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# Developments in Thermal Engineering: A Review on the Strategies of EV Car Battery Thermal Management

Journal of Electrical Systems

**Abstract**: - In the late 19th century, Electric Vehicles (EVs) first came into existence and were developed and undergone profound changes over recent decades. Since electricity renders a level of silence, comfort, and simple operation that can't be attained by the gasoline engine cars of the time, it is one of the most preferred ideas for motor vehicle propulsion. The vehicles that are powered by electric motors employing energy stored in rechargeable batteries or any other energy-storing device are called EVs. Electricity is utilized by the EV as their primary energy source. Advancement in the transportation sector with the need for a sustainable and eco-friendly environment is signified by electric cars. The major source of modern electronic transportation is EV batteries. EV batteries are developing centered on traditional Internal Combustion Engine (ICE) vehicles for more sustainable transportation and improvement of electric mobility. Thermal Management (TM) ensures that the battery operates within the optimal temperature range, thus improving efficiency and preventing overheating. The cooling system, Phase Change Material (PCM), liquid cooling, and heating system are utilized for effective TM and overall vehicle performance to overcome the abovementioned issues. Thus, this review's objective is to explain the EV Battery Thermal Management (BTM), cooling systems for TM of EV battery, Thermal Runaway (TR) prevention for TM of EV battery, the combination of EV battery thermal system with Heating, Ventilation, and Air Conditioning (HVAC), and performance evaluation of TM of EV battery.

***Keywords***: Electric Vehicles, Battery Thermal Management, Cooling Systems, Cooling efficiency and Thermal runaway

## I. Introduction

Owing to numerous factors, there has been an improvement in the demand for EVs recently. The most noticeable factor is that the greenhouse gas emissions are reduced by the EV [1]. When analogized to conventional ICE vehicles across Europe as a whole, EVs are accountable for significantly **lower emissions of** greenhouse gas over their lifetime. The EVs' working principle is that the entire load of a conventional ICE is transferred to a battery-powered engine [2]. EVs are noiseless, highly responsive, and have better energy conversion efficacy and no exhaust emissions along with lower overall vehicle emissions when analogized to conventional ICE vehicles [3]. EVs have lower overall vehicle emissions, particularly when deeming the overall lifecycle from production to operation. When analogized with ICE vehicles powered by renewable energy sources, the overall emissions are generally lower while the manufacturing of EV batteries can be resource-intensive [4]. An increasingly crucial role in renewable energy utilization and storage is played by batteries. For instance, the performance of EVs and Hybrid Electric Vehicles (HEVs) is highly contingent on the capacity of the battery. For monitoring and optimizing the batteries' thermal status, Battery Thermal Management Systems (BTMS) are introduced. A crucial factor for battery operating performance is the battery temperature [5]. Enhancing the Lithium (Li)-ion cells' lifetime is the aim of BTMS. Therefore, the temperature level and distribution are regulated by the Battery System (BS). Specifically, when the cells are liable to higher rates of charging (e.g. quick charging) and discharging (e.g. higher-performance vehicles) and the vehicle is processed in higher or lower ambient

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temperatures, BTMS is essential [6]. The simplified example of a battery EV Thermal Management System (TMS) with customer expectations is explained in Figure 1[7].

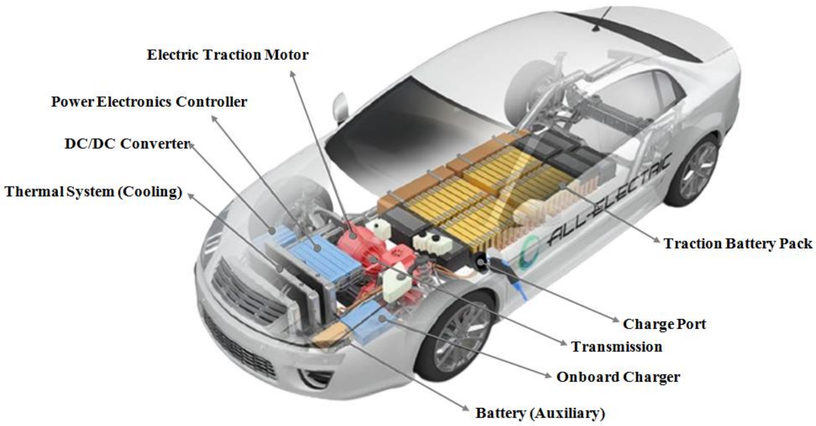


**Fig. 1:** Simplified example of a battery electric vehicle thermal management system with customer expectations

BTMS for EVs must meet the following conditions: (1) higher cooling performance, (2) superior temperature uniformity, and (3) smaller size as well as the weight of the BTM system. Heat generation from the battery turns out to be a severe issue since the capacity of the battery is being augmented in EV applications for extending the driving range [8,9]. Therefore, explaining and identifying the current strategies and developments in TM systems for EV batteries is the aim of the review. Effective TM can optimize battery performance, safety, longevity, and overall vehicle efficiency [10].

Following the introduction section, the research questions and article selection strategy are demonstrated in "Section 2"; the literature review on the strategies of EV car TM is defined in "Section 3"; "Section 4" explains the study's summary; "Section 5" details the conclusion with future recommendations.

