german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

भारी उद्योग मंत्रालय
MINISTRY OF
HEAVY INDUSTRIES

CONVERGENCE energy. simplified
Convergence Energy Services Limited

Green Urban Mobility Partnership

MASTERING ELECTRIC BUS FIRE SAFETY IN INDIA

AN ADVANCED TRAINING PROGRAMME

Imprint

Published by the
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Promotion of Transformation to Sustainable and Climate-Friendly E-mobility
B-5/2, Safdarjung Enclave
New Delhi-110029
India
T 011-49495353
F 011-49495391
E giz-indien@giz.de

Responsible
Raghu Babu Nukala

Project Advisor
Amegh Gopinath

Project Coordinator
Amruta Kulkarni, Mahak Dawra

Project Team
ASDC: Arindam Lahiri, Poonam Rawat, Richie Gupta, Tanya Jogi
External Consultants: Prasanthkumar Palani, Devendran

Reviewers
Jayant Deshmukh, Sanjay Bhatia

Designer
Vishwas Anil Patil

Photo Credits
GIZ India, Delhi Transport Corporation
License free images from Unsplash, Pexels

Disclaimer
Any maps used in the document are for informational purposes only and do not constitute recognition of international boundaries or regions; GIZ makes no claims concerning the validity, accuracy or completeness of the maps nor assumes any liability resulting from the use of the information therein.

GIZ is responsible for the content of this publication on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ)

MASTERING ELECTRIC BUS FIRE SAFETY IN INDIA

AN ADVANCED TRAINING PROGRAMME

Table of Contents

Abbreviations

AC	Alternating Current
ARAI	Automotive Research Association of India
ASDC	Automotive Skills Development Council
ASRTU	Association of State Road Transport Undertakings
BMS	Battery Management Systems
BMZ	German Federal Ministry for Economic Development and Cooperation
BRTS	Bus Rapid Transit System
BTMS	Battery Thermal Management Systems
CERC	Central Electricity Regulatory Commission
CESL	Convergence Energy Services Limited
CIRT	Central Institute of Road Transport
CMVR	Central Motor Vehicle Rules
CNG	Compressed Natural Gas
CPCB	Central Pollution Control Board
DC	Direct Current
E-Bus	Electric Bus
EMPS	Electric Mobility Promotion Scheme
EV	Electric Vehicle
FAME	Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles in India
GIZ	The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GUMP	Green Urban Mobility Partnership
ICATA	International Centre for Automotive Technology
IRDAI	Insurance Regulatory and Development Authority of India
ISC	International Organisation for Standardisation
MHI	Ministry of Heavy Industries
MOHUA	Ministry of Housing and Urban Affairs
MSD	Manual Service Disconnects
NASSCOM	National Association of Software and Services Companies
OEMs	Original Equipment Manufacturers
PPE	Personal Protective Equipment
RTO	Regional Transport Offices
SCBA	Self-Contain Breathing Apparatus
SDG	Sustainable Development Goals
SERC	State Electricity Regulatory Commission
SOP	Standard Operating Procedure
STU	State Transport Undertaking

About the Report

This report provides an overview of fire safety in e-buses, covering the key aspects such as fire incidents, causes, and circumstances. It also delves into topics like battery technology, thermal management, and battery thermal runaway, outlining the safety protocols and standard operating procedures (SOPs) for e-bus safety. The study culminated in the development of the **'Mastering Electric Bus Fire Safety in India: Advanced Training Programme,'** organised by the **Ministry of Heavy Industries (MHI)** in collaboration with **Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH** and **Automotive Skills Development Council (ASDC)**. This national-level training initiative was part of the technical cooperation project, '**Promotion of Transformation to Sustainable and Climate-Friendly E-mobility**,' commissioned by the **German Federal Ministry for Economic Development and Cooperation (BMZ)**.

The outcomes of this study and training programme led to the incorporation of mandatory certification by the fire department, ensuring e-bus depots under the PM E-bus Sewa scheme comply with fire safety standards. As e-buses become increasingly prevalent in Indian cities, concerns about fire safety have emerged. To address these concerns and enhance the skills of the workforce, the project designed a comprehensive training programme focused on e-bus fire safety and high-voltage safety.

© Delhi Transport Corporation

1. Government's Push for E-bus Adoption

The rapid adoption of e-buses represents a pivotal stride towards the decarbonisation of urban transportation, aligning with India's commitment to combat climate change. However, alongside the benefits of electrification come crucial challenges, particularly concerning the safe operation and maintenance of these vehicles.

In this context, the necessity for comprehensive e-bus fire safety training programmes cannot be overstated. This section underscores the urgency and significance of such initiatives by diving into:

- The escalating demand for e-buses.
- The rising frequency of fire incidents.
- The pressing need to bridge the skills gap in the face of evolving technology.

The Indian government's ambitious plan to deploy 50,000 e-buses is expected to significantly boost electric vehicle (EV) adoption. However, with the increasing deployment of e-buses, there is a growing need for enhanced safety measures, particularly fire safety, given the unique challenges posed by EV operations.

Key programmes driving EV adoption:

- FAME-II (Faster Adoption and Manufacturing of Electric Vehicles)
- EMPS 2024 (Electric Mobility Promotion Scheme)
- PM-E Bus Sewa (Public Transport Electrification Initiative)

With approximately **11,000** e-buses currently registered, the demand for specialised **Fire safety training** and protocols will continue to grow to ensure safe operations.

The advancement of electric mobility technology has led to a significant skills gap among the workforce responsible for operating and maintaining e-buses. Traditional training programmes often fall short in equipping personnel with the necessary knowledge to address EV-specific safety challenges.

There is an urgent need to strengthen the capabilities of technicians, drivers, and emergency responders through specialised training initiatives focused on e-bus fire safety and high-voltage systems.

Critical training needs

- High-voltage system safety for technicians.
- Specialised fire safety training for drivers.
- Emergency response training for first responders.

1.1 Fire safety concerns and incidents

While e-buses offer significant environmental benefits, fire safety remains a major concern. Increasing reports of e-bus fires at both global and national levels highlight an urgent need to identify and address critical safety vulnerabilities inherent in e-bus operations. The complex interaction of high-voltage systems, thermal runaway, and battery malfunctions poses considerable challenges, making it essential to implement proactive measures to mitigate fire risks.

