
# A Summary of Expert Perspectives on Safety Readiness of Electric Vehicle Batteries in India

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## Executive Summary

World Resources Institute India (WRI India) hosted a webinar on ‘Safety Readiness of Electric Vehicle (EV) Batteries in India’ to raise awareness regarding the safety challenges of EV batteries and solutions to overcome them. The webinar was part of the “Forum for Decarbonizing Transport” under the NDC-Transport Initiative for Asia. The panel comprised experts (see Appendix A for the list of panelists) who during the discussion highlighted the current safety concerns and charted the way forward for a safer EV battery ecosystem in India.

The panel analyzed the recent EV fire incidents in India and other countries, shedding light on the reasons for them while focusing on operational and technological perspectives. The experts recommended the following measures to build a robust ecosystem for EV batteries:

- Ensure seamless implementation of safety standards and compliance for wEV batteries from the cell to the pack level.
- Use standardized chargers and introduce compliance standards for metered EV connections.
- Deploy safety alert systems for battery packs to prevent fire hazards.
- Encourage skill development and training of service providers and operators.
- Promote innovation in the design of battery packs to improve their operational safety.
- Develop a circular economy for battery packs and EV chargers.

**8 APRIL 2022**

**WEBINAR ON SAFETY READINESS OF ELECTRIC VEHICLE BATTERIES IN INDIA**
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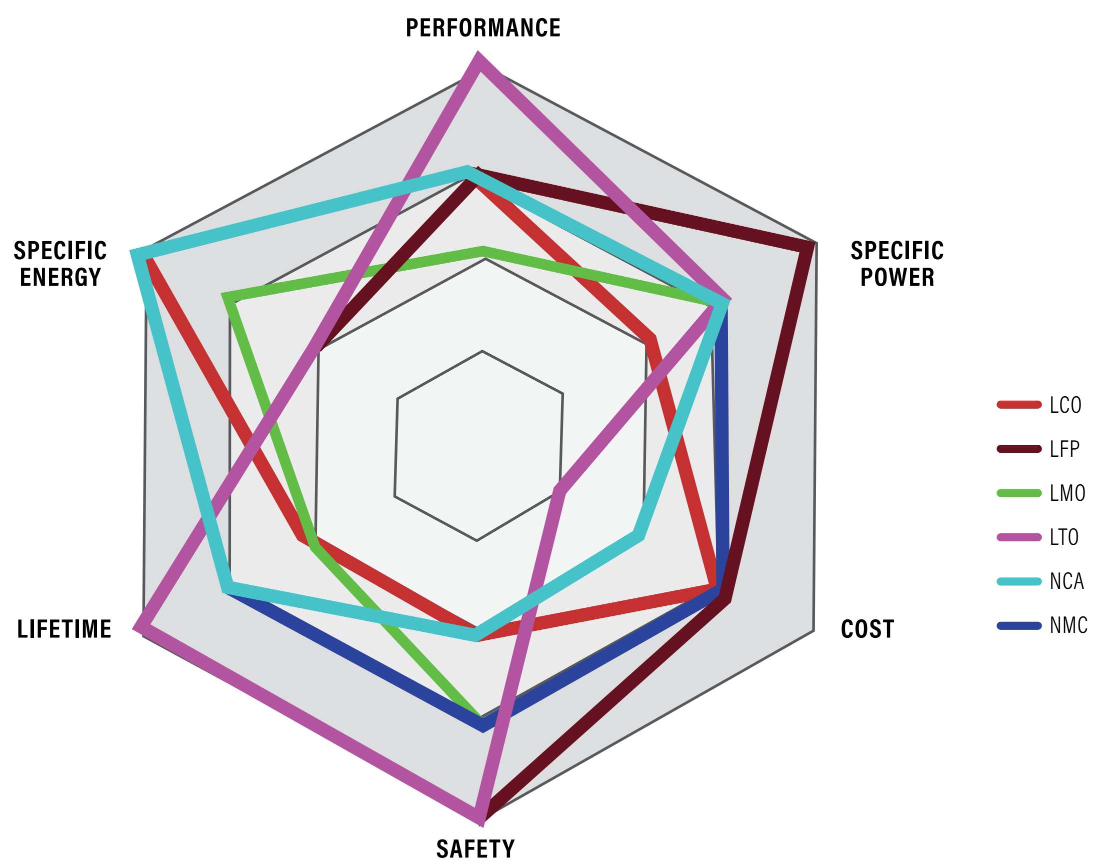
## Introduction

The battery pack is one of the most significant and valuable components in an electric vehicle, accounting for 30 percent to 40 percent of the total cost. The performance and safety of EVs are also heavily dependent on battery quality.

