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A REVIEW ON ELECTRIC VEHICLE BATTERY

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Abstract :

Electric vehicle (EV) batteries are rechargeable batteries that power electric vehicles, storing energy for propulsion. Lithium-ion batteries dominate the EV market due to their high energy density, long cycle life, and decreasing cost. However, they face challenges like degradation, aging, and thermal management, affecting their performance and lifespan. Advanced battery management systems and innovative chemistries like solid-state and lithium-air batteries are being developed to improve EV range, safety, and sustainability. They are usually lithium-ion batteries that have been designed for high energy density and a high power-to-weight ratio. These batteries were initially developed for consumer electronics and laptops, but recent EVs use new variations on lithium-ion chemistry that provide fire resistance, environmental friendliness, rapid charging, and longer lifespans.

***IndexTerms* - Batteries, electrical vehicles, lithium-ion.**

INTRODUCTION

The following introduction talks about the performance of the electric vehicle battery (Lithium-ion battery).

As the world increasingly shifts towards sustainable energy solutions, electric vehicles (EVs) have emerged as a pivotal component in reducing greenhouse gas emissions and combating climate change. At the heart of this technological revolution lies the electric vehicle battery, a complex and rapidly evolving element that determines the performance, efficiency, and overall viability of EVs. With advancements in battery technology, including improvements in energy density, charging speed, and lifespan, the landscape of electric mobility is undergoing significant transformation. This review aims to provide a comprehensive overview of current battery technologies used in electric vehicles, explore emerging innovations, and address critical challenges such as resource sustainability, recycling, and environmental impact. By examining these facets, we hope to illuminate the crucial role that battery technology plays in shaping the future of transportation and its contribution to a more sustainable planet.

LITERATURE REVIEW

Mehmet Simsir et.al., [1] The electric vehicle (EV) market has experienced significant growth over the last decade, with sales projected to reach 14 million units by the end of 2023, a 35% increase from 2022. This growth is driven by national policies, incentives, and high oil prices. China led the global EV market in 2022, accounting for approximately 60% of total sales, followed by the US and Europe. The fabrication of EV batteries involves designing battery cells, preparing raw materials, creating electrodes, and assembling battery cells. The working principle of EV batteries involves converting chemical energy into electrical energy through the movement of lithium ions between two electrodes. As EV adoption continues to surge, it's crucial to develop advanced technologies like smart charging systems, reliable communication networks, and coordinated charging to manage the impact on the power grid. The article highlights the need for global standards to enhance market acceptance and fully harness the benefits of EVs. With the expected continued growth of the EV market, addressing the challenges and benefits of EV charging is essential for a smooth integration of EVs with the grid. New strategies and approaches are being developed to ensure this integration, including thermal management, battery management systems, and charging/discharging technologies.

Emmanual Augustine Etukudoh et.al., [2] The automotive industry is undergoing a significant transformation with the shift towards electric vehicles (EVs), driven by the need for sustainable transportation. Mechanical engineering plays a vital role in developing efficient, sustainable, and technologically integrated EVs. This paper reviews the history of EVs, their design, performance, and optimization, as well as advancements in battery technology, electric drivetrains, and energy management systems. The methodology of EVs involves storing energy in a battery pack, using an electric motor for propulsion, converting AC power to DC power for charging, managing energy flow through power electronics, regulating temperature, and capturing kinetic energy hrough regenerative braking.The paper examines current challenges and ongoing research in the field, highlighting future trends such as breakthroughs in materials science, artificial intelligence integration, and renewable energy synergy. The conclusion emphasizes the crucial role of mechanical engineering in shaping the future of vehicles, making them more efficient, safe, and sustainable. Collaboration with other fields like electrical engineering, computer science, and materials science is essential for innovative vehicle design and accelerating echnological advancements. As the industry evolves, mechanical engineering's importance grows, extending beyond traditional boundaries and creating an environment where innovation thrives

Pabitra Kumar Das et.al., [3] This study compares the environmental impact of electric vehicles (EVs) to traditional vehicles, highlighting the significant advantages of EVs in reducing greenhouse gas emissions. EVs emit 97% less CO_2 equivalent emissions than petrol vehicles and 70% less than diesel vehicles, thanks to the use of clean energy sources and advanced battery technology. The study uses a systematic literature review (SLR) approach to analyze existing knowledge and reduce bias. The review identifies 1088 relevant documents focusing on recent studies published after 2012. The findings suggest that EVs offer a promising solution to overcome the limitations of conventional vehicles, contributing to a more sustainable future. The study concludes that using renewable energy and clean power can further reduce emissions, and recycling vehicle and battery materials can also help cut emissions. EVs, hybrid electric vehicles, and plug-in hybrid electric vehicles are highly efficient and can significantly reduce fuel costs. The study emphasizes the importance of transitioning to EVs to mitigate climate change and improve air quality. Overall, the study provides a comprehensive review of the environmental benefits of EVs and highlights the need for continued research and development to support the adoption of sustainable transportation solutions.

Kaushik Das et.al., [4] Lithium-ion batteries are the preferred choice for electric vehicles due to their high energy and power densities, decreasing cost, and technological advancements. However, their performance degrades over time due to aging and degradation, leading to reduced capacity, power, and increased internal impedance. To estimate the battery's state of health (SOH), machine learning algorithms like KNN, SVR, DT, and RF are used, considering measurable indices like voltage, current, and temperature. The study focuses on developing techniques to estimate battery SOH, including model-based development, data-driven models, and fusion/hybrid models. These techniques simulate and test complex control processes, measure battery capacity and internal resistance, and determine its health and remaining life. The process involves fully charging and discharging the battery, measuring capacity, and calculating health by comparing maximum discharge capacity to nominal capacity. The study aims to manage batteries effectively and ensure reliable electric transportation. The results highlight the need for sustainable transportation solutions due to climate change, pollution, and resource depletion. Advanced techniques for estimating battery SOH are crucial for the widespread adoption of electric vehicles and mitigating environmental impacts. By accurately estimating battery health, electric vehicles can operate efficiently, reducing emissions and promoting a more sustainable future.