## II. RESEARCH QUESTIONS AND ARTICLE SELECTION STRATEGY

A Research Question (RQ) is a perfect and short one that concentrates the research for a paper, project, or literature review. The scope of the research is defined by RQ, which also determines the specific problem or issue the study aims to address. A well-formulated RQ aids researchers stay concentrated on their objectives and renders a framework to collect and analyze data. Moreover, a systematic approach to identifying, examining, and selecting relevant articles and sources for inclusion in a literature review or research study is an article selection strategy.

### *A. List of RQs*

The developed RQ helps the researcher to form an applied idea that can be tested. RQ facilitates the production of an investigation of a problem or issue instead of a simple description of it. The RQs are described in Figure 2.

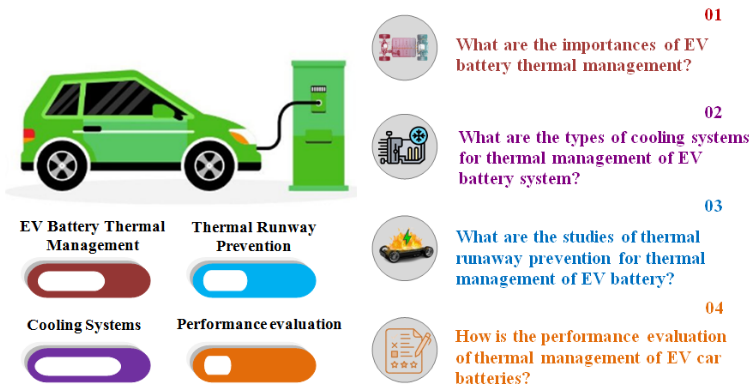

**Fig. 2:** Research questions

*B. Article selection strategy*

To safeguard a comprehensive and related analysis of the topic, choosing the right articles for a review or research involves a planned approach. The article selection process is important to identify related studies concerning objectives. By utilizing related keywords, relevant studies are identified to attain answers to the questions. Especially, the usage of associated keywords is significant in the research process during the article selection phase.

*Inclusion and Exclusion Criteria*

Research studies written only in the English language have been included in the analysis since the English language is found to be unique and understandable to all kinds of people. In the study, the research studies published between 2015 and 2023 are concentrated. The inclusion criteria and exclusion criteria of a study are described in Table 1.

**Table 1:** Inclusion criteria and Exclusion criteria

| Inclusion criteria | Exclusion criteria |
|---|---|
| Papers associated with EV BTMS were included | Papers that only concentrated on the domain of EV were excluded |
| Research studies describing the cooling strategies of EV BTMS were included | Research studies that only describe the challenges related to EV BTMS were excluded |
| In this review-based study, the research studies published between 2015 to 2024 were included | Research studies published before 2015 were excluded |

*Resources of search and selection strategy*

The resources that are used for the literature search and evaluation procedure have been explained in this section.

Resources: To extract data related to the matching objective based on initial research, academic search engines like IEEE Xplore, Xplore, Springer, Elsevier, and Google Scholar are utilized.

Database Selection: Some of the important databases, where the articles were recognized and chosen for the literature review, are Scopus, Science Citation Index Expanded (SCIE), and Web of Science (WOS).

Database Insights: Scopus performed better than the other databases. In addition, since it indicates a comprehensive abstract and citation database of peer-reviewed literature, it is found to be distinct. In the Scopus database, scientific journals and conference proceedings are included, thereby making it an appreciated resource for researchers. To clearly report the process of performing a review-based study, PRISMA is designed by the systematic reviewers. PRISMA guidelines help to ensure that the work is reported in a way to meets the highest standards of clarity. Hence, Figure 3 exhibits the Prisma framework,

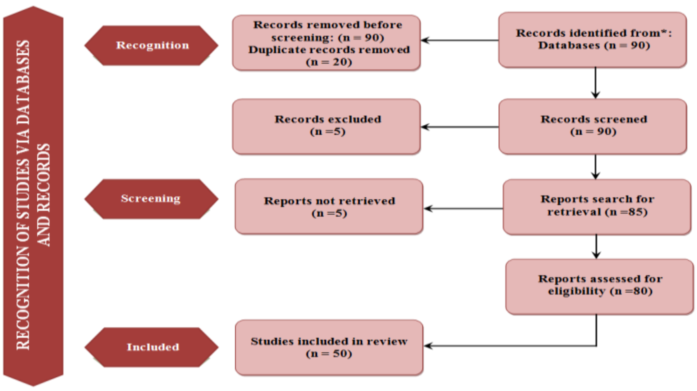

**Fig. 3:** Prisma Framework

*Paper Selection*

A total of 50 papers were chosen for the review-based study after analyzing the accurate count of journals that are associated with the primary keywords. The papers were chosen grounded on predefined criteria. Figure 4 presents the graphical representation of the search results of this review-based study.