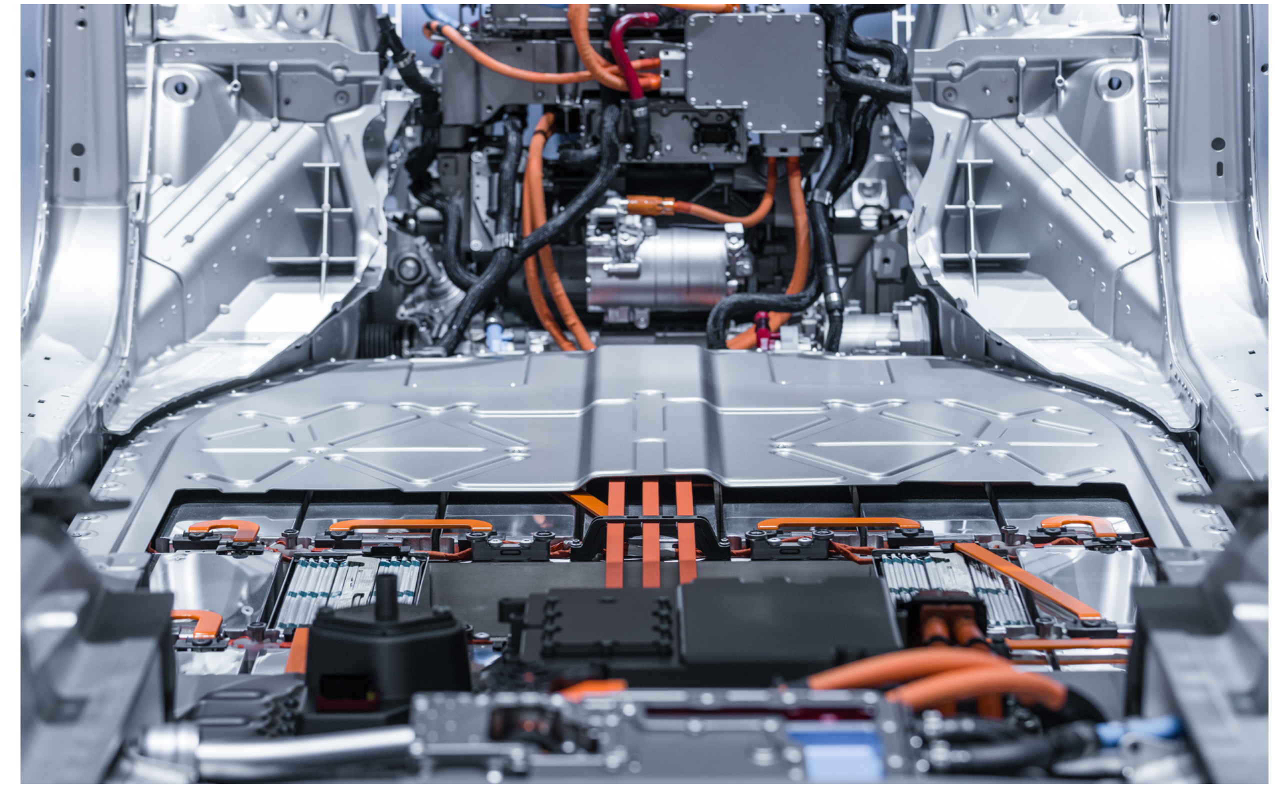
Lithium-ion batteries (LIBs) are the most widely used batteries in electric vehicles and energy storage applications. The LIB chemistries commonly used in EVs include lithium iron phosphate (LFP or $LiFePO_4$), lithium nickel cobalt aluminum oxide (NCA or $Li(Ni_xCo_yAl_z)O_2$), and lithium nickel manganese cobalt oxide (NMC or Li (Ni, Mn, Co) $O_2$). Lately, lithium titanium oxide (LTO) chemistry has emerged as a promising technology for high-power applications due to its better thermal stability, higher charging capability, excellent cycle life, and overall safety (Department of Science & Technology). Figure 1 compares different lithium-ion chemistries to clarify the cell-level performance.

