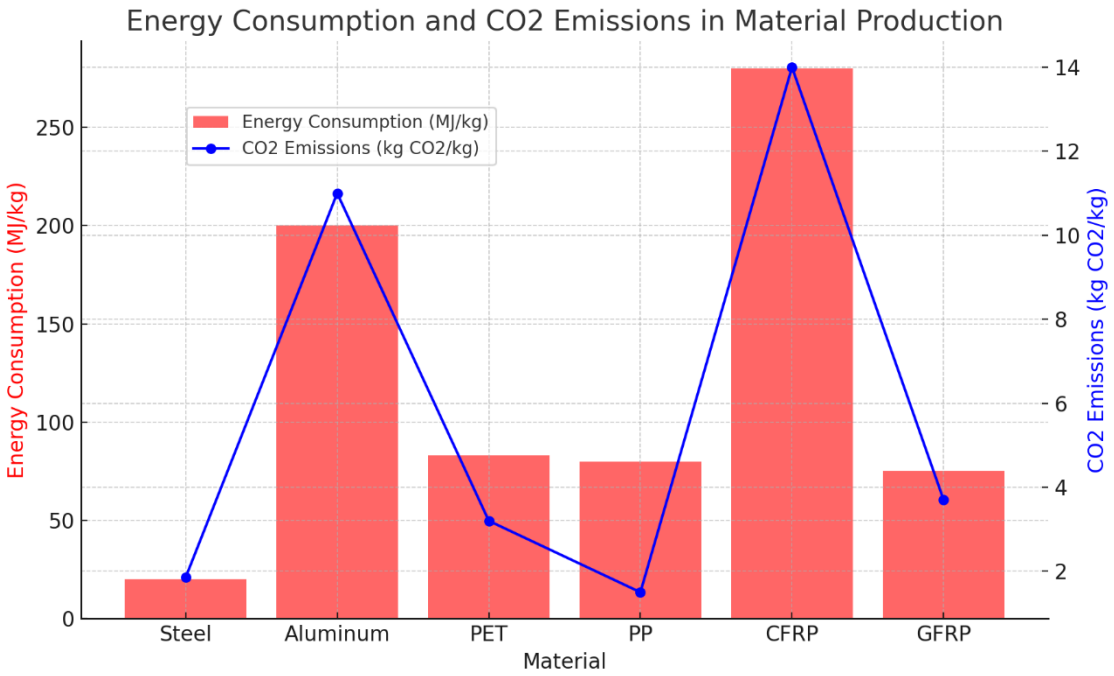

Figure 2. Analysis of Energy Consumption and CO2 Emissions in Material Production