Key risk factors

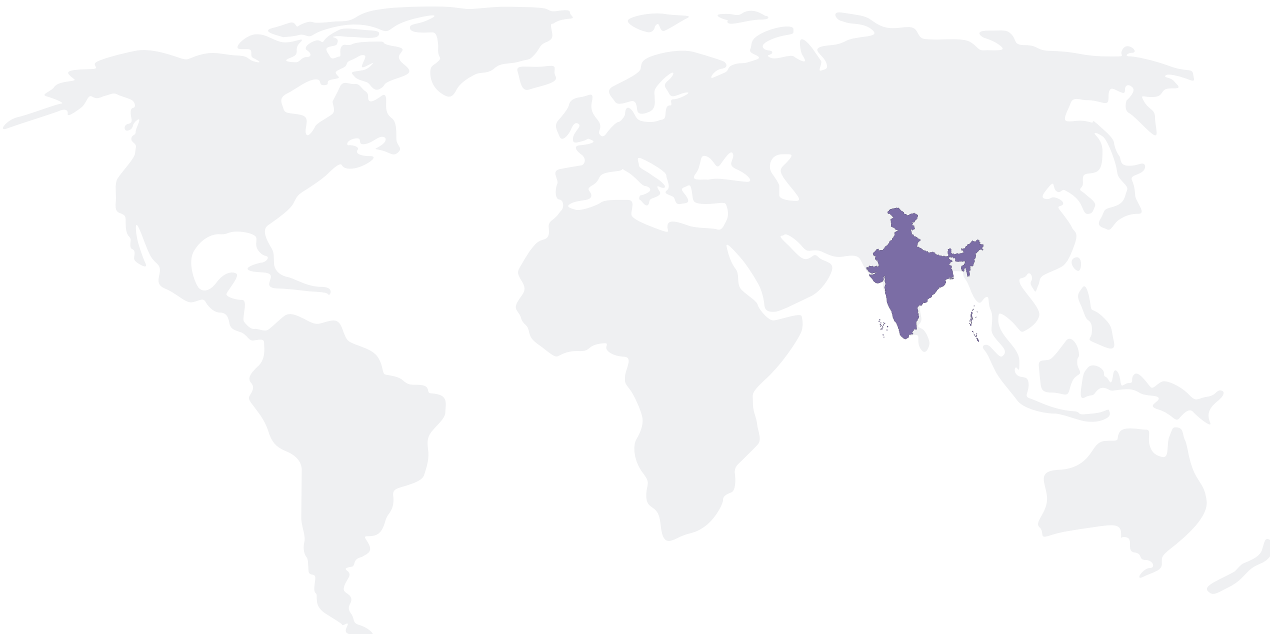
- High-voltage system malfunctions
- External factors like collisions and vandalism
- Battery cell abuse leading to thermal runaway
- Incidents of fire occurring during maintenance or charging

E-bus fire incidents

27 worldwide

6 in India

(Hyderabad, Mumbai, Delhi, Ahmedabad, Surat) until 2024



1.2 Battery technology and safety challenges

E-buses rely on lithium-ion batteries, offering advantages such as:

- High energy density for longer range
- Longer life-cycle for enhanced durability
- High power density, enhancing energy efficiency

Key safety measures

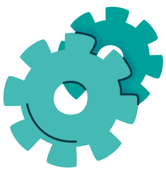
- Battery Thermal Management System (BTMS)**:** Maintains optimal battery temperature to prevent overheating and thermal runaway.
- Battery Management System (BMS): Continuously monitors voltage, current, and temperature to ensure safe and efficient battery operation.

These batteries present unique safety challenges, particularly in temperature management. **Critical risk**: Thermal runaway occurs when excessive heat leads to a rapid temperature increase, creating a potential fire or explosion risk.

High-voltage system safety

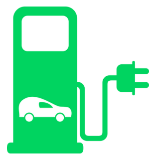
E-buses operate at over 600V DC, requiring specialised knowledge and skills to ensure safe operations during:

Maintenance and repairs



Daily bus operations

Charging and energy transfer



1.3 Need for fire safety training

Empowering workforce for safe e-bus operations

While e-buses help reduce tailpipe emissions, the large-scale shift to electric mobility introduces significant safety concerns, especially regarding high-voltage systems and lithium-ion batteries.

Why safety training is essential?

- Ensures safe bus operations and maintenance.
- Reduces risks associated with battery malfunctions.
- Equips drivers and technicians with essential skills.

Safety trainings for STUs

STUs across India are increasingly recognising the need for specialised safety training. This includes:

- Training for drivers, technicians, and emergency responders.
- Raising awareness on handling e-buses safely and following effective risk management practices.
- Comprehensive fire safety and high-voltage system training.

2. Mastering E-bus Fire Safety in India

The primary aim of the advanced training programmes was to enhance awareness on fire safety related to e-bus operations, focusing on the risks associated with high-voltage systems and lithium-ion batteries while aligning with the global movement towards electric mobility. The initiative sought to familiarise participants with essential government policies that encourage the transition to e-buses, while emphasising the safe management of high-voltage systems and lithium-ion batteries.

The mission of the programme was to address critical safety issues by implementing safety audits, setting requirements for e-buses with their charging infrastructure, raising awareness on the safe disposal of end-of-life vehicles and traction batteries. The main objective was to provide comprehensive training to various stakeholders on fire safety, operational safety, emergency response protocols, and best practices for managing e-buses and their associated infrastructure.

Training programmes and structure

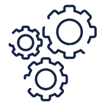
The initiative consisted of **three** distinct training courses:

	Topic	Duration	Focus area	Target group
Training Programme 1	Sensitisation training on e-bus fire safety	2 h	Fire safety protocols for e-buses	• Public transport officials • Fire advisors • Chief fire officers
Training Programme 2	Safe practices in operations and maintenance	6 h	Best practices for managing e-bus fleets	• Operations and maintenance engineers • Technicians
Training Programme 3	Emergency response for e-bus fires	6 h	Emergency response and safety protocols	• Onboard crew members • Firefighters

2.1 Overview of the programme

Introduction to e-bus management and government initiatives

The e-bus management training provided a comprehensive curriculum designed for:

Top management officials	**Operators**	**Maintenance engineers**	**Technicians**
			

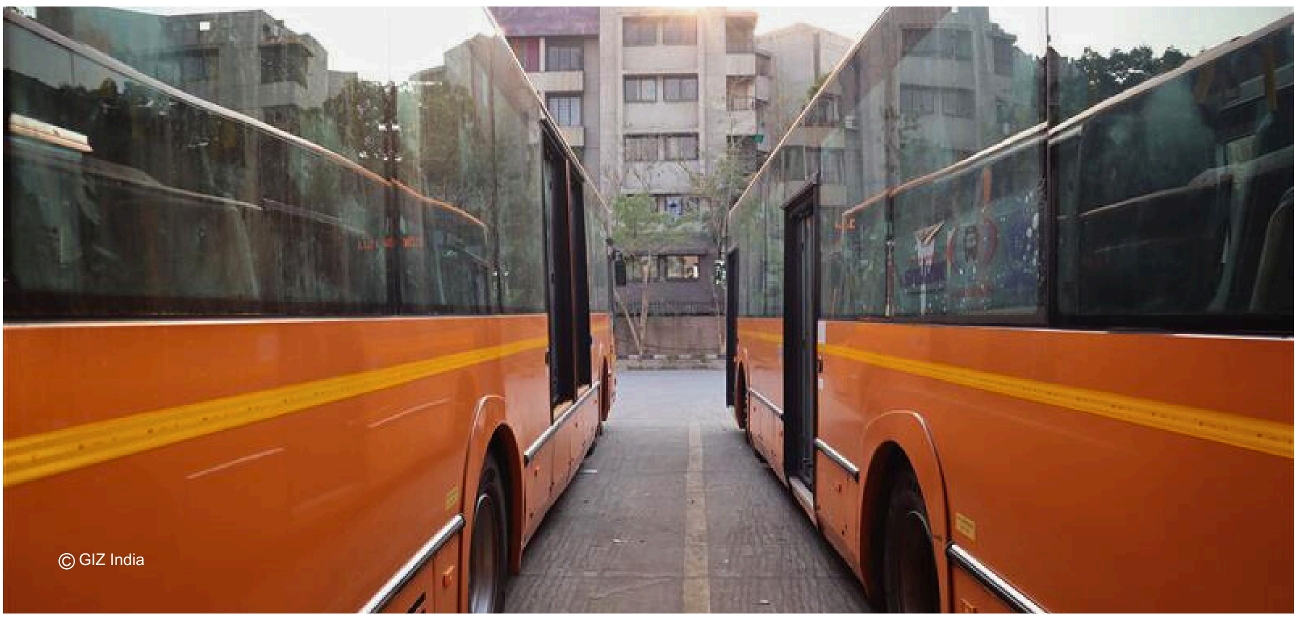
Participants were introduced to Central and State Government initiatives, including FAME and CMVR regulations, shaping the electric mobility landscape in India. Additionally, the session covered charging infrastructure and operational safety considerations, ensuring a holistic approach to e-bus deployment.

Safety protocols and certifications

- **Regulatory compliance:** Participants were introduced to safety certification processes conducted by ARAI, CIRT, and ICAT, ensuring adherence to industry standards.
- **Sustainable practices**: The course emphasised the safe disposal of end-of-life vehicles and traction batteries, reinforcing environmentally responsible operations.
- **High-voltage safety**: Training covered the usage of PPE kits, specialised tools, and safety protocols for handling high-voltage components.
- **Emergency preparedness**: Practical demonstrations focused on fire safety procedures, flood navigation, and first responder protocols for hybrid and e-buses.

Safety features and risk mitigation strategies

Additionally, the curriculum covered safety precautions and technologies adopted by Original Equipment Manufacturers (OEMs) during the design phase of e-buses, highlighting the integration of cutting-edge safety features to ensure reliability. Participants also gained proficiency in understanding electric vehicle accidents through **global case studies**, providing valuable insights into risk mitigation **strategies** and informing strategic **decision-making** processes.



2.2 Methodology adopted

1. **Content tailored to the target audience**
2. **Stakeholder engagement and training nominations**
3. **Identify e-bus depot for hands-on training**
4. **Identify the trainer based on the eligibility criteria**
5. **Coordinate all training logistics**
6. **Training delivery**
7. **Gather post-training feedback**

The training programmes were delivered using a combination of methodologies to ensure effective learning and maximise the impact on participants' knowledge and practices. These methodologies were designed to cater to the diverse needs of the target audience, which included officials from STUs and State Fire Departments, e-bus drivers, technicians, and other relevant stakeholders. The positive outcomes and impact of the training programmes are highlighted below.

Classroom sessions
Traditional sessions covering essential concepts, safety regulations, and best practices for e-bus operations, maintenance, and emergency response.

Practical demonstrations
Hands-on experience with e-bus components, safety equipment, and emergency response procedures for real-world application.

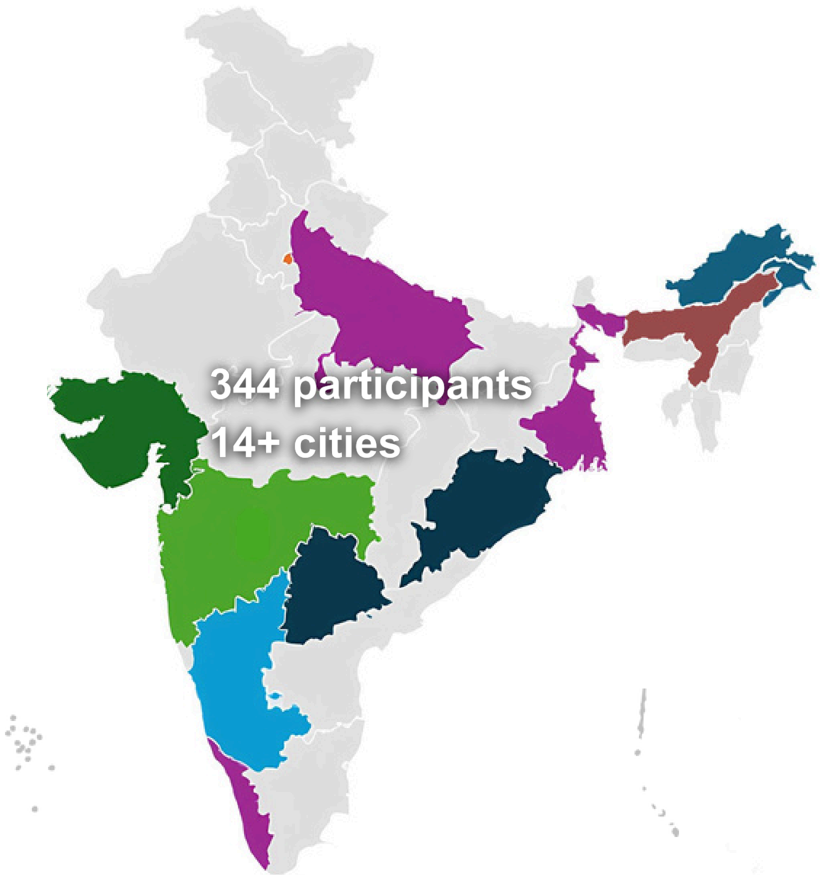
Video learning
Case studies, accident analysis videos illustrating safety measures, and incident responses.

Interactive workshops
Encouraging discussions, experience-sharing, and collaborative problem-solving on e-bus safety issues.

Simulation exercises
Emergency response drills to test decision-making and crisis management skills.

2.3 Focus areas

The training programme covered key aspects of e-bus safety and the electrification of public transport. It began with the rationale for transitioning to electric mobility and learnings from past electric vehicle incidents. Participants learned about e-bus architecture, components, and safety technologies from OEMs, with a strong focus on high-voltage safety, lithium-ion battery fire protection, and the role of the Battery Management System (BMS). The programme also addressed Central Motor Vehicle Rules (CMVR) safety certification tests, daily inspections, maintenance procedures, and SOPs for depots and charging stations. Emergency response protocols for on-road incidents and e-bus fires were discussed, including PPE use, fire-fighting strategies, and manufacturer guidance. The training concluded with best practices for safe operation, maintenance, and emergency handling of e-bus fleets.