Lithium-ion chemistries, however, come with their own set of challenges such as thermal runaway, which is induced by a rise in cell temperature. Although the operating temperature for LIBs can range from −20°C to 60°C, extremely low and high temperatures can lead to performance degradation and irreversible damage. Thermal runaway leads to a ripple effect inside the cell that can lead to a spark or fire incident.

Figure 1 | Comparison of Various Chemistries of Lithium-Ion Cells




Note: The farther the colored line extends along an axis, the better the performance along that dimension.
Source: Ali and Abdeljawad 2020.



## 2. Challenges Associated with EV Batteries

There are several reasons behind the fire safety challenges in the Indian EV market. A careful analysis of recent fire incidents suggests that overcharging and self-ignition due to short circuit were two of the most common causes. Some accidents also occurred as the battery management system (BMS) failed to detect abnormalities at the cell or pack level. The following are the broad categories of such technical faults in EV batteries:

A. **Internal Short Circuit:** This could happen due to a manufacturing defect in the cell (such as burrs or metal lump, misalignment of electrodes, or punctured separators). LIB operation under abnormal conditions, such as overcharging or lower-temperature charging, can lead to lithium dendrite growth or lithium plating (deposition of extra lithium ions on the anode while charging). Poor battery pack design, mechanical deformation during transportation, and a sudden increase in operating temperature can also lead to internal short circuits.

B. **External Short Circuit:** This can be caused by exposure to an external fire or loose connections while assembling the batteries during manufacturing. Severe mechanical deformation, water immersion, corrosion, and electric shock can also trigger an external short circuit.

C. **Overcharging and Overdischarging:** The major reasons for thermal runaway due to charging or discharging could be overcharging of the battery pack, high current, operation at a higher C-rate (the rate at which battery is providing energy), and discharge below the minimum voltage levels.

D. **Exposure to High Temperature:** Most lithium-ion battery chemistries demonstrate low thermal stability at high temperatures. Therefore, considering space and other constraints, especially in small battery packs, an efficient thermal management system (TMS) is strongly recommended for LIBs in EVs. Manufacturing faults, such as a loose electrical connection, can also cause a sudden temperature rise. Extreme ambient temperature due to increased self-heating is another leading cause of fire in EVs.

**E. Mechanical Deformation and Impact:** Mechanical deformation or cell punctures can occur during transportation and movement of batteries. It can also be caused by faulty cells or crashing of cells due to collision during transportation.

Some of the other reasons for recent EV battery fires are as follows:

- **Quality Concerns:** To reduce the total cost of EVs, some manufacturers are importing low-quality cells for the battery pack.
- **Design Concerns:** Design Concerns: Poor battery pack design and lack of suitable batteries and TMSs in battery packs, especially in electric two-wheelers (e-2Ws) and three-wheelers (e-3Ws) which dominate the Indian
- **EV market.Lack of Knowledge and Skills:** Most consumers and service providers lack the knowledge to maintain and service electric vehicle components, including critical components such as batteries and BMSs.
- **Extreme Operational Conditions:** Variations in ambient temperate due to varying climatic zones and road conditions in India can also lead to fire incidents.

Low-quality cells, low-efficiency BMSs, and inadequate protection against overcharging have emerged as the major reasons for the recent fire incidents. It is crucial to develop a framework to understand the safety readiness of the current battery technologies available in the market and design solutions to minimize fire hazards. Understanding the root causes of such incidents can help manufacturers implement preventive measures to minimize risks. In this webinar, we looked at these incidents in light of available data and information from various sources in the literature and case studies to improve the safety readiness of EVs in India.