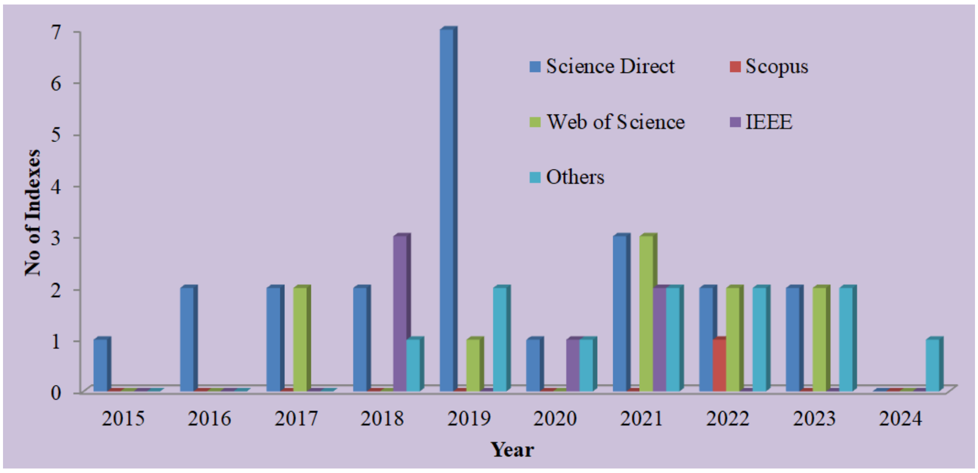


**Fig.4:** Search results of the article

## III. OVERVIEW OF EV BATTERY THERMAL MANAGEMENT

While ensuring passenger comfort in the cabin, the TMS is accountable for keeping the electric motor, the power electronics, and the battery at the correct temperature [11]. A significant aspect of EVs to ensure optimal performance, safety, efficiency, and longevity of the battery is BTM [12]. An EV's battery temperature is regulated by the BTMS [13], which ensures that the battery functions within the desired temperature range [14].

Joshua, et al [15] explained the BTMS for EV utilizing heat pipes. For the heat pipe portion, the entire system's modeling was performed centered on a 2-stage analysis, and for the cold plate portion, a single-phase analysis was done. As per the outcomes, the applied system had the potential to disintegrate 50W heat load effectively as of every cell at a temperature lower than the provided 55°C limit.

Zhen, et al [16] examined the combination of a TMS with battery cooling and motor waste heat recovery for EVs. Some of the parameters analyzed were environmental temperature, waste heat load, and compressor speed. Analysis signified that the State of Charge (SOC) was diminished by up to 10.60% with battery cooling.

Chong, et al [17] defined the real-time BTM approach for Connected and Automated HEVs (CAHEVs) grounded on Iterative dynamic programming. The outcomes illustrated the feasibility as well as the effectiveness of the applied BTM strategy, thus causing considerable BTM energy reduction.

Choon, et al [18] optimized the TMS in EV battery packs for sustainable transportation. For attaining the maximal and average temperature along with fluid flow velocity, analyses like Computational Fluid Dynamics (CFD) were performed. It was found from the outcomes that the 3 parallel as well as 8 series (3p8s) battery pack design with a cell arrangement angle ($\theta = \pi/3$) was the most feasible. It also could operate consistently in TM.

Sowmya, et al [19] described the BTMS for EVs. The trade-offs analyzed for the BTMS systems were cost, performance, size, dependability, Energy Consumption (EC), weight, and safety. In the software MATLAB/SIMULINK, these systems' model was built. As per the outcomes, when analogized with the different driving cycles in cold weather, the BTMS feature was strongly affected by diverse driving cycles in hot weather. The most crucial factor for the BTMS was the ambient temperature.

Ming, et al [20] explained the system simulation on refrigerant-centric BTM technology for EVs. Some of the parameters analyzed grounded on the vehicle system approach were thermal response, system's irreversibility, and Energy Efficiency (EE). As per the outcomes, a negative effect on both the energetic and the exergetic Coefficient of Performance (COP) was created by the intensification of stated driving conditions.

### A. *Cooling systems for thermal management of EV battery system*

A crucial role in ensuring the efficient and safe operation of EV batteries is played by the BTMS [21]. For cooling the battery pack, air is utilized in this method. The air carries away the heat generated during operation while air flows over the battery surface. This is termed as air cooling system [22]. One of the other most popular methods for EV BTM is liquid cooling [23]. When compared with air cooling, liquid cooling offers better performance. However, it is slightly more expensive and necessitates additional components [24]. The studies of both air and liquid cooling for TM of EV BSs with their aim, findings, and limitations are explained in Table 2.