2.4 Key stakeholders

The training programme brought together key stakeholders from organisations such as the Association of State Road Transport Undertakings (ASRTU), Bengaluru Municipal Transport Corporation (BMTC), BRTS Cell - Surat, Capital Region Urban Transport - Bhubaneswar (CRUT), and Convergence Energy Solution Limited (CESL). Participants also included representatives from Fire and Emergency Services - Assam, Kanpur City Transport Services, Karnataka State Road Transport Corporation (KSRTC), Kerala State Road Transport Corporation (Kerala SRTC), and Lucknow City Transport Services. Additionally, officials from Mira Bhainder Municipal Transport, Mumbai Fire Brigade, Pune Mahanagar Parivahan Mahamandal, Telangana State Disaster Response and Fire Services, Brihanmumbai Electric Supply and Transport Undertaking (BEST), Ulhasnagar Municipal Corporation, West Bengal Transport Corporation (WBTC), Ahmedabad Janmarg Limited (AJL) and Ahmedabad Municipal Corporation (AMC) contributed to the programme, fostering a collaborative exchange of expertise and best practices.

© Unsplash

3. Training Programme Highlights and Insights

3.1 Training I: Sensitisation training on e-bus fire safety

Training Programme 1

Topic	Duration	Focus area	Target group
Sensitisation training on e-bus fire safety	2 h	Fire safety protocols for electric buses	• Public transport officials • Fire advisors • Chief fire officers

3.1.1 Introduction

Global trends and government initiatives

The training highlighted the impact of climate change on urban mobility and the need for e-bus adoption. Participants explored central and state government initiatives, including FAME policies and other regulatory frameworks promoting public bus transport electrification. The session also provided insights into global e-bus fire incidents, safety technologies, testing methods, and charging infrastructure standards. Additionally, the training emphasised the responsibilities of bus operators in the safe disposal of end-of-life vehicles and traction batteries, ensuring sustainability in fleet management.

Safety knowledge and risk mitigation

Participants gained a comprehensive understanding of safety technologies implemented by OEMs to enhance e-bus safety and reliability. The course covered certification processes by agencies such as ARAI, CIRT, and ICAT, ensuring compliance with safety and operational standards. Practical sessions focused on safety audits, high-voltage risk mitigation, and charging infrastructure requirements. Moreover, the training addressed the safe disposal of traction batteries, equipping participants with the knowledge to ensure regulatory compliance and environmental sustainability.

Key learnings

- Government initiatives and FAME policy supporting electric mobility.
- Global safety trends and e-bus fire incident analysis.
- OEM safety technologies and certification requirements.
- Risk mitigation strategies for e-bus operations.
- Sustainable disposal of batteries and end-of-life vehicles.

3.1.2 Course structure

Global trends and government policies

The course provided a comprehensive overview of climate change and its impact on urban mobility, highlighting the need for electrification of public bus transport. Participants were introduced to the central and state government initiatives, including FAME policies and regulatory frameworks supporting e-bus adoption. Through case studies of electric vehicle accidents globally, they gained a deeper understanding of potential risks, safety challenges, and best practices to enhance decision-making in electric bus operations.

Safety standards and regulatory compliance

The training emphasised safety technologies implemented by OEMs, ensuring high standards of reliability and risk mitigation. Participants examined safety certification tests conducted by agencies such as ARAI, CIRT, and ICAT, aligned with Central Motor Vehicle Rules (CMVR). Additionally, the course addressed safety audits and compliance measures for charging infrastructure, equipping participants with critical knowledge to uphold operational and regulatory standards. The session also underscored the importance of environmentally responsible disposal of End-of-Life electric buses and traction batteries, promoting sustainability in fleet management.

Key learnings

- Government policies and FAME initiatives supporting electric mobility.
- Global EV accident analysis and risk mitigation strategies.
- OEM safety technologies and certification processes.
- Safety audits and regulatory compliance for buses and charging stations.
- Sustainable disposal practices for batteries and End-of-Life vehicles.

© GIZ India

3.1.3 Key takeaways

- **Optimal charging practices:** Participants gained valuable insights into best practices for e-bus charging, ensuring enhanced battery longevity and operational efficiency.
- **Battery explosion risks and prevention:** Technical discussions covered the causes of battery explosions, risk mitigation strategies, and the progression from cell failure to full battery pack incidents.
- **Enhanced safety awareness:** The session heightened awareness of critical safety protocols, including environmental and operational factors that influence battery stability.
- **Strategic battery placement:** The e-bus depot visit highlighted how battery placement affects overall design and operations (rooftop vs lower chassis) on safety, cooling efficiency, and overall vehicle performance.
- **Practical demonstrations:** Hands-on insights into cooling system integration and battery management reinforced theoretical knowledge, supporting risk-informed decisions in e-bus operations.

© GIZ India


© GIZ India

3.2 Training II: Safe practices in operations and maintenance

Training Programme 2	Topic	Time	Focus area	Target group
	Safe practices in operations and maintenance	6 h	Best practices for managing e-bus fleets	• Operations and maintenance engineers • Technicians

3.2.1 Introduction

Training objectives and skills development

The training programme was designed to equip operations, maintenance engineers, and technicians with essential skills to address challenges in electric vehicle maintenance. It familiarised participants with best practices and standard operating procedures (SOPs) for ensuring safe and efficient e-bus operations. Through the analysis of global electric vehicle incidents and case studies, participants developed a deeper understanding of potential safety risks. The training also provided insights into e-bus architecture and components, enabling effective maintenance and operational practices.

Safety protocols and practical applications

The programme emphasised electrical safety, covering high-voltage battery risks, mitigation strategies, and the use of personal protective equipment (PPE) kits and lockout-tagout (LOTO) procedures. Participants also gained hands-on experience in interpreting wiring diagrams, implementing safety precautions, conducting routine inspections, and understanding e-bus charging systems.

The training covered key learning areas essential for safe and efficient e-bus operations. Participants developed a comprehensive understanding of e-bus architecture and components, along with the ability to identify and mitigate risks associated with high-voltage batteries. They gained proficiency in applying electrical safety protocols, including the use of personal protective equipment (PPE) kits and lockout/tagout (LOTO) procedures. The programme also equipped them with skills to interpret wiring diagrams and implement safety measures during maintenance activities. In addition, participants learned routine inspection procedures to maintain operational efficiency and became familiar with emergency response protocols and the operation of charging stations.