## 3. Market Analysis and Case Studies of EV Battery Fires

India has several climatic zones with the average temperature ranging from −2°C to 47°C. In view of this, it is important to undertake a performance analysis to determine a suitable LIB chemistry based on EV operations in different climatic conditions.

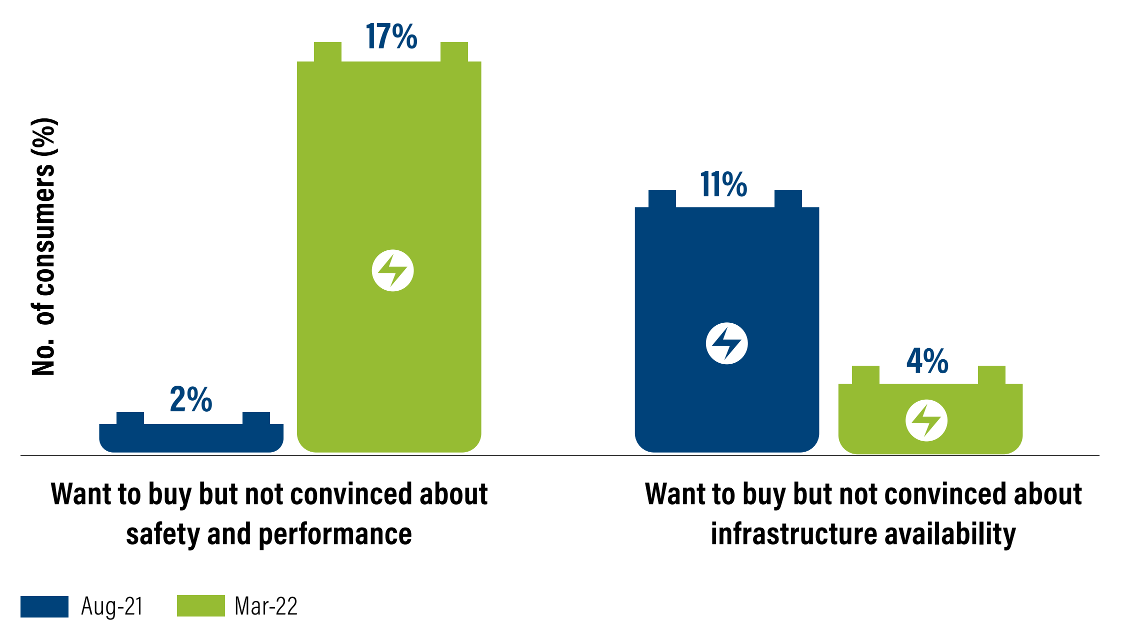
Currently, e-2Ws and e-3Ws account for more than 90 percent of the EV market in India. Fire incidents have become frequent in EVs—especially in the e-2W and e-3W categories—creating anxiety (See Figure 2) among potential consumers (Contractor, 2022).

A fire incident was also reported recently in an electric bus that was charging at a bus depot in Hyderabad (Deccan Chronicle, 2022). Reportedly, the e-bus caught fire when it was plugged in for charging for over an hour after completing a trip. The fire was attributed (The Times of India, 2022 to a short circuit). It is imperative to seek solutions that can reduce the impact on human life and prevent these incidents.