**Table 2:** Studies of both air and liquid cooling for thermal management of EV battery system with its aim, findings, and limitations

| Author | Cooling system | Aim | Findings | Limitations |
|---|---|---|---|---|
| Mohsen Akbarzadeh et al. [25] | Liquid Cooling Plate (LCP) embedded with PCM | To develop an innovative hybrid cooling system for Li-ion batteries' TM in EVs | The pump's energy was effectively reduced by the hybrid LCP's usage. | The effect of the thermophysical properties of PCM was not explored to optimize the cooling system. |
| Thomas Imre Cyrille Buidin and Florin Mariasiu [26] | Air-Based BTMS | Aimed to investigate the accuracy of data that was acquired through temperature's numerical analysis inside battery packs | The presented model provided a more accurate calculation with a direct impact on optimizing design as well as construction. | However, the model was only adapted to liquid cooling analysis, while the other sorts of TM were not investigated. |
| Yoong Chung et al. [27] | BTMS | Intended to explore thermal analysis for EVs using pack-level design of BTM | As per the findings, the battery pack design significantly develops the BTMS's performance. | The maximum temperature differences indicated poor results under high C-rate conditions. |
| Gang Zhao et al.[28] | Trapezoid Air-Cooling BTMS | Investigating the performance development of EVs using a Trapezoid Air-Cooling BS | At the 60 L/s inlet air flow rate, the trapezoid design provided superior cooling performances with a maximal temperature diminution of 1.17 ◦C. | Nevertheless, the study didn't fully cover the trapezoid battery pack module's full-scale numerical simulation. |
| Ankit Singh Bisht et | Vortex Generator Li- | Investigate the | The vortex | But, the |

| | | | | |
|---|---|---|---|---|
| al.[29] | Ion Batteries | vortex generators' performance for effectual cooling of Li-Ion Batteries in Hybrid EVs | generators outperformed at the 30◦ attack angle than at the 45◦ and 60◦ attack angles. Along with that, the vortex generator outperformed regarding thermohydraulic performance than the delta winglet vortex generator. | protruded BTMS's weight was very low. |
| Olanrewaju M. Oyewola et al.[30] | Air-cooled Li-ion BTMS | To examine design optimization of air-cooled Li-on battery for EVs utilizing step-like divergence plenum | As per the outcome, the 4-step case methodology with a 45 m step length rendered a decrease in maximal temperature and maximal temperature difference than the Z-type model. | Nevertheless, decreasing the step length to 28, 25, and 20 mm didn't provide any enhancement. |

Muhammad Muddasar [31] detected the air-cooled BTMS for EVs and also investigated numerous optimizations. For examining air-flow channel optimization, cell arrangement with battery packs, and air inlet/outlet position variations, numerous optimization techniques were employed in this study. Lastly, the study found that when compared with air-cooled BTMS, the active air-cooled BTMS was more effective for long-distance vehicles. Nevertheless, a lot of power was required by the active air-cooled BTMS for effective performance.

Gang Zhao et al.[32] assessed the air-cooling BTMS in EVs utilizing a higher-performance Vortex adjustment design. In this, to enhance the heat transfer coefficient in EC, the modified aerodynamic patterns together with thermodynamic properties were utilized. The study exhibited that at both lower and higher airflow rates, Design 1's cooling performance was enhanced. The Tmax and ΔT of Design 1 were lower than the conventional design at a relatively higher flow rate (47.52 L/s).

*B. Tthermal runaway prevention for thermal management of EV battery*

A critical aspect of BTM in EVs is TR prevention. It is necessary to ensure that proper TM begins during the battery design phase [33]. A combination of design considerations, specialized materials, monitoring systems, and protective measures are involved in TR prevention. It is crucial to monitor battery cells for signs of TR. Abnormal temperature increases or other warning signs can be detected by advanced sensors and monitoring systems [34].

Mark, et al [35] described the TR prevention of Li-ion batteries by the TMS. Owing to the mentioned Li-ion batteries' higher voltage, energy density, and negligible memory impacts, they were found to be more fit in numerous applications. Analysis revealed that for both enhanced pack performance and inhibition of TR or propagation, the TM of Li-ion battery packs utilizing Latent Heat Systems (LHS®) had proven to be highly efficient.

Jichao, et al [36] explained the big-data-centric TR prognosis of BSs for EVs. For TR, a thermal security management strategy was established under the Z-score framework. The outcomes signified that both the time as well as the location of the temperature fault were accurately forecasted by the applied methodology within battery limits. Regardless of the data types along with application fields, the applied method was flexible in the entire disorder systems with irregular variations.

Da, et al [37] examined the DBSCAN-centric TR diagnosis of BSs for EVs. Grounded on battery voltage, 2-dimensional fault characteristics were extracted, and for diagnosing the Potential Thermal Runaway Cells (PTRC), DBSCAN clustering was utilized. As per the outcomes, the applied methodology accurately predicted the PTRC's location in the battery pack a few days prior to the occurrence of TR.

Jichao, et al [38] elucidated the TR prognosis of BSs utilizing the improved multi-scale entropy in real-world EVs. A real-scenario-centric TR prognosis on a Li (NiCoMn)O2 ternary battery in an electric bus was presented. The outcomes exhibited that an abnormal cell was detected one week prior to the accident. By removing the redundant scales, prognosis sensitivity was optimized.

*C. Integration of battery EV with HVAC systems*

An important aspect of optimizing energy utilization, confirming battery safety, and enhancing vehicle lifespan is the combination of battery EVs with HVAC systems [39]. For power storage, battery EVs rely on Li-ion batteries. For maintaining these batteries' performance and prolonging their lifespan, efficient TM is crucial [40]. The combination of battery EVs with HVAC systems encompasses careful design and coordination for ensuring optimal performance, EE, and passenger comfort.