S Padmanabhan et.al., [5] The growing demand for electric vehicles and devices has increased the need for lithium-ion batteries, leading to concerns about accessing essential minerals and properly disposing of old batteries. Improving battery recycling in India can bring advantages, opportunities, and challenges. However, there is a lack of awareness among people, authorities, and recyclers about the health risks, environmental impacts, and regulations related to electronic waste. A proposed three-step approach can change public behavior and improve e-waste management.Applying circular economy principles to electric vehicle batteries is crucial to conserve resources, minimize environmental impact, and maximize their value. Designing batteries for durability and easy repair, using modular designs, can extend their lifespan and reduce waste. India's electric vehicle infrastructure is still in its early stages, but it's gaining momentum. With India accounting for 7% of global carbon emissions, promoting electric vehicles is crucial to combat rising pollution and address climate change. The global shift towards a low-carbon economy is driving a significant transformation in international climate policies. Improving battery recycling and adopting circular economy principles can enhance the sustainability of electric vehicles and mitigate environmental impacts. By addressing battery management issues and promoting eco-friendly practices, India can maximize the benefits of electric vehicles and minimize their environmental footprint.

Anahita Jannisar Niri et.al., [6] This study investigates how different ingredients in brake pads affect particle emissions, which are harmful to human health. Brake pads contain various ingredients, but it's unclear how each one contributes to emissions. Researchers tested individual ingredients using a tribometer and found that abrasives and metal fibers emit significantly more particles than lubricants and aramid fibers.The goal is to optimize brake pad ingredients to reduce harmful emissions, as disc brakes are a crucial safety feature but also generate toxic particle emissions. The European Commission's Euro 7 regulation aims to reduce non-exhaust emissions, including brake wear particles.The study tested four brake pad ingredients (aramid fiber, steel, graphite, and silicon carbide) and a reference material using a tribometer. The results show that certain ingredients emit more particles than others, highlighting the need to produce low-emitting brake pads to improve air quality and public health.In summary, the study examines how different brake pad ingredients affect particle emissions and aims to find ways to reduce harmful emissions and improve air quality.

Saravankumar Thangavel et.al., [7] Electric vehicles (EVs) are gaining popularity due to concerns about air pollution and high fuel costs. They are seen as a green transportation option, and it is expected that most cars will be EVs by 2030. However, making EVs efficient is a challenging task. EVs use batteries to store energy, which is converted into a usable form by the DC-DC converter, allowing the vehicle to run. This study aims to explore the optimal use of batteries, DC-DC converters, and motors in EVs, as well as examine emission control methods in renewable energy-based charging stations. The results show that lithium-ion batteries are the top choice for EVs, followed by Full Bridge converters (with isolation) and Boost converters (without isolation) as the most efficient and reliable options. The study compares EVs to traditional internal combustion engine vehicles, highlighting the advantages of EVs, including cost-effectiveness, environmental benefits, and improved human health. The findings of this study can help optimize the performance of EVs, making them a more viable option for sustainable transportation. As the world shifts towards green energy solutions, EVs are poised to play a crucial role in reducing emissions and mitigating climate change.

B. Anil Kumaret.al., [8] The Ferdowsi Converter is a innovative solution to address power quality (PQ) issues in electric vehicle (EV) charging. By combining two interleaved Buck-Boost converters with a common input inductor, it achieves nearly unity power factor (PF) across a wide input voltage range, reducing harmonic distortion (THD) and ensuring efficient charging. The converter operates in discontinuous conduction mode (DCM) with a simplified PT control strategy, making it a reliable and cost-effective option for EV charging applications. The increasing adoption of EVs necessitates robust charging infrastructure to support daily usability and long-term adoption. Conventional chargers often result in lengthy charging times and limited capacity, highlighting the need for advanced charging solutions. The Ferdowsi Converter addresses these concerns by providing a streamlined architecture with fewer components, promising improved reliability, reduced energy costs, and extended battery life. The results demonstrate the converter's superior PQ, achieving a THD as low as 0.07% and operating in phase with the mains voltage. This makes it a viable and efficient choice for EV charging applications, supporting the growing demand for sustainable transportation solutions. By enhancing PQ, the Ferdowsi Converter contributes to minimizing power quality concerns, promoting the widespread adoption of EVs and reducing greenhouse gas emissions.

Irfan Çetin et.al., [9] The automobile industry is shifting towards electric vehicles (EVs) to reduce carbon emissions and air pollution, driven by regulations like those in the European Union. However, EV batteries still face challenges in cycle life, adaptability, range, and charging times. Battery Thermal Management Systems (BTMSs) are crucial for optimizing battery performance by maintaining ideal temperatures, which is essential for efficiency and safety. Research focuses on improving BTMS efficiency and compatibility across diverse EV battery types. Air cooling, liquid cooling, and PCM cooling are prominent BTMS methods, each with unique strengths and weaknesses. Air cooling systems, including passive and active methods, have been investigated to optimize temperature uniformity and reduce hot spots in battery packs. The goal is to develop effective cooling systems to ensure reliable battery performance. Continuous advancements in battery and thermal management technologies are crucial for improving the overall performance, reliability, and market competitiveness of electric and hybrid vehicles. International agreements aim to mitigate carbon emissions, and EVs are a key technological advancement in transportation, offering environmental benefits, high energy efficiencies, and reduced urban pollution and carbon emissions. The development of efficient BTMSs is critical for the widespread adoption of EVs, and ongoing research aims to address the challenges associated with battery thermal management. By improving BTMS efficiency and compatibility, the industry can unlock the full potential of EVs and support the transition to sustainable energy solutions