Figure 2 | Consumer Concerns regarding Electric Vehicle Purchase

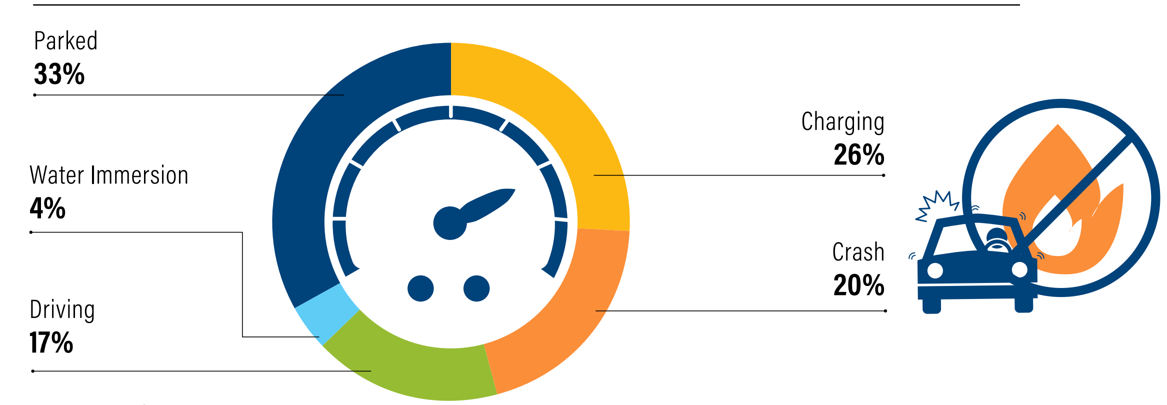



Source: ET Auto 2022. "Consumer concerns about safety of e-scooters grow 8X in past 6 months." April 01, 2022.

The following insights, which emerged from the knowledge presentation, establish that in-depth investigations need to be conducted on EV battery fire incidents to minimize their occurrence and create a safer EV ecosystem:

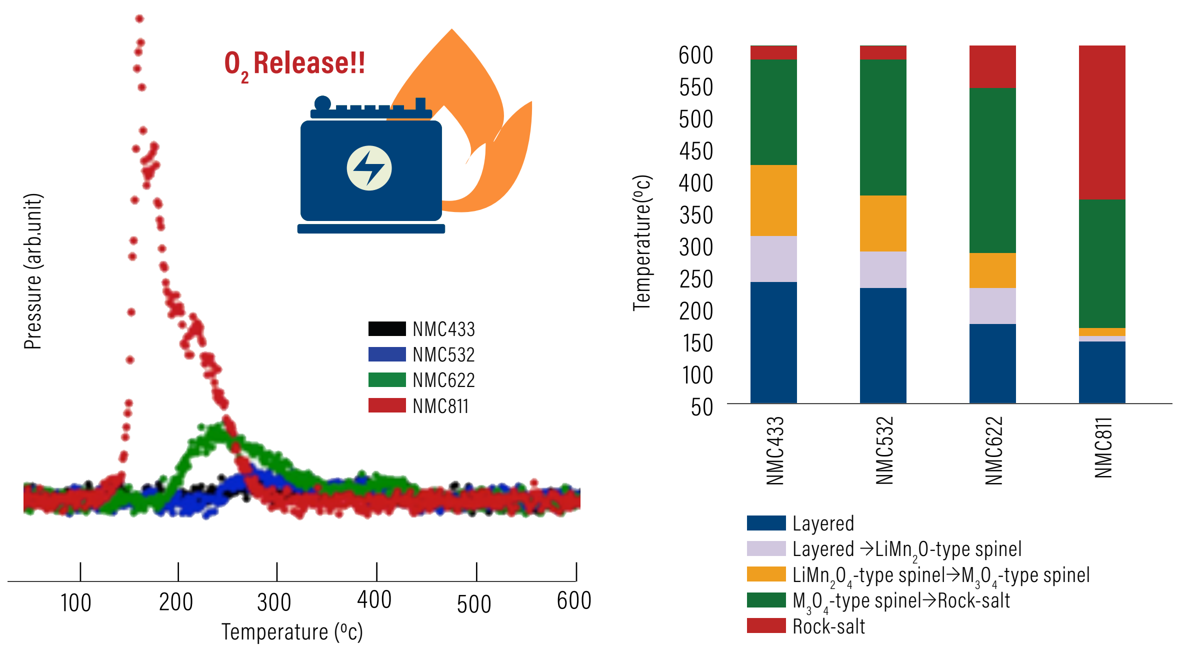
- A higher share of self-ignition (about 33 percent) and overcharging (about 26 percent) EV conditions have been recorded in global fire accidents (See Figure 3), leading to concerns around cell quality, battery pack design, and the BMS used for battery safety.
- Recalling EVs from the market can hinder EV adoption, which will ultimately lead to a loss of capital for original equipment manufacturers (OEMs). Therefore, advances are required in the R&D and testing ecosystem that will help address battery-related issues. For example, innovation at the material level can help improve the safety and performance of LIBs. As shown in Figure 4, the Lithium Nickel Manganese Cobalt Oxide (NMC 532) variant provides the optimum balance between thermal stability and performance.