Tianshi, et al [41] described the status as well as the development of EV-integrated TM from BTM to HVAC. The status of EV TM globally and the fundamental proposal for further development in the sector were presented. The applied method was an effective way to advance the temperature limitation, promote the broad application of EVs in many more weathers as well as regions, and realize lower EC by utilizing numerous thermal sources and recycling wasted heat in EVs.

Shuofeng, et al [42] investigated the 2-layer real-time optimization control approach for Integrated BTM and HVAC systems in connected as well as automated HEVs. When analogized to those with accurate previews, HVAC and BTM consumption, total consumption, and battery consumption were enhanced by 3.40%, 0.52%, and 0.70%, respectively. The simulation outcomes regarding the benefits of the applied strategy were confirmed by the real-time experimental outcomes.

Taek, et al [43] explained the experimental investigation on heating performances of integrated batteries as well as HVAC systems with series as well as parallel circuits for EVs. For accurately predicting the heating performances of integrated systems with serial as well as parallel circuits for battery and HVAC, a network model was applied. Integrated systems with serial circuits exhibited higher HVAC heating capacity (5726.33 W) compared to integrated systems with parallel circuits (3869.15 W).

*D. Performance of thermal management of EV car batteries*

EV performance, safety, efficiency, and lifespan are influenced by BTM processes significantly [44]. Some of the significant parameters used for analyzing the performance of TM of EV car batteries are cooling efficiency, EC, cost-effectiveness, and safety features [45].

Maan Al-Zareer et al [46] employed 3D modeling for comparing a compact refrigerant-based system with a larger-spaced model. The compact design maintained battery temperatures below 35°C with a variation of 4°C, and variations were kept within 2°C and a maximal temperature of 31.5°C in the Artemis motorway cycle, presenting negligible performance impact from battery spacing.

Joshua Smith et al. [47] assessed cooling plate designs with production-optimized plates that offered adequate thermal performance and mechanical integration. While achieving high EE, the U-flow layout diminished average module temperature and temperature differences. Specifically, owing to the long channel length, cooling plate 2 had a higher EC.

Seho Park and ChangsunAhn [48] introduced a Stochastic Model Predictive Control (SMPC) for battery cooling. While maintaining reliable temperature control, the SMPC reduced EC by 91% compared to regular models. The performance ranged between 55-85% of the globally optimal level, with potential for enhancement via better disturbance forecasting and control algorithms.

AbubakarGambo, et al [49] evaluated hybrid TM for EV batteries centered on Li-ion tech. For superior thermal control, PCM-based systems integrated with air/liquid/heat pipes were applied. For Li-ion modules, passive management was developed that analyzed finite element-based thermal performance under abuse conditions. At various PCM shrink levels, the open medium configuration diminished the maximum temperature by 1.172 to 1.860 °C.

Mao Li et al. [50) optimized an air-centered BTMS for a battery module with 36 Li-ion cells. The maximal temperature difference of cooling air in passages and battery cells was diminished from 23.9 K to 2.1 K (91.2%) and from 25.7 K to 6.4 K (75.1%) by adjusting passage spacing, thus enhancing temperature uniformity as well as thermal performance.

## IV. SUMMARY OF THE STUDY

To store energy for propulsion, EVs rely on high-capacity Li-ion batteries. These batteries' efficient TM is vital for their performance, safety, and longevity. Owing to internal resistance and chemical reactions, heat is formed by Li-ion batteries during charging as well as discharging. High temperatures can reduce capacity and degrade battery materials. In EVs, numerous TM cooling systems are employed, including liquid and air cooling methods. Proper TM has an important impact on battery safety, longevity, and performance. It improves EE, mitigates thermal hazard risks, and extends the EV batteries' lifespan by minimizing degradation. It is clear from Figure 2 that the framed RQ is centered on diverse research concepts, such as EV BTM, cooling systems, and performance metrics. RQ has been categorized into 5 types: RQ1, RQ2, RQ3, RQ4, and RQ5.

- Significance of EV battery thermal management [1]: This RQ's main aim is to describe deeply the importance of EV BTM, and it is explained in section 3.1.
- Types of cooling systems for thermal management of EV battery system [2]: RQ2 exemplifies the types of cooling systems for TM of EV BSs and has been described in table 2 of section 3.2.
- Studies of thermal runaway prevention for thermal management of EV battery [3]: This RQ's main aim is to explain the studies of TR prevention for TM of EV battery, which is described in section 3.4.
- Performance evaluation of thermal management of EV car batteries: This RQ intended to explain the performance evaluation of TM of EV car batteries and is shown in section 3.5.

Thus, significant advantages like augmenting the efficacy of hybrid, plug-in hybrid, and EVs are rendered by TM. Indeed, still, the majority of the energy losses are associated with thermal generation, and superior performances of vehicle subsystems and superior occupant comfort could be led by governing such thermal fluxes correctly.