Lutfi A. Al-Haddad et.al., [10] The paper presents a novel battery pack design for Electric Vehicles (EVs) that maintains a uniform temperature distribution, allowing the battery to operate within its optimal temperature range. The design features a main channel where cool air passes through, ensuring a consistent temperature. The study focuses on Battery Thermal Management Systems (BTMS) to address the critical need for optimal battery performance and safety in various climates. The paper explores different BTMS methods, including air-cooling, phase change materials (PCMs), and liquid cooling, each with unique advantages and considerations. The design approach involves defining objectives and constraints, specifying module details, analyzing thermal response, predicting thermal behavior, and designing and optimizing the BTMS. The study uses finite element analysis (FEA) and machine learning-based neural networks to determine heat flux distribution in an EV hybrid battery system. FEA-based simulations effectively characterized heat flux distribution, while neural networks reduced computation time and demonstrated efficiency in heat flux prediction. The results highlight the importance of BTMS in EVs, which play a crucial role in reducing carbon emissions from the transportation sector. The novel battery pack design and simulation approach can contribute to the development of more efficient and sustainable EVs. The study's findings can also inform the design and optimization of BTMS for various EV applications

Boran Yang et.al., [11] Electric vehicles (EVs) are promoted as a sustainable alternative to traditional vehicles, reducing greenhouse gas (GHG) emissions by 27%-57%. However, EVs are not completely emission-free, as their battery packs generate carbon emissions during production, use, and recycling. This study focuses on analyzing and optimizing energy consumption to reduce indirect emissions. The research methodology involves conducting a Life Cycle Assessment (LCA) to evaluate the carbon footprint of EV battery packs. The LCA framework includes defining research goals, conducting life-cycle inventory analysis, identifying system inputs and outputs, determining calculation methods, and assessing results. The study highlights that producing lithium-ion batteries emits an average of 120 kg CO_2-eq./kWh. To reduce emissions, designers and manufacturers can use this model to evaluate and compare different battery pack designs, such as swapping liquid cooling for air-cooling. Future studies will explore energy loss in cells with different electrochemical systems and compare energy loss in different thermal management system configurations. By optimizing battery pack design, EV designers can minimize carbon emissions and create more sustainable vehicles. This research contributes to the development of eco-friendly EVs, supporting the transition to a low-carbon transportation sector. The study's findings can inform design decisions, enabling the creation of EVs with reduced environmental impact.

Bteguh Satriadi et.al., [12] As electric vehicles (EVs) gain popularity, the number of spent lithium-ion batteries will increase, posing environmental and health risks if not disposed of properly. Conventional recycling methods are costly, energy-intensive, and may produce secondary pollutants. Biohydrometallurgy, an eco-friendly and cost-effective alternative, can extract valuable metals from spent EV batteries. Lithium-ion batteries have become crucial in daily life, powering portable electronics, medical devices, and EVs. As EVs advance, researchers focus on improving battery durability, performance, and safety. This study aimed to develop sustainable and high-performance EV battery designs by investigating battery aging mechanisms, analyzing factors affecting performance and lifespan, and developing innovative battery management systems. The methodology involved a comprehensive approach to enhance battery safety and durability while evaluating the environmental impact and cost-effectiveness of the approaches. The study concludes that bioleaching, a hydrometallurgical technique, offers a sustainable solution to the growing problem of electronic waste, including spent lithium-ion batteries. This approach can help mitigate environmental concerns and support the transition to eco-friendly EV battery recycling and metal extraction. By prioritizing durability and performance, researchers can develop sustainable EV battery designs that minimize environmental impact.

Bmekhmonov Rustamkhon et.al., [13] As electric vehicles (EVs) become increasingly popular, the question of what to do with their batteries once they're no longer needed in vehicles arises. This paper explores the benefits of giving EV batteries a second life as energy storage devices. Used EV batteries still have significant energy capacity and can be repurposed to support sustainable energy solutions.Repurposing EV batteries can stabilize power grids, particularly in areas with high renewable energy use, addressing intermittency issues with solar and wind power. This approach is cost-effective, reducing the need for new battery production. The methodology involves collecting and evaluating data on used EV batteries, assessing their capacity and condition, and developing strategies for repurposing them as energy storage solutions.The study tests and validates the performance of repurposed EV batteries in stabilizing power grids and analyzes the cost-effectiveness and environmental benefits of this approach. The results are compared with traditional energy storage solutions, and the methodology is refined based on the findings and industry feedback.The conclusion highlights the potential of reusing old EV batteries for storing energy in stationary locations, supporting sustainable energy and environmental protection. This approach can help address the growing challenge of what to do with old EV batteries, reducing waste and promoting a more circular economy.

Bhisham Alghamdi et.al., [14] This study investigates cooling systems for electric vehicle batteries, focusing on a phase change material (PCM) and thermoelectric cooling system. The results show that using only PCM allows battery temperatures to reach a dangerous 85°C, while adding thermoelectric cooling reduces the temperature to 76°C, still too high and risking overheating and battery damage.The study highlights the importance of finding sustainable energy solutions, particularly for electric vehicles, which require electricity to recharge their batteries. Renewable energy sources, such as solar energy, offer a promising solution. The experimental study tests four different configurations of a Battery Thermal Management System (BTMS) using PCM and thermoelectric cooling.The results demonstrate that using only PCM is insufficient to maintain a safe battery temperature, and adding a thermoelectric module helps but is still inadequate. This poses a risk of thermal runaway, harming battery performance and safety. The study emphasizes the need for improvements to ensure battery safety and performance.The research aims to address the challenges of global warming, pollution, and energy scarcity by exploring sustainable energy solutions for electric vehicles. By developing effective cooling systems for electric vehicle batteries, the study contributes to the transition to a more sustainable and environmentally friendly transportation sector.

Bji-Xiang Wang et.al., [15] Researchers are developing passive cooling methods to prevent thermal runaway in electric vehicles, particularly when the vehicle is turned off and charging. Traditional active cooling systems shut off in this state, making passive cooling crucial for safety. A new material made of a thin layer of graphene film has been developed to enhance thermal radiation and improve heat dissipation.The material was tested in a battery-cooling scenario and showed promising results. Thermal runaway can cause fires and explosions in lithium-ion batteries, making thermal management a critical safety concern. To improve battery safety, researchers tested two lithium-ion batteries with different cooling schemes, including passive and forced-air cooling.The experiments used a heat pipe and heat sinks to enhance cooling and measured temperature distribution with an infrared camera. The results highlight the importance of passive cooling methods to prevent thermal runaway. The new graphene material shows potential for improving battery safety and preventing thermal runaway.The study aims to address the critical safety concern of thermal runaway in electric vehicles, particularly during charging. By developing effective passive cooling methods, researchers can improve battery safety and prevent catastrophic consequences. The graphene material offers a promising solution for enhancing thermal radiation and cooling batteries.