3.2.2 Course structure

E-bus safety and operational knowledge

The training provided a global perspective on electric vehicle accidents through video-based case studies, enhancing participants' understanding of potential risks and best practices. It covered e-bus architecture, components, and essential electrical safety protocols. Key topics included identifying and mitigating high-voltage battery risks, using PPE kits and specialised tools, and implementing the Lockout-Tagout (LOTO) process for safe high-voltage disconnection.

Safety protocols and emergency response

Participants learned to interpret wiring diagrams, understand safety color codes, and follow emergency response guidelines. The curriculum covered safety precautions for welding, e-bus body repairs, routine inspections, and maintenance, with special focus on pressure washing and emergency scenarios like fires or flooding. Training also included the safe operation of e-bus charging stations.

The training provided participants with key learnings essential for the safe operation and maintenance of e-buses. They gained a clear understanding of e-bus safety and operational protocols, along with the ability to identify and mitigate risks associated with high-voltage batteries. The programme enhanced their proficiency in using personal protective equipment (PPE kits), specialised tools, and implementing lockout/tagout (LOTO) procedures. Participants also developed skills in interpreting wiring diagrams and emergency response guides. Additionally, they acquired knowledge of critical safety precautions necessary for conducting maintenance and inspections, gained awareness of emergency response procedures and safety measures related to charging stations.

3.2.3 Key takeaways

The session addressed critical aspects of e-bus charging safety, focusing on waterproofing standards and infrastructure planning.

IP ratings and waterproofing standards

- Misconceptions about battery packs being fully waterproof were clarified, detailing the limitations of IP67, IP68, and IP69 ratings as per IEC and ISO standards.
- Emphasis was placed on mitigating water ingress in high-voltage batteries and charging stations through robust design and maintenance.

Weather protection and charging infrastructure

- Most e-bus chargers, typically rated IP54 or IP55, are not fully waterproof, necessitating additional weather protection.
- Charging stations should be positioned at higher elevations to minimise water exposure and ensure operational reliability.
- Effective planning of charging infrastructure is essential for long-term safety and efficiency.

3.3 Training III: Emergency response for e-bus fires

	Topic	Time	Focus area	Target group
Training Programme 3	Emergency response for e-bus fires	6 h	Emergency response and safety protocols	• Onboard crew members • Firefighters

3.3.1 Introduction

E-bus safety and operational best practices

The training programme was designed to educate on-board crew members and maintenance technicians on best practices for working safely around e-buses and high-voltage components, including traction battery packs. It also covered emergency response procedures for fire incidents under various scenarios.

Participants gained a foundational understanding of e-bus architecture, components, and safety protocols. The training emphasised the application of electrical safety principles, high-voltage protective measures, and safe driving practices to enhance operational efficiency and road safety.

Emergency response and mitigation techniques

The programme focused on identifying and mitigating high-voltage battery thermal runaway risks while reinforcing the importance of preventive maintenance and safety precautions. Practical exercises provided hands-on experience in conducting daily inspections and executing emergency response measures, including fire suppression and flood navigation strategies.

Additionally, the training prepared participants to handle emergency situations effectively, ensuring the safety of passengers and crew through structured response protocols and best practices for first responders.

> The training programme covered key learning areas essential for safe and efficient e-bus operations. Participants developed a solid understanding of e-bus components and safety protocols, along with proficiency in high-voltage safety measures and appropriate emergency response actions. They gained hands-on experience in conducting preventive maintenance and routine inspections. The programme also provided knowledge of fire mitigation strategies and techniques for navigating flood situations, ultimately enhancing participants' preparedness to ensure the safety of both passengers and crew.

3.3.2 Course structure

Fundamentals of e-bus operation and safety

The training covered core concepts, including the layout and components of e-buses, electrical safety protocols, and safe driving practices. High-voltage protective measures were emphasised, focusing on the proper use of PPE kits, specialised tools, and Lockout Tagout procedures for high-voltage disconnection and deactivation.

Emergency handling and maintenance procedures

Participants gained proficiency in interpreting wiring diagrams, safety colour codes, and emergency response guides. Practical demonstrations covered routine maintenance, high-voltage safety precautions, and emergency response protocols, including fire and flood scenarios. Special focus was placed on best practices for first and second responders in hybrid and e-bus operations.

The training provided participants with key learnings essential for working in e-bus environments. They gained a comprehensive understanding of e-bus components and associated safety measures, along with proficiency in high-voltage protection, proper use of personal protective equipment (PPE) kits, and Lockout Tagout (LOTO) procedures. The programme also equipped them with critical emergency response skills for dealing with fire, flood, and high-voltage incidents. Additionally, participants received hands-on experience in maintenance tasks, including welding and pressure washing, with a focus on safety precautions. Overall, the training enhanced their preparedness to handle operational challenges in e-bus settings.

3.3.3 Key takeaways

- **Battery technology differentiation:** Improved understanding of the technical and safety differences between 24V lead-acid and 650V lithium-ion batteries, emphasising the need for specialised handling protocols.
- **Lithium-Ion battery safety:** Addressed misconceptions about lithium-ion battery handling, reinforcing the importance of hazard mitigation techniques and adherence to procedural safety protocols.
- **High-Voltage risk awareness:** Deepened understanding of ISO 6469 standards, emphasising the physiological risks of high-voltage exposure and the critical importance of adhering to strict safety protocols.
- **PPE compliance in high-voltage environments:** Established Personal Protective Equipment (PPE) kits as a critical requirement, ensuring accurate selection and safe application to prevent electrical hazards.
- **Standardised safety protocols:** Reinforced the importance of ISO 6469 compliance, promoting rigorous safety adherence to safeguard technicians in electric vehicle maintenance and operations.


© GIZ India

4. Recommendations for Fire Safety

This section outlines the safety practices and recommendations for using an e-bus, covering aspects such as charging, on-road usage, fire safety, and operational maintenance. This section is intended for various stakeholders involved in the operation and management of e-buses.

4.1 Basic requirements for designing a depot or charging station

A. Design considerations of charging station

- Charging station shall not be close to potential fire or explosion hazards.
- Charging station shall not be located in dusty or corrosive gas places, and the downwind side of the prevailing wind.
- The location of charging station shall avoid low-lying outdoor areas, places prone to water accumulation/ flooding.
- The charging area shall have better ventilation conditions like charging in open area with adequate air flow.
- The ambient temperature of charging station shall meet the requirement of normal charging for electric vehicle battery
- In areas of wet weather, equipment and means for monitoring and treating air humidity shall be provided
- When charging equipment is installed indoors, ventilation facilities shall be installed to prevent increase in temperature.
- Charging equipment shall be installed at a safe height from the ground to prevent rain/water seepage and flooding.
- The design of safety monitoring system for large charging station shall be set up with video safety monitoring system, intrusion alarm and entrance and exit control design.
- Monitoring cameras shall be set in charging area and business window of charging station. It shall have a linkage interface with fire alarm system.
- Entrance and exit control equipment shall be set up at the entrance and exit of charging station.
- The camera shall be installed near the surveillance target and not vulnerable to external damage
- All detection points need to support 24-hour uninterrupted video recording
- The retention time of audio and video information collected by video surveillance system shall not be less than 30 days.
- All detection points should be capable of capturing images even in low-light or night-time conditions.