## V. CONCLUSION

A significant aspect of confirming the safety, reliability, along with performance of EVs is the TM of EV car batteries. The effective TM's impact on battery performance, safety, and longevity cannot be improved. By minimizing degradation, proper thermal regulation augments EE, diminishes the risk of thermal hazards, and extends the lifespan of EV batteries. The usage of advanced materials, integrated cooling systems, and smart TM algorithms are included in the emerging trends for further optimizing battery temperature control and augmenting overall EV performance. The limitation is that additional maintenance and servicing over the lifespan of the vehicle might also be required by complex TM systems. This could cause higher maintenance costs for EV owners and potential downtime if cooling system components necessitate repairs or replacements. Future researchers should take into account this limitation and find the optimum solution for diminishing the maintenance costs effectively. Overall, an essential aspect of EV technology is the TM of EV car batteries. Manufacturers can enhance battery reliability, ensure vehicle safety, and accelerate the transition toward sustainable and efficient electric mobility by employing robust TM strategies.

Conflicts of interest: The authors declare no conflicts of interest.

## REFERENCES

[1] Iflah Aijaz and Aijaz Ahmad, "Electric Vehicles for Environmental Sustainability", Springer, 1st Edition, ISBN-978-3-030-80701-6, 2022, https://doi.org/10.1007/978-3-030-80702-3_8

[2] Serap TEPE, "The Interval-Valued Spherical Fuzzy Based Methodology and its Application to Electric Car Selection", Duzce University Journal of Science & Technology, vol. 9, pp. 1970-1983, 2021.

[3] Electric vehicles, "Reducing Pollution with Electric Vehicles", Energy Gov, 2024. https://web.archive.org/web/20180512115459/https://www.energy.gov/eere/electricvehicles/reducing-pollution-electric-vehicles

[4] Qinyu Qiao, Fuquan Zhao, Zongwei Liu, Shuhua Jiang and Han Hao, "Compartive Study of Life Cycle CO2 Emissions from the Production of Electric and Conventional Vehicles in China", Energy Procedia, vol. 105, pp. 3584-3595, 2017.

[5] Lyu Y, Siddique A. R. M, Majid S. H, Biglarbegian M, Gadsden S. A and Mahmud S, "Electric vehicle battery thermal management system with thermoelectric cooling", Energy Reports, vol. 5, pp. 822-827, 2019.

[6] Matthew Keysera, Ahmad Pesarana, Qibo Lia, Shriram Santhanagopalana, et al., "Enabling Fast Charging – Battery Thermal Considerations", Journal of Power Sources, vol. 367, pp. 228-236, 2017.

[7] Zerwas T, Jacobs G, Brand L, Dehn S, Sputz K, Hopfner G, Matz C, Guist C, Berroth J, Konrad C and Kohl J, "Customer-centric and function-oriented development of mechatronic systems", Forsch Ingenieurwes , vol. 87, pp. 507-519, 2023.

[8] Hamidreza Behi, Mohammadreza Behi, Danial Karimi, Joris Jaguemont, Morteza Ghanbarpour, Masud Behnia, Maitane Berecibar and Joeri Van Mierlo, "Heat pipe air-cooled thermal management system for lithium-ion batteries: High power applications", Applied Thermal Engineering, vol. 183, pp. 1-13, 2021.

[9] Jianan Zhang, Lei Zhang, Fengchun Sun and Zhenpo Wang, "An Overview on Thermal Safety Issues of Lithium-ion Batteries for Electric Vehicle Application", IEEE Access, vol. 6, pp. 23848-23863, 2018.

[10] Yan Wang, Qing Gao, Tianshi Zhang, Guohua Wang, Zhipeng Jiang and Yunxia Li, "Advances in Integrated Vehicle Thermal Management and Numerical Simulation", Energies, vol. 10, no. 10, pp. 1-30, 2017.

[11] Yanqi Zhao, "Battery Thermal Management Using Composite Phase Change Materials", Thesis, The University of Birmingham, 2020.

[12] Amber Negi and Risha Mal, "Electric Vehicle Battery Heat Management using A Thermoelectric Cooler Powered by Solar PV with MPPT", Technoaretepublishers, 1st Edition, ISBN- 978-93-92106-02-6, 2022, https://doi.org/10.36647/978-93-92106-02-6.2

[13] Hamidreza Behi, Danial Karimi, Rekabra Youssef, Mahesh Suresh Patil, Joeri Van Mierlo and Maitane Berecibar, "Comprehensive Passive Thermal Management Systems for Electric Vehicles", Energies, vol. 14, pp. 1-15, 2021.

[14] Tyler J Shelly, Justin A Weibel, Davide Ziviani and Eckhard A Groll, "Comparative Analysis of Battery Electric Vehicle Thermal Management Systems under Long-Range Drive Cycles", Applied Thermal Engineering, vol. 198, pp. 1-42, 2021.

[15] Joshua Smith, Randeep Singh, Michael Hinterberger and Masataka Mochizuki, "Battery thermal management system for electric vehicle using heat pipes", International Journal of Thermal Sciences, vol. 134, pp. 517-529, 2018.

[16] Zhen Tian, Wei Gan, Xuelai Zhang, Bo Gu and Lin Yang, "Investigation on an integrated thermal management system with battery cooling and motor waste heat recovery for electric vehicle", Applied Thermal Engineering, vol. 136, pp. 16-27, 2018.