Elna Jk Nilson et.al., [16] As electric vehicle adoption grows, concerns about lithium-ion battery fires and explosions increase. This study investigates the combustion of gases released by damaged or heated Liion batteries using computer simulations. The researchers tested various gas mixtures and found that flame speed and temperature varied significantly.The study aims to improve safety measures and prevent fires in electric vehicles by understanding gas production and composition, and factors affecting gas production. The methodology involved identifying the problem of thermal runaway, researching gas production and composition, and determining factors affecting gas production.The experimental approach included testing different battery chemistries, varying state of charge and temperature, and measuring gas production and composition. The study used calibrated sensors for gas detection and temperature control devices.The conclusion highlights the development of a new model to understand how gases from Li-ion batteries burn, which can be used to study different battery mixtures. This research contributes to improving lithium-ion battery safety and mitigating the risk of thermal runaway, fires, and explosions in electric vehicles.The study's findings can inform the development of safer battery designs, improved battery management systems, and more effective emergency response strategies. By understanding the combustion behavior of gases released by Li-ion batteries, researchers can reduce the risk of fires and explosions, ensuring a safer transition to electric vehicles.

Arif Devi Dwaipayan et.al., [17] Electric vehicles, particularly Battery Electric Vehicles (BEVs), are gaining popularity in Indonesia. However, battery problems can lead to thermal issues, including overheating and explosions. Despite having a Battery Management System (BMS), risks still exist. To address this, an outreach activity was conducted in partnership with Bluebird Group Bali to educate drivers on battery maintenance and safety.The activity targeted 24 special electric vehicle drivers and covered topics like battery types and maintenance. Various materials, including guidebooks, brochures, and stickers, were used to engage participants. The goal was to educate drivers without disrupting their operations.The event was successful, with 85.40% of participants expressing satisfaction. The activity aimed to promote safe transportation by teaching drivers how to maintain and handle batteries properly. By doing so, it can reduce the risk of battery-related accidents and ensure a smoother transition to electric vehicles.The study highlights the importance of battery maintenance and safety in electric vehicles, particularly in Indonesia, where their adoption is increasing. By educating drivers and promoting best practices, the risk of battery-related accidents can be minimized, and the overall safety of electric vehicles can be improved.

Ahmad A et.al., [18] Electric vehicles (EVs) are gaining popularity due to improved lithium-ion batteries, performance, government incentives, and environmental concerns. This article explores the progress and future potential of lithium-ion batteries, including energy density, life, safety, and fast charging. It also discusses material sourcing, supply chain, and recycling, crucial for sustainable growth and adoption of EVs.In 2023, around 1 in 4 new cars sold globally were electric, with China, Europe, and the US accounting for 95% of sales. Emerging markets like Southeast Asia and Brazil are also seeing increased electric car sales. Governments are implementing bans on gasoline and diesel vehicles and offering incentives for electric vehicle adoption, driving growth.Lithium-ion batteries have improved significantly since their introduction in 1991. They work by moving lithium ions between electrodes and can be made with different materials, making them versatile. The article highlights the progress in lithiumion battery technology, including increased energy density, longer life, and improved safety.The future of electric vehicles and lithium-ion batteries looks promising, with continued investment and improvement expected. Recycling options are emerging, and the industry is working towards sustainable growth and adoption of EVs. With lithium-ion batteries getting better and safer, they are ideal for electric vehicles, and their future looks bright.

Kanit Hantanasirisakul et.al., [19] As electric vehicles (EVs) become more popular, the demand for lithium-ion batteries is increasing, raising concerns about rare metal availability and environmental impacts. To address this, reusing and recycling spent batteries is crucial. This review explores options like reusing batteries in less demanding applications, repairing electrode materials, and recovering valuable components through recycling.By 2030, there will be 220 million EVs on the road, generating a large number of old batteries. The recycling market for lithium-ion batteries is growing rapidly, but improper handling can harm the environment and human health.

Sustainable recycling and reuse processes are essential.The review highlights the challenges of reusing EV batteries, including predicting battery aging behavior and evaluating the battery's state of health (SOH) and remaining useful life (RUL). Various tests are necessary to assess the battery's condition, and disassembling may be required for packs with faulty cells.Recycling lithium-ion batteries is complex, but extracting their remaining value can help lower the cost of new EVs. The best approach is to reuse batteries from EVs, reducing waste and creating a more sustainable battery life cycle. This requires developing efficient and cost-effective methods for evaluating and reusing batteries, as well as addressing safety concerns. By doing so, the environmental and economic benefits of EVs can be maximized.

Oscar E. Rojas et.al., [20] Lithium-ion batteries, which power electric vehicles, are affected by various environmental conditions. This review paper examines over ten performance parameters to understand their impact on battery performance, integrity, and safety. The study finds that temperature and vibration have a critical impact on battery performance, but there is a lack of research on how these factors affect batteries.The paper highlights the importance of improving battery performance for widespread electric vehicle adoption. However, heat and vibration from external and internal sources affect battery performance, and combined research on these effects is limited. The paper proposes a new solution for the automotive industry and academia.A thorough literature review was conducted to identify performance parameters affecting lithium-ion battery packs. The review involved searching for relevant journal articles, selecting papers, reading and analyzing them, and extracting information related to battery performance improvement or deterioration.The conclusion emphasizes the need to study how vibrations and temperature changes combine to impact battery safety and performance. Despite extensive research, there is still a need for further investigation to improve battery performance and safety. The paper provides a comprehensive theory on the effects of vibration and temperature on lithium-ion battery packs, highlighting the importance of addressing these factors for reliable and efficient battery performance..