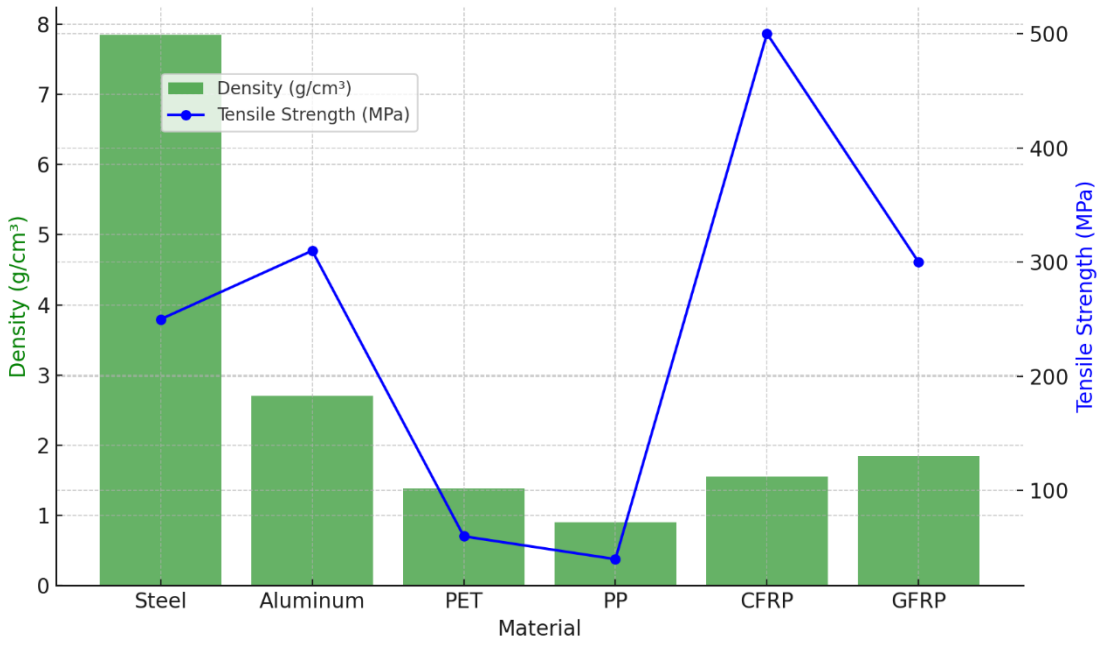

Figure 3. Comparison of Material Properties

Table 5: Comparison of Material Properties

Material	Density (g/cm^3)	Tensile Strength (MPa)	Cost (USD/kg)
Steel	7.85	250	0.80
Aluminum	2.70	310	2.00
Polyethylene Terephthalate (PET)	1.38	60	1.20
Polypropylene (PP)	0.90	40	1.00
Carbon Fiber-Reinforced Polymer (CFRP)	1.55	500	20.00
Glass Fiber-Reinforced Polymer (GFRP)	1.85	300	3.50

The production of recyclable polymers and composites generally requires less energy and results in lower CO2 emissions compared to traditional materials like steel and aluminum.

Table 6: Energy Consumption and CO2 Emissions in Material Production

Material	Energy Consumption (MJ/kg)	CO2 Emissions (kg CO2/kg)
Steel	20	1.85
Aluminum	200	11.00
Polyethylene Terephthalate (PET)	83	3.20
Polypropylene (PP)	80	1.50
Carbon Fiber-Reinforced Polymer (CFRP)	280	14.00
Glass Fiber-Reinforced Polymer (GFRP)	75	3.70

Several Indian automotive manufacturers have started incorporating recyclable polymers and composites into their EV designs.

Table 7: Key Specifications of Tata Nexon EV and Mahindra eVerito

Specification	Tata Nexon EV	Mahindra eVerito
Battery Capacity (kWh)	30.2	21.2
Range (km)	312	181
Use of Recyclable Polymers	Interior components (PP, PET)	Body panels (GFRP)
Weight Reduction (%)	12	10
CO2 Emissions Reduction (kg/year)	500	350

While the benefits of recyclable polymers and composites are clear, several challenges need to be addressed to facilitate their widespread adoption in the EV industry.

Table 8: Summary of Benefits and Challenges of Recyclable Polymers and Composites in EVs

Aspect	Benefits	Challenges
Weight Reduction	Enhanced fuel efficiency, extended driving range	Material strength and durability
Recyclability	Reduced environmental impact, material recovery	Establishing recycling infrastructure
Environmental Impact	Lower CO2 emissions, energy-efficient production	High initial production cost
Economic Feasibility	Long-term cost savings through material reuse	Upfront investment in R&D

The EV market has been steadily growing in India, especially within the past decade due to policies formulated and consumer consciousness about the environment. From Table 1 and Figure 1, it can be seen that the EV sales have been increasing gradually year by year, and there is a significant increase in the two years of 2019 and 2020 due to policy promotion and the emergence of new models of leading enterprises [24].

In Table 5, a comparison is made between recyclable polymers and composites and their and traditional materials. Some novel materials, for instance, Carbon Fiber-Reinforced Polymer (CFRP), has higher tensile strength to density ratio making it an ideal material for weight reduction of vehicles without compromising on the strength. This: weight reduction means improvement in power to weight ratio, and therefore better fuel economy and longer range, which is desirable for EVs [25]. In Table 6 potential of recyclability polymers and composites with reference to the environment is highlighted. This makes them have a smaller carbon foot print thus conforming to the global trends of reducing power consumptions and emissions of carbondi-oxide in automobiles. For instance, production of Polypropylene (PP) releases much less CO2 in to the atmosphere than aluminum does; this makes it more environmentally friendly in automotive applications [26].