[17] Chong Zhu, Fei Lu, Hua Zhang, Jing Sun and Chris Mi, "A Real-Time Battery Thermal Management Strategy for Connected and Automated Hybrid Electric Vehicles (CAHEVs) Based on Iterative Dynamic Programming", IEEE Transactions on Vehicular Technology, vol. 67, no. 9, pp. 8077-8084, 2018.

[18] Choon Kit Chan, Chi Hong Chung and Jeyagopi Raman, "Optimizing Thermal Management System in Electric Vehicle Battery Packs for Sustainable Transportation", Sustainability, vol. 15, pp. 1-14, 2023.

[19] Sowmya Sunkara and Syed Hayath, "Battery Thermal Management System for Electric Vehicles", Indian Journal of Software Engineering and Project Management, vol. 3, no. 1, pp. 1-6, 2023.

[20] Ming Shen and Qing Gao, "System simulation on refrigerant-based battery thermal management technology for electric vehicles", Energy Conversion and Management, vol. 203, pp. 1-13, 2020.

[21] Asif Afzal, Mohammed Samee A. D, Abdul Razak R. K and Ramis M. K, "Thermal management of modern electric vehicle battery systems (MEVBS)", Journal of Thermal Analysis and Calorimetry, vol. 144, pp. 1271-1285, 2021.

[22] Hengrui Liu, Chuang Wen, Anthony Chun Yin Yuen, Yu Han, Sherman Chi-Pok Cheung, Sanghoon Kook and Guan Heng Yeoh, "A novel thermal management system for battery packs in hybrid electrical vehicles utilising waste heat recovery", International Journal of Heat and Mass Transfer, vol. 195, pp. 1-25, 2022.

[23] Ningbo Wang, Congbo Li, Wei Li, Xingzheng Chen, Yongsheng Li and Dongfeng Qi, "Heat dissipation optimization for a serpentine liquid cooling battery thermal management system: An application of surrogate assisted approach", Journal of Energy Storage, vol. 40, pp. 1-12, 2021.

[24] Faiza M. Nasir, Mohd Z. Abdullah and Mohd A. Ismail, "Experimental Investigation of Water-Cooled Heat Pipes in the Thermal Management of Lithium-Ion EV Batteries", Arabian Journal for Science and Engineering, vol. 44, pp. 7541-7552, 2019.

[25] Mohsen Akbarzadeh, Joris Jaguemont, Theodoros Kalogiannis, Danial Karimi, Jiacheng He, Lu Jin, Peng Xie, Joeri Van Mierlo and Maitane Berecibar, "A novel liquid cooling plate concept for thermal management of lithium-ion batteries in electric vehicles", Energy Conversion and Management, vol. 231, pp. 1-14, 2021.

[26] Thomas Imre Cyrille Buidin and Florin Mariasiu, "Modeling Approach of an Air-Based Battery Thermal Management System for an Electric Vehicle", Applied Sciences, vol. 11, no. 15, pp. 1-16, 2021.

[27] Yoong Chung and Min Soo Kim, "Thermal analysis and pack level design of battery thermal management system with liquid cooling for electric vehicles", Energy Conversion and Management, vol. 196, pp. 105-116, 2019.

[28] Gang Zhao, Xiaolin Wang, Michael Negnevitsky, Hengyun Zhang and Chengjiang Li, "Performance Improvement of a Novel Trapezoid Air-Cooling Battery Thermal Management System for Electric Vehicles", Sustainability, vol. 14, no. 9, pp. 1-21, 2022.

[29] Ankit Singh Bisht, Vijay Singh Bisht, Prabhakar Bhandari, Kamal Singh Rawat, Tabish Alam and Paolo Blecich, "The Use of a Vortex Generator for the Efficient Cooling of Lithium-Ion Batteries in Hybrid Electric Vehicles", Processes, vol. 11, pp. 1-13, 2023.

[30] Olanrewaju M. Oyewola, Adetokunbo A. Awonusi and Olawale S. Ismail, "Design optimization of Air-Cooled Li-ion battery thermal management system with Step-like divergence plenum for electric vehicles", Alexandria Engineering Journal, vol. 71, pp. 631-644, 2023.

[31] Muhammad Muddasar, "Optimization, Modelling and Analysis of Air-Cooled Battery Thermal Management System for Electric Vehicles", ECSarXiv *Preprints, pp. 1-11,*2022. https://doi.org/10.1149/osf.io/z768q

[32] Gang Zhao, Xiaolin Wang, Michael Negnevitsky, Chengjiang Li, Hengyun Zhang and Yingyao Cheng, "A High-Performance Vortex Adjustment Design for an Air-Cooling Battery Thermal Management System in Electric Vehicles", Batteries, vol. 9, no. 4, pp. 1-19, 2023.

[33] Qibo Li, Chuanbo Yang, Shriram Santhanagopalan, Kandler Smith, Joshua Lamb, Leigh Anna Steele and Loraine Torres-Castro, "Numerical Investigation of Thermal Runaway Mitigation through a Passive Thermal Management System", Journal of Power Sources, vol. 429, pp. 80-88, 2019.