Figure 3 | Statistics of Electric Vehicle Fire Accidents




Source: IDTechEx, 2021

Figure 4 | Structural Innovation and Chemical Composition Changes for Improved Thermal Stability of NMC Variants




Note: The numbers after nickel manganese cobalt represent the percentage content of each element in the battery chemical composition (arb. = arbitrary; NMC = nickel manganese cobalt).

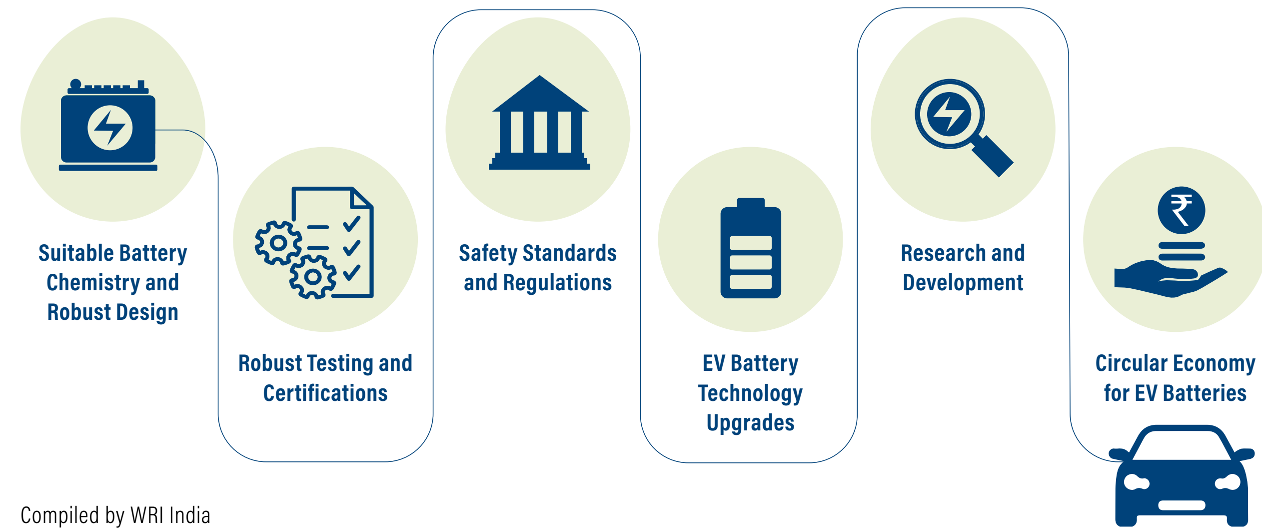
Source: Bak et al. 2014.

## 3. Webinar Outcomes

The webinar explored the following themes:

- Safety standards and regulations needed to address EV fire safety risks.
- The importance of a high-quality BMS and battery data monitoring.
- Safety readiness of EVs with small battery packs (e-2Ws and e-3Ws) in India.
- Safety readiness of e-bus depots and public EV charging infrastructure.
- The role of innovation and R&D in addressing safety concerns.


Figure 5 | Key Action Points for Electric Vehicle Battery Technologies




Compiled by WRI India

## Key Lessons and Entry Points for Action

### 1. Battery Chemistry and Design Tailored to Indian Conditions

Electric 2Ws and 3Ws, which are dominant in the Indian EV market, require small battery packs for energy storage. As these cells are not manufactured locally, the battery packs are usually imported or assembled in India using imported cells from other countries. Original equipment manufacturers (OEMs) must, therefore, familiarize themselves with the battery chemistry details and have a holistic understanding of such imported products. The increasing demand for EVs, coupled with the price-sensitive nature of the Indian market, has led to rising imports of cheap, low-quality battery packs. The import of such cells, especially in the e-2W segment, can lead to serious operational challenges. Poor design of battery packs and extreme temperature conditions can lead to safety failures. Lithium-ion phosphate (LFP) cells are a viable option for such cost-effective applications. Also, LFP chemistry is suitable in specific EV segments where space is not a major concern, due to the lower energy density.