Q.L. Yuea et.al., [21] This study investigates the thermal management of electric vehicle battery packs, focusing on liquid cooling systems. The research finds that interspersed cooling plates reduce peak temperatures by 15% compared to bottom-mounted designs, enhancing thermal performance. Optimal coolant flow direction and higher flow rates also improve thermal performance, while inlet temperature adjustments have minimal impact on temperature uniformity.The study highlights the importance of efficient thermal management in electric vehicles, as high temperatures can accelerate battery aging, elevate safety risks, and reduce battery capacity and lifespan. The research compares four thermal management system designs for a lithium-ion battery pack during a 2.0 C discharge process.The results show that Type B performs best, maintaining a maximum temperature of 36.33 °C and reducing temperature difference to 10.81 °C, with a significantly higher cooling power-to-volume ratio. This design effectively dissipates 62.2% of battery heat at 2.0 C discharge. The study demonstrates the importance of optimal thermal management system design for maintaining optimal battery performance and safety in electric vehicles.The findings of this study can inform the development of more efficient thermal management systems for electric vehicles, contributing to improved battery performance, safety, and overall vehicle efficiency. By reducing peak temperatures and temperature differences, electric vehicles can operate more reliably and sustainably

Mengqi Hu et.al., [22] The paper highlights the growing importance of electric energy and the crucial role of lithiumion batteries in electric vehicles (EVs). Lithium-ion batteries offer high specific energy, low self-discharge, and strong cycling performance, making them ideal for EVs. Despite safety concerns, the use of lithium ions in cathodes ensures safer operation.The paper discusses the characteristics of lithium-ion batteries, including their high energy density, stable voltage output, and excellent cycle life. It also explores the development of new cathode materials, such as $LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$ (NCM811), which offers improved thermal stability and capacity.However, NCM811 faces challenges, including Jahn-Teller lattice distortion, which decreases capacity during recharges and discharges. The cyclic properties of NCM materials also decrease as the density of Ni increases.The paper concludes that electric vehicles offer greater simplicity, quieter operation, and lower maintenance costs compared to liquid fuel vehicles, contributing to their increasing popularity as a sustainable transportation option. Lithium-ion batteries play a critical role in this trend, and ongoing research aims to improve their performance and safety.Overall, the paper emphasizes the importance of lithium-ion batteries in the transition to sustainable transportation and highlights the need for continued innovation to address the challenges facing these critical components.

Patcharin Saechan et.al., [23] The abstract highlights the importance of efficient thermal management of lithium-ion battery packs in electric vehicles (EVs) to prevent capacity degradation and safety issues. Air cooling systems are preferred due to their cost-effectiveness, simplicity, and reliability, but maintaining uniform temperatures remains a challenge. Research focuses on optimizing cooling strategies through numerical simulations to enhance battery pack design and performance planning.The introduction emphasizes the growing demand for lithium-ion batteries in EVs due to their high energy density, specific power, and long cycle life. However, battery performance and longevity are sensitive to temperature extremes, requiring effective thermal management systems to maintain optimal temperatures.The study investigates air-cooled thermal management of a cylindrical battery pack, exploring different cell layouts and cooled-air velocities. The results show stable initial heat generation, increasing towards discharge completion due to thermal coefficients and internal resistance. This highlights the need for precise cooling strategies to maintain battery performance and longevity under various discharge rates.The study demonstrates the importance of thermal management in lithium-ion battery packs and the need for optimized cooling strategies to ensure efficient and safe operation. The findings can inform the development of more effective thermal management systems for EVs, contributing to improved battery performance, longevity, and overall vehicle efficiency.

Elisa Braco et.al., [24] This study examines the impact of degradation on reused electric vehicle battery modules, focusing on performance, capacity variation, and behavior in second-life applications. The findings show that reused modules experience decreased performance at low temperatures and high discharge rates, which worsens with aging. The capacity dispersion within modules remains similar between new and reused samples, but inter-module differences are significantly greater in second-life scenarios.The study analyzed battery modules from the Nissan Leaf electric vehicle, dividing them into used (second-life) and brand-new groups. The results highlight the significant impact of temperature on capacity measurements in reused modules, with a sixfold effect compared to discharge current. Energy efficiency in second-life modules is also affected by temperature and discharge current, with degradation causing up to 76% energy loss in practical applications.The study demonstrates the importance of considering degradation when repurposing electric vehicle batteries for second-life applications. The findings can inform the development of strategies to mitigate the effects of degradation and optimize the performance of reused battery modules in applications such as energy storage and battery swapping. By extending the life of electric vehicle batteries, second-life applications can help reduce waste and support the transition to a more sustainable energy future.

Weidong Chena et.al., [25] This paper reviews recent advancements in lithium-ion batteries for electric vehicles (EVs), highlighting their benefits and limitations. It discusses common methods for sorting batteries and critically examines challenges in estimating remaining useful life (RUL) and state-ofcharge (SOC). The paper proposes a novel approach for sorting retired lithium-ion batteries and accurately predicting their RUL and SOC.The introduction emphasizes the importance of transitioning to EVs to mitigate carbon dioxide emissions and highlights the advantages of lithium-ion batteries, including high energy density and long service life. However, it also notes challenges such as cost, stability, and safety concerns.The paper discusses the importance of sorting lithium-ion batteries to improve consistency and reduce inconsistencies in battery pack performance. It notes that cell-to-cell variations in resistance, OCV, and SOC can significantly affect the overall efficiency and lifespan of the battery pack.The conclusion summarizes the critical research topics in lithium-ion batteries, including capacity estimation, battery sorting, RUL prediction, circuit modeling, and SOC algorithms. It evaluates existing methods, discussing their strengths and weaknesses, and proposes a novel approach for sorting retired lithium-ion batteries and accurately predicting their RUL and SOC.