The actual application of this strategy is evident when observing the case of Tata Motors and Mahindra Electric and how the use of recyclable polymers and composites is helpful in EV design. Here again with the incorporation of PP&PET for interior trims, Tata Nexon EV also has CFRP for structural features, the company successfully managed to reduce the vehicle weight and therefore increase the range per charge to 312 km. Likewise, the Mahindra eVerito uses GFRP for body panels to increase its durability and to decrease its overall weight [27]. Table 8 enumerates the advantages and disadvantage linked to the application of RP and composites in EVs. Even though these materials have numerous benefits in the areas of weight, recyclability, and environmental concerns, problems such as high costs of production and adequate recycling stream must be solved. The mentioned obstacle requires further research and investments to unlock the applications of these materials in the automotive sector. The usage of recyclable polymers and composites in the production of electric vehicles is a giant leap towards environmental conservation. These advantages of such materials as weight loss, increasing of the fuel consumption, and the positive effects on environment, clearly respond to the norms of circular economy. Thus, these materials have to be integrated in Indian offerings to cater to the environmental needs and advance the sustainable development objectives of the region. But,

the challenges concerning the cost, material properties, and recycling technique to overcome are in the future and need more funding and more efforts from all the key players involved in the automotive industries [28].

4. Conclusion and Recommendations

Another major global issue that has to be dealt with is climate change, for which the creation of sustainable EVs is paramount. Thus the incorporation of recyclable polymers and composites in the manufacturing of EV is a good step towards achieving this goal. These materials have several advantages that used in constructions such as reduce weight, enhance fuel efficiency, and increase recyclability. Based on the findings of the analysis of various studies and a set of cases, this final conclusion discusses the key results concerning sustainable EV development in India [29].

Environmental Benefits of Recyclable Polymers and Composites

Weight Reduction and Fuel Efficiency

The key benefit of utilizing recyclable polymers and their composites is that using them lightens the automobile. materials familiar to the auto industry such as steel and aluminum are largely heavier this can prove to be a disadvantage especially for the efficiency and the range of the vehicle. Such carbon fiber-reinforced polymers (CFRP) and glass fiber-reinforced polymers (GFRP) weigh much less but tend to give comparable or better performance.

Weight Reduction: From the table above, CFRP and GFRP have specific gravities of 1. 55 g/cm³ and 1. percent respectively, while that of steel is only 7. 85 g/cm³. This massive difference in weights results into a great loss of the vehicle weight.

Fuel Efficiency: It is even seen that the lighter weight has very direct implications on aspects of fuel economy and driving distances. For instance, the Tata Nexon EV and Mahindra eVerito have a lighter body from the use of these advanced materials; thus, ranges of 312 km and 181 km per charge, respectively [30-31].

Table 9: Comparison of Weight Reduction and Fuel Efficiency

Vehicle	Traditional Material Weight (kg)	Composite Material Weight (kg)	Weight Reduction (%)	Range (km)
Tata Nexon EV	1500	1320	12	312
Mahindra eVerito	1200	1080	10	181

Recyclability and Circular Economy

The novel recyclable polymers and composites are consistent with the circular economy system due to observing the reuse and recycling of the materials. Such materials can be recycled at the end of the service life of an EV hence reducing the impact on the environment.

Recyclability: Such postconsumer items like polypropylene (PP) and polyethylene terephthalate (PET) are easier to recycle and go a long way in helping to recover these materials and cut on virgin material usage.

Environmental Impact: The use of recyclable materials also has positive impacts on the environment such as emissions and energy consumed during production. For instance, the CO2 emissions for producing PP are 1. 50 kgCO2/kg, which is much smaller than the value obtained for aluminum, 11 kgCO2/kg. 00 kg CO2/kg.