Station layout

- The charging station comprises various components, including internal buildings, traffic lanes within and around the station, a designated charging area, a temporary parking zone, and power supply and distribution facilities.
- The layout of the station buildings shall be designed to allow clear visibility of the charging area.
- The accesses of the station shall be smoothly connected with the road outside the station
- Measures shall be taken to set up to prevent electric vehicles from colliding charging facilities.

Equipment layout

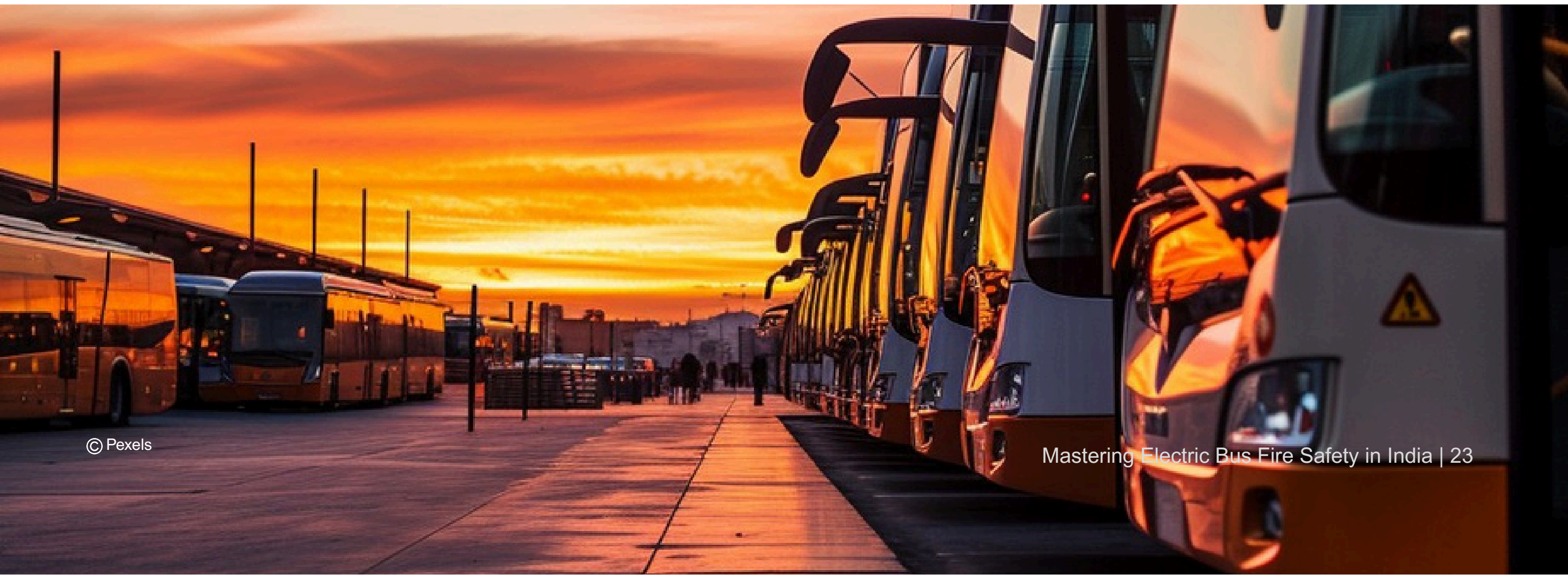
- The arrangement of charging equipment shall not hinder the charging and passage of other vehicles.
- Measures shall be taken to protect the safety of charging equipment and operators.
- The layout of electrical equipment shall follow the principles of safety, reliability and applicability.
- The layout shall be convenient for installation, operation, treatment, and maintenance and commissioning.

B. Recommended safety considerations for transformer and distribution

- With reasonable capacity configuration, the design of high and low voltage transformers should meet the requirements for safety.
- Transformers should have a higher capacity, be constructed with non-combustible materials, and feature enclosures with a minimum protection rating of IP2X.
- Transformer cabinet, bracket, foundation section steel and casing shall be separately and reliably connected with protective conductor with complete fasteners and anti- loosening parts.
- The medium and low voltage distribution systems shall be connected using sectional unit bus configurations. Switchgear should be compact, oil-free, and designed for minimal maintenance or maintenance-free operation.
- Ensure appropriate cable selection, optimised routing, and safe, well-planned installation to maintain system reliability and safety.
- Copper core XLPE insulation type and flame-retardant cable shall be selected for power cables
- Protective measures shall be taken when cabling is likely to be damaged by mechanical external force, vibration, immersion and corrosive or contaminant substances.
- Cable laying must strictly avoid defects such as wringing, armoring deformation, sheath damage, and significant surface abrasions.
- The selected distribution boxes shall comply with standards ensuring reliable protection against electric shock.
- If special power transformers are installed, the power lines shall be buried using metal-sheathed or insulated-sheathed cables and routed into the charging station through steel conduits to ensure lightning protection.

C. Safety requirements for operation and maintenance of e-bus charging infrastructure

- Conduct daily inspections to promptly identify and eliminate potential safety hazards.
- Implement a structured routine inspection system for all equipment.
- Perform safety risk assessments, ensure timely fault maintenance, investigate and resolve issues, and maintain detailed maintenance records.
- Understand common faults, safety features, and compliance requirements associated with charging equipment.
- Identify and address faults occurring in the charging infrastructure.



D. Recommended practices for safe charging of e-buses

- Ensure the e-bus is in Park mode before charging, with the parking brake engaged and the ignition switch turned off.
- Open the charge port door and remove the dust covers to access the charging interface.
- Insert the charging paddle into the port until a click is heard, indicating a secure connection and the start of the charging process.
- Once properly connected, the instrument cluster will confirm the connection by displaying "Charger Connected."

E. Handling an e-bus fire safely at depot

- Check for signs of smoke, fire, or explosion from the high-voltage battery.
- Immediately shut down the power supply to the charging stations.
- Disconnect the charging cable from the e-bus, if connected.
- If accessible, turn off the 24V disconnect switch located outside the e-bus.
- Relocate any nearby buses to a safe distance from the affected vehicle.
- If the high-voltage battery is not involved, use an ABC fire extinguisher for fire suppression while wearing appropriate PPE kits.
- Notify the control room and emergency responders, providing accurate and relevant information.
- Ensure sufficient clearance around the vehicle to facilitate safe access for fire response teams.
- If the high-voltage battery is involved, use a large volume of water to cool the battery and suppress the fire.
- Isolate the affected e-bus at a minimum distance of 15 meters from nearby structures or combustible materials.
- Monitor the vehicle for at least 24 hours for any risk of re-ignition before proceeding with further investigation or recovery actions.