Talal Alharbi et.al., [26] This paper proposes a planning approach for using old electric vehicle batteries (REVBs) in microgrids to store energy and power, considering their degradation over time. The goal is to find the optimal way to use these batteries to meet power demand while minimizing costs. A power sharing strategy is also proposed to extend the life of the batteries and reduce costs.The introduction highlights the importance of microgrid adequacy, which refers to the ability of a microgrid to meet power demand over a long period. Battery Energy Storage Systems (BESSs) help ensure adequacy, but REVBs' capacity decreases over time due to degradation.The paper addresses the gaps in previous studies, which neglected battery degradation and replacement costs. The proposed approach ensures microgrid adequacy while considering degradation and costs. A new concept, the energy-to-power ratio, is used to measure microgrid adequacy.The results show that using a power sharing strategy can increase the microgrid's energy capacity by 8% in later years, while maintaining a good balance between energy and power. This strategy helps allocate power among REVB units, ensuring successful operation and minimizing costs. The approach can help make microgrids more efficient and costeffective.Overall, the paper presents a new approach to planning microgrids using REVBs, considering degradation and costs, and proposes a power sharing strategy to optimize their use.

Gangling Zhao et.al., [27] This paper explores the environmental impact of using electric vehicle batteries as energy storage to help achieve net-zero emissions by 2050. The study finds that swapping batteries, reusing retired batteries, and using vehicle-to-grid technology can reduce environmental impacts, depending on factors like battery chemistry, temperature, and mileage. The UK's transition to electric transportation can reduce peak electricity demand and minimize waste by repurposing old electric vehicle batteries for energy storage. The study uses a consequential Life Cycle Assessment approach to compare different electricity generation scenarios, considering impacts from various electricity generations and battery applications. The results show that renewable energy sources like hydropower and wind power have lower environmental impacts compared to fossil fuel-based power generation. However, frequent use of vehicle-to-grid technology by electric vehicles increases environmental impacts. The study concludes that repurposing electric vehicle batteries can support a more sustainable energy system, but it's crucial to consider the full lifecycle emissions. The UK National Grid's proposal to use vehicle batteries for energy storage without considering lifecycle emissions is highlighted as a concern. The study's findings can inform strategies for reducing environmental impacts and achieving net-zero emissions by 2050.

Fazel Mohammadi et.al., [28] The growing population and increasing number of vehicles on the road have led to higher CO2 and hydrocarbon emissions, driving the growth of the battery market, particularly in the Electric Vehicle (EV) industry. The global battery market is worth billions of dollars annually, with Lead-Acid, Nickel Metal Hydride, and Lithium-ion batteries being the most common types used in EVs.The resurgence of EVs is driven by two main reasons: reducing dependence on fossil fuels and decreasing greenhouse gas emissions. Hybrid Electric Vehicles (HEVs) also offer a more environmentally friendly option, emitting less CO2 than traditional InternalCombustion Engine (ICE)-based vehicles.The comparison between batteries shows that Lithium-ion batteries have the highest energy density and longest cycle life, making them the most suitable for EVs. The annual demand forecast for EVs is expected to increase, driven by government policies and declining battery costs.In conclusion, Energy Storage Systems(ESSs), especially batteries, have improved human lives by enabling the adoption of EVs and HEVs, which reduce greenhouse gas emissions and conserve natural resources. Car manufacturers are working to enhance battery technology, management systems, and affordability to make EVs and HEVs more widely available. The continued improvement of batteries will be crucial for the widespread adoption of EVs and HEVs, contributing to a more sustainable transportation sector.

Markus Eider et.al., [29] The article discusses the importance of preserving battery health in electric vehicles (EVs) to support sustainable transportation. EV batteries can degrade quickly due to factors like fast charging, extreme temperatures, and improper use. To address this, the article presents a system that provides personalized guidance to users on how to treat their batteries kindly. The system predicts when guidance is needed and offers user-friendly tips based on the vehicle's context.The article highlights the impact of user behavior on battery degradation and the importance of adopting battery-friendly habits. It explains that lithium-ion battery degradation is caused by factors like temperature, state of charge, and cumulative use. To prevent degradation, users should keep the battery temperature within a nominal range, avoid extreme state of charge levels, and maintain a balanced operating point.The system presented in the article aims to promote battery-friendly EV usage by providing context-based guidance. Testing shows that the system works well, helping users adopt habits that extend battery life and support sustainable transportation. As the number of EVs grows globally, preserving battery health is crucial to reduce waste and minimize the environmental impact of sourcing key materials like manganese and cobalt.

Peter Sturm A et.al., [30] As battery-electric vehicles (BEVs) become more popular, tunnel safety risks are changing. The Austrian Government funded a study in 2018 to investigate tunnel safety and BEVs, including fire tests, simulations, and safety assessments. The goal is to understand the risks and develop effective emergency strategies.The study found that lithium-ion batteries behave differently in fires compared to traditional fuels. Researchers discovered that a minimum charge level is needed for a fire to start, and fully discharged batteries didn't catch fire even when heated to 250°C. However, fully charged batteries showed significant self-heating at 140°C.Full-scale car fire tests showed that electric and gasoline cars burn similarly, but electric cars released 1.0-1.5 MW more heat than gasoline cars at their peak, suggesting a slightly higher fire risk. The study concludes that BEVs pose unique fire risks due to their different combustion behavior, making firefighting more challenging.More research is needed to understand the risks and develop effective safety measures. The study highlights the importance of reevaluating tunnel safety risks as BEVs become more popular, and the need for further research in actual road tunnels to understand the risks and develop effective safety measures. The goal is to ensure tunnel safety as the number of BEVs on the road increases.

J. Malinauskaitea et.al., [31] The increasing number of electric vehicles (EVs) on the road poses a significant challenge in managing old lithium-ion batteries. The EU and UK policies on battery waste are lacking, failing to encourage innovation in reusing and recycling batteries. By 2030, there will be 125 million EVs on the road, generating nearly 5 million tons of lithium-ion batteries, with recycling technologies struggling to keep up.The current regulations categorize EV batteries as "industrial batteries" without specific guidelines for recycling and disposal, leading to a potential waste problem. Globally, over 11 million tons of spent batteries are expected to be discarded by 2030, with many ending up in landfills outside the EU.To address this challenge, effective battery waste management requires a strong connection between technology and regulations. Better technologies are needed to separate materials, and standardized battery designs and shapes can improve recycling. Policies must hold manufacturers responsible for recycling and reusing old batteries.By addressing these challenges, we can overcome the barriers to successful battery recycling and create a more sustainable future. The paper highlights the need for better policies to avoid a battery waste problem and support a circular economy, encouraging innovation in reusing and recycling batteries.