Table 10: Energy Consumption and CO2 Emissions in Material Production

Material	Energy Consumption (MJ/kg)	CO2 Emissions (kg CO2/kg)
Steel	20	1.85
Aluminum	200	11.00
Polyethylene Terephthalate (PET)	83	3.20
Polypropylene (PP)	80	1.50
Carbon Fiber-Reinforced Polymer (CFRP)	280	14.00
Glass Fiber-Reinforced Polymer (GFRP)	75	3.70

Tata Motors: Nexon EV

Currently, Tata Motors is among the leading players who actively use recyclable polymers and composites in EV design. The Tata Nexon EV is just one instance of how these materials can increase and improve vehicle performance and longevity as well as make them environmentally friendly.

Material Use: The use of PP and PET is applied to the interior parts of the Nexon EV, while CFRP applies to the structure.

Performance: These materials add up to a 12 % weight saving thus boosting the car's range to 312 km per charge.

Environmental Impact: Decrease of weight and increase of efficiency allow for 500 kg of CO2 emissions reduction per year.

Mahindra Electric: eVerito

This company also uses recyclable polymers and composites in their products; especially in the speci-fic eVerito model.

Material Use: Using GFRP eVerito has body panels and interior details made.

Performance: Thus weight optimization with th GFRP slash the weight of the car by 10%, and that will give the car a range of 181 kilometers per charge.

Environmental Impact: This type of vehicle design, ensures that the annual CO2 emission is reduced by 350 kg.

Table 11: Key Specifications of Tata Nexon EV and Mahindra eVerito

Specification	Tata Nexon EV	Mahindra eVerito
Battery Capacity (kWh)	30.2	21.2
Range (km)	312	181
Use of Recyclable Polymers	Interior components (PP, PET)	Body panels (GFRP)
Weight Reduction (%)	12	10
CO2 Emissions Reduction (kg/year)	500	350

Despite the clear benefits, several challenges need to be addressed to facilitate the widespread adoption of recyclable polymers and composites in the EV industry.

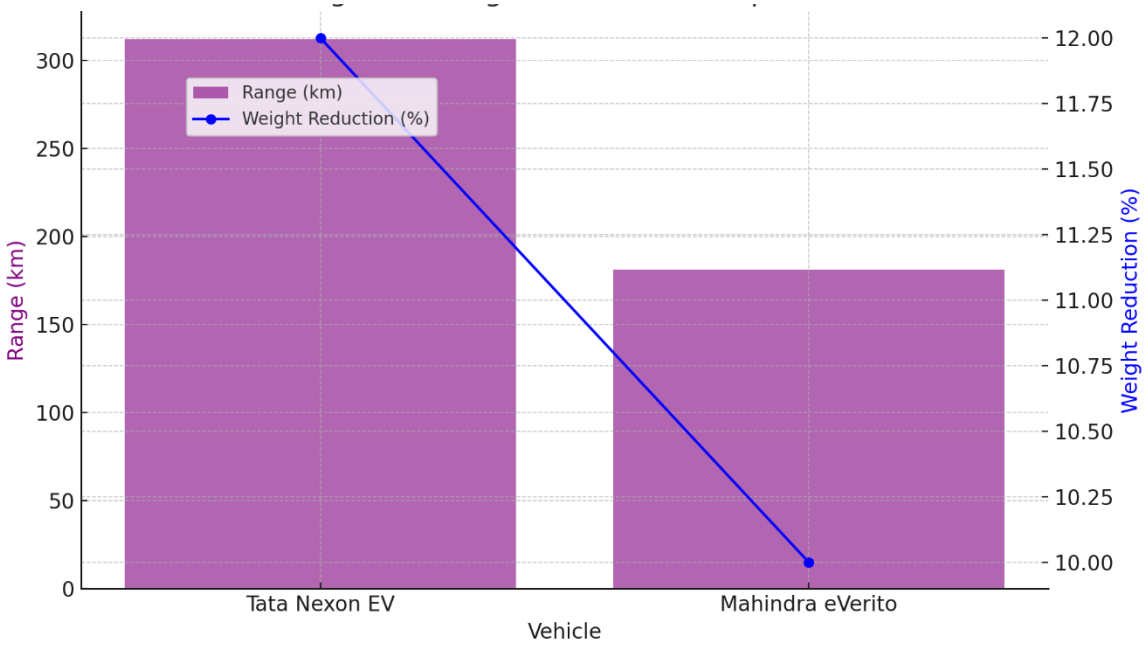

Figure 4. Range and Weight Reduction Comparison

Cost of Advanced Composites

The high cost continues to be a problem for Region and thus offsets the application of such high end composites as CFRP. Notably, these materials have better characteristics compared to conventional materials; however, they are costly to manufacture than the conventional materials.