F. Depot audit

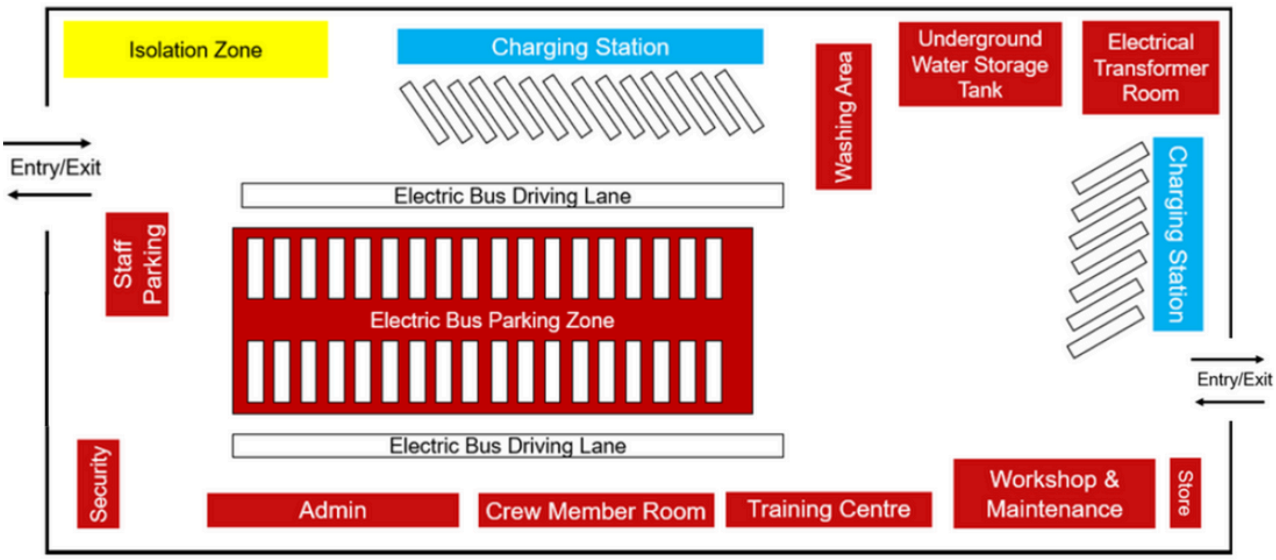
Objectives

The objective of this audit is to conduct a comprehensive assessment of the e-bus depot's operational ecosystem. Through meticulous scrutiny of infrastructure, operational protocols, and training initiatives, our aim is to identify any latent safety risks that may compromise the seamless integration of e-buses. The audit will rigorously benchmark the depot's practices against the latest EV safety standards, pinpointing discrepancies and areas requiring improvement. Our ultimate goal is to furnish a set of targeted, actionable recommendations aimed at strengthening the safety and well-being of depot personnel and visitors, while also safeguarding the depot's infrastructure and the surrounding environment from potential hazards associated with e-bus operations. This audit serves as a pivotal step towards fostering a safer and more sustainable future in public bus transportation.

Scope

- **E-bus parking infrastructure:** Safety and adequacy of parking facilities for e-buses.
- **E-bus service bay service and maintenance section:** Evaluation of the service bays designated for e-buses, including tools, equipment, and safety measures for servicing and maintenance.
- **High voltage battery safety:** Assessment of the storage, management, and emergency procedures for high-voltage batteries, including fire risk management and spill containment.
- **E-bus charging infrastructure:** Examination of charging station design, operation, maintenance standards, and SOPs to ensure safe charging practices.
- **E-bus washing infrastructure and SOPs:** Safety protocols for washing e-buses, focusing on electrical safety and water ingress prevention.
- **Transformers, electrical panels, civil infrastructure, cabling and distribution boxes:** Inspection of the entire electrical infrastructure supporting e-bus operations for compliance with electrical safety standards.
- Entry/Exits, Emergency paths and Pathways
- **E-bus crew member and technician training facilities:** Review of training programmes and facilities for crew members and technicians, emphasising e-bus operations, high-voltage safety, and emergency procedures.
- **Integration with existing diesel and CNG fleet operations:** Analysis of safety protocols for the integration of e-buses with diesel and CNG buses, including cross-contamination risks and cross type safety protocols.
- **Emergency response readiness:** Preparedness for e-bus specific incidents, such as battery fires and electrical malfunctions, including emergency equipment, training, and evacuation procedures.
- **Environmental safety impacts:** Evaluation of the environmental safety measures in place for e-bus operations, including hazardous material handling and disposal.

Reference layout for safe e-bus depot operations



Audit criteria and reference

Regulatory standards

- National and international standards for electric vehicle safety, including battery handling and charging infrastructure.
- Workplace safety regulations applicable to bus depots operating mixed fleets
- Company-specific safety protocols for electric, diesel, and CNG buses
- Central Electricity Authority (measures relating to safety and electric supply) regulations, 2023
- Technical Standards for Connectivity of the distributed generation resources (amendment) regulations, 2019
- Charging Infrastructure of EVs - Revised consolidated guidelines and standards, January 2022.
- BIS Standards for E-charging
- Indian AIS Standards relevant to e-buses and Charging stations
- Emergency Response Guides for the concerned e-bus model
- Operations and Service Manuals of concerned e-bus model
- Operation and Service Manuals of concerned Chargers and Charging Infrastructure

Audit methodology

1. Document review:

- Examination of e-bus operation manuals, safety protocols, and manufacturer guidelines
- Review of training programmes for handling e-buses, battery safety, and charging procedures
- Inspection of incident logs related to e-buses and charging equipment.

2. Site inspection:

- In-depth assessment of e-bus charging stations for safety compliance and operational integrity
- Evaluation of battery storage and maintenance areas, focusing on ventilation, fire suppression, and emergency access
- Review of signage, emergency shutdown procedures, and safety equipment for e-bus areas.

3. Interviews:

- Discussions with e-bus operators, maintenance staff, and safety officers about procedures and concerns
- Engagement with management on policies for integrating e-bus operations within the mixed fleet.

4. Data analysis:

- Statistical analysis of safety incidents involving e-buses and charging stations
- Assessment of adherence to established safety training and emergency response drills.