**ENTRY POINTS FOR ACTIONS:** Battery OEMs should determine the suitable battery chemistry at the outset, considering both the user's requirements and the tropical climate of the country. They should also determine the appropriate battery architecture (which includes the arrangement of cells and batteries for the desired capacity and insulation creation through certified test procedures). These measures will ensure that the battery design will withstand the extreme climatic and road conditions that prevail in India.

### 2. Robust Testing and Certification of EV Batteries

To build consumer confidence, the problem of thermal runaway—a major reason for the recent incidents—must be analyzed and resolved. Testing and certification of cells and batteries play a crucial role in ensuring EV safety. In the initial stages, OEMs should conduct a thorough analysis to understand the characteristics of cells and batteries. Random sample testing should be performed on all imports. Moreover, a rigorous approach to testing and certification will prevent substandard materials from entering the market.

**ENTRY POINTS FOR ACTIONS:** Government authorities must establish a rigorous procedure for cell/battery testing to ensure their quality and robustness. Methods such as simulation can help clarify the electrochemical behavior in a thermal environment and heat mapping can be useful in resolving the complex cooling challenges.

### 3.Stringent Safety Standards and Regulations

Battery manufacturers must meet all the statutory standards from cell to pack level and tests at the battery level must include off-nominal conditions as well. Hazardous categories under off-nominal testing should include electrical, thermal and mechanical environments. Moreover, the power utility plays a crucial role in the EV charging business. Although certification and conformance to standard IS 17017 is mandatory for the installation of chargers at malls, homes, government premises and curbs, complete adherence to the guidelines is still a concern.

The measures introduced by the Central Electricity Authority (CEA) for safe electricity supply (which includes the procedure to install and commission public and semi-public charging stations) must be strictly followed. Charge point operators must fulfill all safety requirements before receiving a metered connection from power utilities or DISCOMs for EV charging. Until India formulates its own standards, the global standards (e.g. UL (Underwriters Laboratories) and IEC (International Electrotechnical Commission) standards) should be adopted by Indian operators.

**ENTRY POINTS FOR ACTIONS:** The Indian Ministry of Power has provided guidelines and standards for EV charging infrastructure that must be strictly followed by all stakeholders. Furthermore, the Bureau of Indian Standards (BIS) recently formulated an Indian standard: IS 17855:2022 (Press Information Bureau Delhi, 2022) which includes the procedure to test the safety and performance of battery packs in India. BIS is also in the process of publishing two more standards that will be tailor-made to Indian climatic conditions.

### 4. Battery Technology Upgradation for Indian Conditions

It is imperative to import good-quality cells to minimize EV-related fire incidents in India. Most OEMs in China are focusing on LFP chemistry as a reliable battery technology. LFP batteries with a blade-shaped design have recently passed the nail penetration test (considered to be the gold standard for safety tests), thus paving the way for their global acceptance. Battery swapping is fast emerging as a safer solution for light EVs such as e-2Ws and e-3Ws. Moreover, for high-power applications such as forklifts, tractors, and mining and defense vehicles, LTO is the most suitable chemistry. Although, it has a lower energy density, its higher thermal stability and discharge rate make it a promising technology for these applications. Henceforth, to give primacy to safety concerns, constant upgradation in EV battery technology for short-term planning and continuous R&D for long-term planning will be required.

**ENTRY POINTS FOR ACTIONS:** The EV battery ecosystem in India must evolve in tandem with global innovations. As the current cell technologies and designs are not robust against the unique challenges posed by Indian conditions, innovations to address these issues must be encouraged through multi-sectoral partnerships between government and private players.

### 5. Promote Innovation Across All Levels of Battery Production

Research and testing of cells/batteries must be conducted to understand their performance in Indian conditions before launching them in the market. Battery manufacturers should design and size battery packs such that they can operate within their optimal temperature bounds and fulfill charge/discharge requirements. Among LIB chemistries, NMC cells have higher energy density and are the most suitable for swappable operations. Swappable batteries are first cooled to the optimum temperature range and then charged in a controlled environment, where they are monitored continuously through sensors for temperature and voltage checks.