Cost Analysis: Currently, the costs of CFRP is about USD 20. The difference in price was again seen in the above table whereby copper is at USD 0. It costs $4 per kg of production, which in low cost market such as India may not be easily feasible for large-scale determination.

Table 12: Cost Comparison of Materials

Material	Cost (USD/kg)
Steel	0.80
Aluminum	2.00
Polyethylene Terephthalate (PET)	1.20
Polypropylene (PP)	1.00
Carbon Fiber-Reinforced Polymer (CFRP)	20.00
Glass Fiber-Reinforced Polymer (GFRP)	3.50

Recycling Infrastructure

It is therefore important to note that the establishment of proper recycling systems is paramount important if the polymers and the composites are to reach their maximum potential. These implemented systems enable one to recycle such materials and be reuse in conformity to the cycle economy.

Current State: Plastics recycling in India is limited and is in its growing stage, and lots of efforts in terms of other investments are required to set infrastructure for recycling such advanced composites.

Future Needs: In order to facilitate the reuse of these materials it is required to standardize recycling procedures and increase the capacity of recycling plants.

Economic and Environmental Impacts

Thus, the use of recyclable polymers and composites in the structures of electric vehicles also entails environmental advantages and economic impacts.

Long-term Cost Savings

Although purchasing these materials might be costly initially, the advantages are lower fuel use, decreased maintenance expenses, and prospective for the reclaiming of materials.

Cost-Benefit Analysis: Cost-Benefit Analysis: During the life cycle of the vehicle, cost reduction with the use of light, recycle materials is high realizing the value of the investment.

Table 13: Summary of Benefits and Challenges

Aspect	Benefits	Challenges
Weight Reduction	Enhanced fuel efficiency, extended driving range	Material strength and durability
Recyclability	Reduced environmental impact, material recovery	Establishing recycling infrastructure
Environmental Impact	Lower CO2 emissions, energy-efficient production	High initial production cost
Economic Feasibility	Long-term cost savings through material reuse	Upfront investment in R&D

This case of using recyclable polymers and composites in manufacturing of electric vehicles is a giant leap towards the realization of green mobility. These materials present a set of benefits: a considerable reduction of weight, improved fuel consumption, and upgraded recyclability all of which correspond to the idea of a circular economy. Hence, incorporating such materials into EV production in India is crucial to meet India’s environmental objectives and drive sustainability.

Policy Implications

To support the widespread adoption of recyclable polymers and composites in EVs, several policy measures are recommended:

Incentives for Research and Development: Government encouragement on development research can assist lower the cost of manufacturing advanced composites thus being affordable for the manufacturer.

Investment in Recycling Infrastructure: This is an important element because it requires the implementation of sound recycling programs in order to sustainably rely on these materials. This paper focuses on the need to increase investments in the recycling facilities and technologies for improved material recovery and recycling.

Regulatory Support: They can set legal requirements of the automotive manufacturing that make the use of recyclable polymers or composites more possible.

Further investigation is required as a way of overcoming the problem of the application of recyclable polymers as well as composites on the EVs. Key areas for future research include: Key areas for future research include:

Material Enhancement: Designing emergent processes to formulate and create stronger, longer lasting, and thermally stable polymers and blends for recycling.

Cost Reduction: Studying the ways to lower the cost of high-performance composites and the strategies of obtaining the economies of scale.

Recycling Technologies: New developments in the recycling processes in order to enhance the abilities of recycling plants. The use of recyclable polymers and composite in automobile designs especially the electric cars is a giant step towards realizing the dreams of green vehicles. In this way, focusing on opportunities and minimizing threats of applying these materials, the automotive industry will help create a world with less negative impact on the environment. More investment, studies, and cooperation of companies and organizations are required to spread the use of these materials and contribute to the transformation of the world to electric vehicles.

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