Jinhua Xiaoa et.al., [32] The increasing demand for electric vehicle batteries (EVBs) raises concerns about resource usage, manufacturing costs, and environmental harm. Disassembling EVBs is crucial for recycling and reducing waste, but the process is complex and difficult to share information. To address this, the paper proposes a standardized model using STEP, EXPRESS-G, and IDEF0 languages to improve information sharing and make battery disassembly easier.The model aims to boost efficiency, reduce labor costs, and enable robotic disassembly in the future. The paper demonstrates the basic design of EVBs, creates a data model to describe the disassembly process, and illustrates the step-by-step process for disassembling batteries.The goal is to make it easier to disassemble vehicle batteries efficiently and accurately, reducing environmental harm and resource waste. The paper identifies areas for future research, including testing and developing a platform for sharing disassembly information. By standardizing the disassembly process, the paper contributes to the development of better recycling systems and the reduction of waste in the electric vehicle industry.The proposed model has the potential to improve the sustainability of the electric vehicle industry by enabling more efficient and effective recycling of EVBs. By making it easier to disassemble and recycle EVBs, the model can help reduce the environmental impact of the industry and support the growth of a more circular economy.

Samarendra Pratap Singh et.al., [33] The adoption of electric vehicles (EVs) is crucial for sustainable development and addressing environmental issues. Lithium-ion (Li-ion) batteries power EVs, but estimating their state, health, and lifespan is a significant challenge. This study reviews EV types, battery characteristics, and research on Li-ion battery health monitoring. It summarizes techniques and models used to estimate battery performance, state-of-charge, capacity, and remaining lifespan.Accurately estimating a battery's state-of-charge is crucial to prevent unexpected system shutdowns and protect batteries from damage. Researchers have developed mathematical models to simulate battery behavior. The study classifies EVs into hybrid, plugin hybrid, and battery EVs, and discusses propulsion systems.The paper concludes that EVs are the future of transportation, but battery systems need improvement. Researchers use physical, data-driven, and combined models to enhance battery performance and safety. The study provides valuable information for researchers and discusses safety tests. The goal is to ensure EV reliability and efficiency, addressing concerns and challenges in the EV market.The study highlights the importance of accurate battery state estimation and the need for continued research in Li-ion battery health monitoring. By improving battery performance and safety, EVs can become a more viable option for sustainable transportation, reducing carbon emissions and addressing environmental issues.

Vima Mali et.al., [34] The paper reviews research on battery thermal management systems (BTMSs) to improve battery performance and safety in electric vehicles (EVs). It focuses on enhancing thermal performance with suitable BTMS selection and design, and using supercapacitors to reduce thermal load. A well-designed BTMS regulates battery temperature, ensuring safety and longer battery life.The paper summarizes recent developments in BTMS, including direct and indirect cooling methods, and highlights the benefits of using supercapacitors to reduce thermal load, cost, and weight in EVs. Experimental studies on BTMS are discussed, including natural convection and forced convection cooling methods.The paper concludes that designing an efficient BTMS is crucial for EVs, and that air-based cooling systems have limitations due to low thermal conductivity and poor heat transfer efficiency. The goal is to enhance battery thermal performance by selecting and incorporating suitable BTMS, addressing the need for efficient heat management in EVs.The paper aims to contribute to the development of more efficient and sustainable EVs, by improving battery performance and safety through better thermal management. By addressing the challenges of heat management in EVs, the paper seeks to support the transition to a cleaner and more sustainable transportation sector.

J.T. Marcos et.al., [35] The growing demand for electric vehicles and rapid innovation in battery technology creates uncertainties in the supply chain. This paper identifies and analyzes these uncertainties through a content analysis of media articles. The study finds 102 instances of uncertainty, mainly related to environmental factors, control, and supply.The key causes of uncertainty are cobalt, availability and quantity of materials, stock control policies, government regulations, and political instability. The study highlights the need to address these uncertainties to ensure a stable supply chain for lithium-ion batteries.The paper introduces environmental uncertainty as a new source, including unpredictability in the business environment, government legislation changes, political instability, and technological innovations. The study uses the "uncertainty circle" to describe sources of uncertainty, categorizes them, and classifies them into levels.The goal is to provide a clear understanding of these uncertainties to help decisionmakers develop effective strategies. The paper concludes that addressing these uncertainties is crucial for a stable supply chain, particularly in the context of cobalt, lithium, and nickel.The study's findings can help car manufacturers and battery suppliers develop strategies to mitigate these uncertainties and ensure a stable supply chain for lithium-ion batteries. By understanding the sources of uncertainty, decision-makers can better manage the closed-loop supply chain and reduce the risks associated with raw material availability, government regulations, and technological innovations.

Mehmet Sen et.al., [36] The widespread adoption of electric vehicles (EVs) is hindered by concerns about lithium-ion batteries' (LIBs) range, safety, and risk of fire/explosion. This review examines LIBs' working principle, performance, and failures, highlighting factors that affect their performance and cause issues. It also evaluates potential replacement batteries for EVs, discussing their challenges. The study compares various battery technologies, weighing their advantages and disadvantages. The authors believe EVs are the future of transportation and that developing better battery systems is essential. The review aims to contribute to the EV industry and provide valuable insights for designers, researchers, and manufacturers. The growth of EVs has transformed the automotive industry, bringing significant changes and opportunities. However, advanced batteries are not yet commercially available for EVs. Research and development efforts are ongoing to improve LIB performance and reduce costs. New materials like silicon are being explored to increase energy density and fast-charging capabilities, but they also have drawbacks. Despite challenges, future batteries are expected to be commercialized soon. Meanwhile, LIB prices are decreasing, making EVs more accessible. The review highlights the need for continued innovation in battery technology to support the widespread adoption of EVs and achieve a sustainable transportation future.