They are then cooled down again before insertion in the vehicles, thus maximizing safety. In higher-energy cells such as NMC, challenges are inherent, necessitating more R&D to ensure that they operate safely within the temperature and voltage limits.

In parallel, attention should be paid to BMS standards, testing, and increasing the number of cell-testing facilities. Innovations such as solid-state electrolyte batteries are also safer and thermally stable in tropical conditions.

**ENTRY POINTS FOR ACTIONS:** Greater focus is required on the creation of innovation centers and testing facilities for EV batteries suitable for Indian tropical conditions. Apart from batteries, the BMS also plays a crucial role in monitoring cell parameters and protecting the battery pack from various stressors. A low-quality BMS could lead to failure in recording battery issues, which in turn could lead to fire incidents. Indian EV manufacturers should also focus on creating high-quality BMSs that can give accurate readings and prevent cells from catching fire.

### 6. Creation of a Circular Economy for EV Batteries

Each stakeholder in the value chain must acknowledge the challenges associated with EV fires and their impact on human life and India's e-mobility mission. The performance of batteries in rough and extreme operating conditions must be verified before they are commercialized. Going forward, stakeholders need to explore the creation of a safer circular economy for battery packs that includes reusability and recycling of used batteries.

**ENTRY POINTS FOR ACTIONS:** Some studies suggest that second-life batteries start at 80 percent State of Health (SoH) and their common End of Life (EoL) is 60 percent SoH (Casals et al., 2019). Once the second life of the battery reaches its EoL, it should be recycled. During second life (when the SoH is between 60 and 80 percent), batteries can be used for off-grid or microgrid applications in rural areas (Cohn, 2021). Eventually, materials from cells/batteries can be recovered to reduce the consumption and mining of primary raw materials, promoting a sustainable circular economy of EV batteries. For a safe and efficient ecosystem for second-life batteries and end-of-life recycling, a standard process needs to be established to ensure judicious removal and testing of batteries after the end of first life in EV applications.

## APPENDIX A: LIST OF PANELISTS

**Dr. Judy Jeevarajan**
*Panelist*
Vice President & Executive Director, Electrochemical Safety Research Institute, Underwriters Laboratories (UL)

**Mr. Abhishek Ranjan**
*Panelist*
Sr. Vice President, Strategy (Utilities & Retail), ReNew Power

**Dr. Rashi Gupta**
*Panelist*
Founder & Managing Director, Vision Mechatronics Pvt. Ltd

**Mr. Arun Sreyas Reddy**
*Panelist*
Founder, RACEnergy

**Mr. Ketsu Zhang**
*Panelist*
Executive Director, BYD India Pvt. Ltd

**Mr. Sanjay Gopalakrishnan**
*Panelist*
Senior Vice President, BYD India Pvt. Ltd

**Ms. Neha Tapadiya**
*Panelist*
Co-Founder, Scion Energy Storage

**Mr. Pawan Mulukutla**
*Moderator*
Director, Integrated Transport, Electric Mobility and Hydrogen

**Dr. Parveen Kumar**
*Panelist*
Senior Program Manager, Electric Mobility, WRI India

## ABBREVIATIONS

**BMS:** Battery management system
**BIS:** Bureau of Indian Standards
**CO2:** Carbon dioxide
**CEA:** Central Electricity Authority
**CPO:** Charge point operator
**Discom:** Distribution company
**EoL:** End of Life
**EV:** Electric vehicles
**E-2W:** Electric two-wheeler
**E-3W:** Electric three-wheeler
**FADA:** Federation of Automobile Dealers Associations
**GoI:** Government of India
**IEC:** International Electrotechnical Commission
**LIB:** lithium-ion battery
**LFP:** lithium iron phosphate
**LTO:** lithium titanium oxide
**MoP:** Ministry of Power
**NDC:** National Determined Contribution
**NMC:** Lithium nickel manganese cobalt oxide
**NCA:** Lithium nickel cobalt aluminum oxide
**OEM:** Original equipment manufacturer
**R&D:** Research & development
**SoC:** State of Charge
**SoH:** State of Health
**UL :** Underwriters Laboratories

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