[34] Shuoqi Wang , Languang Lu, Dongsheng Ren, Xuning Feng, "Experimental Investigation on the Feasibility of Heat Pipe-Based Thermal Management System to Prevent Thermal Runaway Propagation", Journal of Electrochemical Energy Conversion and Storage, vol. 16, no. 3, pp. 1-11, 2019.

[35] Mark Hartmann and Joe Kelly, "Thermal Runaway Prevention of Li-ion Batteries by Novel Thermal Management System", IEEE Transportation Electrification Conference and Expo,13-15 June, Long Beach, CA, USA, 2018. https://doi.org/10.1109/ITEC.2018.8450177

[36] Jichao Hong, Zhenpo Wang and Peng Liu, "Big-Data-Based Thermal Runaway Prognosis of Battery Systems for Electric Vehicles", Energies, vol. 10, pp. 1-16, 2017.

[37] Da Li, Zhaosheng Zhang, Peng Liu and Zhenpo Wang, "DBSCAN-Based Thermal Runaway Diagnosis of Battery Systems for Electric Vehicles", Energies, vol. 12, pp. 1-15, 2019.

[38] Jichao Hong, Zhenpo Wang and Fei Ma, et al., "Thermal Runaway Prognosis of Battery Systems Using the Modified Multi-Scale Entropy in Real-World Electric Vehicles", IEEE Transactions on Transportation Electrification, vol. 7, no. 4, pp. 2269-2278, 2021.

[39] Abdulhadi Abdulsalam Abulifa, Azura Binti Che Soh, Mohd Khair Hassan, Raja Mohd Kamil Raja Ahmad and Mohd Amran Mohd Radzi, "Energy Management System in Battery Electric Vehicle Based on Fuzzy Logic Control to Optimize the Energy Consumption in HVAC System", The International Journal of Integrated Engineering, vol. 11, no. 4, pp. 11-20, 2019.

[40] Sourav Chowdhury, Lindsey Leitzel, Mark Zima, and Mark Santacesaria, et al., "Total Thermal Management of Battery Electric Vehicles (BEVs)", CO2 Reduction for Transportation Systems Conference, 6-8 June, Turin-Italy, 2018.

[41] Tianshi Zhang, Chun Gao, Qing Gao, Guohua Wang, MingHui Liu, Yuanke Guo, Cong Xiao and Yan Y. Y, "Status and development of electric vehicle integrated thermal management from BTM to HVAC", Applied Thermal Engineering, vol. 88, pp. 398-409, 2015.

[42] Shuofeng Zhao, Mohammad Reza Amini, Jing Sun and Chunting Chris Mi, "A Two-Layer Real-Time Optimization Control Strategy for Integrated Battery Thermal Management and HVAC System in Connected and Automated HEVs", IEEE Transactions On Vehicular Technology, vol. 70, no. 7, pp. 6567-6576, 2021.

[43] Taek-Kyu Lim, Kunal Sandip Garud, Jae-Hyeong Seo, Moo-Yeon Lee and Dong-Yeon Lee, "Experimental Study on Heating Performances of Integrated Battery and HVAC System with Serial and Parallel Circuits for Electric Vehicle", Symmetry, vol. 13, no. 1, pp. 1-25, 2021.

[44] Rekabra Youssef, Sazzad Hosen, Jiacheng He, Mohammed AL-Saadi, Joeri Van Mierlo and Maitane Berecibar, "Novel design optimization for passive cooling PCM assisted battery thermal management system in electric vehicles", Case Studies in Thermal Engineering, vol. 32, pp. 1-10, 2022.

[45] Huiming Zou, Wei Wang, Guiying Zhang, Fei Qin, Changqing Tian and Yuying Yan, "Experimental investigation on an integrated thermal management system 2 with heat pipe heat exchanger for electric vehicle", Energy conversion and management, vol. 118, pp. 88-95, 2016.

[46] Maan Al-Zareer, Ibrahim Dincer and Marc A. Rosen, "A Thermal Performance Management System for Lithium-Ion Battery Packs", Applied Thermal Engineering, vol. 165, pp. 1-36, 2019.

[47] Joshua Smith, Michael Hinterberger, Christoph Schneider and Juergen Koehler, "Energy Savings And Increased Electric Vehicle Range Through Improved Battery Thermal Management", Applied Thermal Engineering, vol. 101, pp. 647-656, 2016.

[48] Seho Park and Changsun Ahn, "Computationally Efficient Stochastic Model Predictive Controller for Battery Thermal Management of Electric Vehicle", IEEE Transactions on Vehicular Technology, vol. 69, no. 8, pp. 8407-8419, 2020.

[49] Abubakar Gambo Mohammed, Karem Elsayed Elfeky and Qiuwang Wang, "Recent advancement and enhanced battery performance using phase change materials based hybrid battery thermal management for electric vehicles", Renewable and Sustainable Energy Reviews, vol. 154, pp. 1-18, 2022.

[50] Mao Li, Yuanzhi Liu, Xiaobang Wang and Jie Zhang, "Modeling and optimization of an enhanced battery thermal management system in electric vehicles", Frontiers of Mechanical Engineering, vol. 14, pp. 65-75, 2019.