Md Mahmud et.al., [37] Lithium-ion batteries in electric vehicles (EVs) offer many benefits, but can be prone to safety issues and performance problems due to temperature fluctuations. To address this, researchers are exploring phase change materials (PCMs) to regulate battery temperature. This review paper discusses various thermal management strategies for Li-ion batteries, including their advantages, disadvantages, and cost-effectiveness. CMS can help manage battery temperature by absorbing and releasing heat during charging and discharging, improving performance and lifespan. They can be integrated into the battery pack or used separately and combined with other cooling technologies. The choice of PCM depends on factors like operating temperature range, heat generation, and desired thermal performance. The paper concludes that EVs need to operate in varying climates, which can be challenging for lithium-ion batteries. To maintain performance, LIBs require temperature stability, which can be achieved through cooling techniques like air, liquid, and PCM cooling. However, air cooling systems are bulky and inefficient, while electric heating can lead to uneven temperature distribution, reducing battery lifespan. PCM cooling offers a promising solution, but further research is needed to optimize its use in EVs.The paper highlights the importance of thermal management in EVs and the potential of PCMs to improve battery performance and safety. By regulating battery temperature, PCMs can help EVs operate efficiently in varying climates, making them a more sustainable transportation option.

Thomas L et.al., [38] Lithium-ion batteries are widely used in various applications, but laboratory testing of larger multi-cell packs lacks safety guidance. This paper addresses safe testing of commercial highcapacity single cells and multi-cell packs, considering potential hazards and failure modes. It proposes control measures like fuses, contactors, and good system design practices, as well as enclosures and fire suppression systems as backups.The paper highlights the importance of proper manufacturing and design to prevent battery failures, which can be catastrophic. It focuses on the risks associated with testing lithium-ion batteries, providing examples and procedures to address these risks. A Failure Modes and Effects Analysis (FMEA) was conducted to identify potential battery failure modes in laboratory testing, helping develop strategies for safe testing and mitigating hazards.The paper concludes that simple steps can prevent battery failure by respecting safety-critical limits. Additional measures, such as contactors and fuses, can enhance safety and minimize risks, but incur a cost. The investment is estimated at £200 per series string, depending on the system specification and maximum operational current rating. The paper aims to propose methods to mitigate risks associated with testing lithium-ion batteries, tailored to the specific type of battery being tested.The paper emphasizes the importance of safety in laboratory testing of lithium-ion batteries, highlighting the potential hazards and failure modes. By following the proposed control measures and safety practices, the risks associated with testing can be minimized, ensuring a safer testing environment.

Zhi Xu et.al., [39] Researchers used computer simulations to study how to improve cooling of electric vehicle battery packs using air flow. They found that changing the air inlet position and speed significantly affects cooling performance. Moving the inlet from 20mm to 30mm reduced battery temperature by 4.17 K, while increasing air speed from 2m/s to 5m/s reduced temperature by 8.5-18.5 K.The study aimed to optimize inlet position and air speed to improve cooling due to better airflow and heat transfer. The findings provide valuable guidelines for designing better battery cooling systems in electric vehicles. The research focused on air cooling, a common solution due to its low cost and high reliability. The study investigated various aspects of air cooling, including optimizing inlet angle, outlet angle, and channel width, as well as designing secondary inlets and studying channel sizes and inlet Reynolds numbers. The results show that adjusting the inlet position and air speed can significantly improve cooling performance, reducing battery temperature and increasing its reliability and lifespan.The study's conclusions can be used to develop more efficient battery thermal management systems, enabling wider adoption of electric vehicles. By optimizing air cooling systems, manufacturers can improve the performance, reliability, and safety of electric vehicles, addressing a critical challenge in the industry.

S. Wiriyasart et.al., [40] Battery thermal management systems are crucial for electric vehicles (EVs) due to the significant impact of temperature on energy storage, durability, and efficiency. This study used computer simulations to find the best cooling method for EV battery modules. It found that the temperature distribution is most affected by coolant flow direction, mass flow rate, and type.Using nanofluids as a coolant reduced the maximum temperature by 28.65% compared to traditional methods, but increased pressure drops. Nanofluids also provided better cooling than water. The study's approach can help optimize EV battery cooling systems to maintain a safe temperature range. Previous studies have explored various cooling methods, including aircooling, heat pipes, and liquid cooling. This study conducted grid-independent tests to ensure accurate results and assumed a constant heat generation of 12.24 W from the battery cell, making the results conservative and applicable to real-world scenarios. The study concludes that modern heat transfer technologies are needed to evenly distribute the heat generated by the battery pack. Optimized cooling performance is required to effectively manage heat and ensure the overall performance of the battery pack, given the limited space and cooling capacity of EV cooling systems. The study's findings can help improve the design and performance of EV battery cooling systems, enhancing the efficiency, reliability, safety, durability, and lifespan of high-power density battery packs.

CONCLUSION:

The future of transportation is undoubtedly electric, and a thorough analysis reveals that electric vehicles (EVs) will play a vital role in shaping the industry's landscape. With an expected average of 14 million units manufactured annually, EVs are poised to revolutionize the way we travel. Mechanical engineers will be at the forefront of this transformation, collaborating with electrical engineers to design efficient propulsion systems, computer science engineers to develop advanced vehicle software, and materials scientists to create innovative battery technologies. The battery management system (BMS) is a critical component in this endeavor, ensuring optimal performance, safety, and longevity. By optimizing battery performance, the BMS plays a major role in extending the range and lifespan of EVs, making them a viable option for consumers. And finally electric vehicles, hybrid electric vehicles and plug-in hybrid electric vehicles are highly efficient. electric vehicle batteries have shown significant advancements in recent years, offering improved energy density, longer lifespan, and faster charging capabilities. Despite challenges such as high cost and limited infrastructure for charging, the growing demand for electric vehicles and ongoing research and development efforts are driving innovation in battery technology. With continued investment and innovation, electric vehicle batteries have the potential to revolutionize the automotive industry and play a crucial role in reducing greenhouse gas emissions and combating climate change.

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