4.2 Safety requirements while the bus is in motion

A. Key safety tips for drivers operating e-buses

- Driver should always keep an eye on the dashboard indicator lights (Tell-tale lamps) if any light is blinking continuously or the STOP light is indicated on the dash board the bus needs to stopped immediately.
- Drivers should be trained to understand the fault codes displayed on the dashboard screen, they should also be able to navigate the dash board screen
- The drivers should be trained to know the locations of the battery main cut off switch, emergency switches for use in the emergency situations
- When driving through deep water, the vehicle's speed should not exceed 15 km/h. In conditions with large water ripples, the speed should be reduced to below 5 km/h
- In such cases, if any audio-visual signals are observed, such as a fault alarm on the instrument cluster, they should be promptly addressed.
- When there is a fault alarm, the driver shall drive the vehicle away from the water surface as soon as possible, pull up the parking brake lever, cut off the power, disconnect the service switch, and then contact the depot for help.

B. E-bus water wading or flood conditions

- E-bus components like traction motor, inverter, and battery packs come with high levels of protection against dust and water.
- Driving electric vehicles in normal rain conditions does not pose any risk to the vehicle.
- During rainy seasons, the charging stations or parking spaces of the e-buses shall be provided with adequate drainage facilities to prevent water stagnation.
- Avoid operating e-buses in floodwater conditions exceeding 100 mm in depth, as it may compromise high-voltage components.
- If an e-bus becomes immobilised in floodwater, press the 24V emergency disconnect switch to isolate the high-voltage battery.
- Call the control room for further instructions to follow.

C. Recommendations for towing an e-bus

- If the bus is to be towed with the rear or drive wheels on the ground, the driveshaft must be removed to prevent the drive motor input shaft from rotating.
- This will prevent any damage to the motor and inverter components which are highly expensive components.

4.3 Recommendations for handling an e-bus in the event of a fire

A. Key recommendations for passenger travelling in e-buses

- Immediately inform the driver or conductor if any unusual sounds are heard from the e-bus.
- Report to the driver or conductor without delay if smoke or flames are observed coming from the bus.
- In case of fire, exit the bus safely and promptly alert the fire safety department.
- In an emergency, press the emergency stop push buttons provided in the e-bus to notify the crew.
- Do not ride on or sit over the high-voltage battery packs.

- Avoid placing luggage or other items on top of the high-voltage battery compartments.
- Notify the crew immediately if any damaged electrical cables are found inside or outside the bus.

B. Emergency response of crew members for an e-bus fire incident on road

- If crew members or passengers notice smoke or fire, the driver must immediately cease acceleration and safely move the vehicle to an isolated area.
- Ensure the vehicle is not stopped near any flammable or explosive environments, such as fuel stations.
- Crew members should promptly operate the emergency doors and alert passengers to evacuate the bus.
- Inform the fire department using the emergency contact numbers provided on the e-bus.
- If the high-voltage battery is involved in the fire, notify both the control room and the fire department without delay.
- If only smoke is observed and no flames are visible, safely turn off the 24V low-voltage battery disconnect switch.
- Identify the type of e-bus and refer to the manufacturer’s emergency response guide.
- Secure the vehicle by setting it to park mode and placing wheel chocks.
- If accessible, disconnect the 24V low-voltage battery following the manufacturer’s instructions.
- Ensure that the e-bus is isolated from other vehicles or other structures by maintaining a safe distance.
- Evacuate all individuals from the area, and only trained emergency responders equipped with full PPE and SCBA (Self-Contained Breathing Apparatus) should approach the vehicle.
- If the main battery pack is on fire, request additional water supply and oxygen cylinders.
- Apply water directly to the battery pack until its temperature reduces to safe levels.
- Continuously monitor battery temperature using a thermal infrared camera.
- Take measures to control and collect runoff water, as extinguishing lithium-ion battery fires with water can generate hazardous substances like hydrofluoric acid.

C. Emergency response of fire fighters for an e-bus fire incident on road

- Identify the type of e-bus involved and consult the emergency response guide provided by the manufacturer.
- Secure the vehicle by engaging the parking mode and using wheel chocks.
- If accessible, disconnect the 24V low-voltage battery using the cut-off switch, following the manufacturer's safety instructions.
- Maintain a safe distance by isolating the e-bus from nearby vehicles and structures on the road.
- Evacuate all individuals from the area, and ensure that only trained emergency responders equipped with full PPE and SCBA are permitted to approach the vehicle.
- If the main high-voltage battery pack is involved in the fire, immediately request additional water supply and oxygen cylinders for firefighting efforts.
- Directly apply water to the battery pack area until its temperature is reduced to a safe level.
- Continuously monitor the battery temperature using a thermal infrared camera to detect any signs of re-ignition.
- Implement appropriate measures to control and collect runoff water, as using water to extinguish a lithium-ion battery fire can produce hazardous substances such as hydrofluoric acid.

D. General recommendations for handling an e-bus fire safely

- Use large volumes of water to suppress fires involving high-voltage batteries.
- Be aware that battery fires may take up to 24 hours to fully extinguish.
- Always establish or request access to an additional water supply before engaging the fire.
- If water is not immediately available, use dry chemical agents, CO_2, foam, or other suitable fire-extinguishing materials as an interim measure.
- For small fires not involving lithium-ion batteries, apply standard vehicle firefighting procedures.
- Always use insulated tools when overhauling or handling any high-voltage components.
- Ensure adequate fire knockdown before entering a high-temperature zone or area of active fire.
- Due to the risk of re-ignition, high-voltage batteries should be stored in an open, monitored area at least 15 meters away from any buildings, vehicles, or combustible materials.

© GIZ India

4.4 Recommendations for repair and maintenance of the e-bus

A. Post-incident e-bus recovery considerations

- Immobilise and disable the vehicle if it has not already been secured.
- Never disconnect or touch any exposed high-voltage (HV) components or wiring.
- Attempt to contact an authorised dealer or manufacturer representative for technical support.
- Do not breach, remove, or tamper with the high-voltage battery under any circumstances.
- Use a thermal imaging camera to actively monitor the temperature of the high-voltage battery.
- Ensure that no signs of fire, smoke, or heat are present for at least one hour before the vehicle is handed over to second responders.
- Always inform second responders about the potential risk of battery re-ignition.
- Store the damaged e-bus or any burned lithium-ion battery at a minimum distance of 50 feet (15 meters) from buildings, vehicles, or combustible materials.

B. Safe repair and maintenance of charging equipment

- Charging equipment operators shall regularly engage qualified professionals for the repair and maintenance of charging units.
- Inspect the entire charger casing for any dents, scratches, deformations, or other visible defects.
- After prolonged use, check incoming lines inside the charger for signs of rust, burrs, or cracks.
- Ensure the charger is clean and organised, and verify that the suction outlet has a dust-proof net and the exhaust outlet is clear.
- Check all connection terminals on the charger’s main board and power board for any signs of looseness.
- Verify that all switches, relays, and contactors are functioning correctly.
- Confirm that the insulation resistance is not less than 10 MΩ between the charger input loop and ground, output loop and ground, and between the input and output circuits.

C. AC/DC charging socket inspection

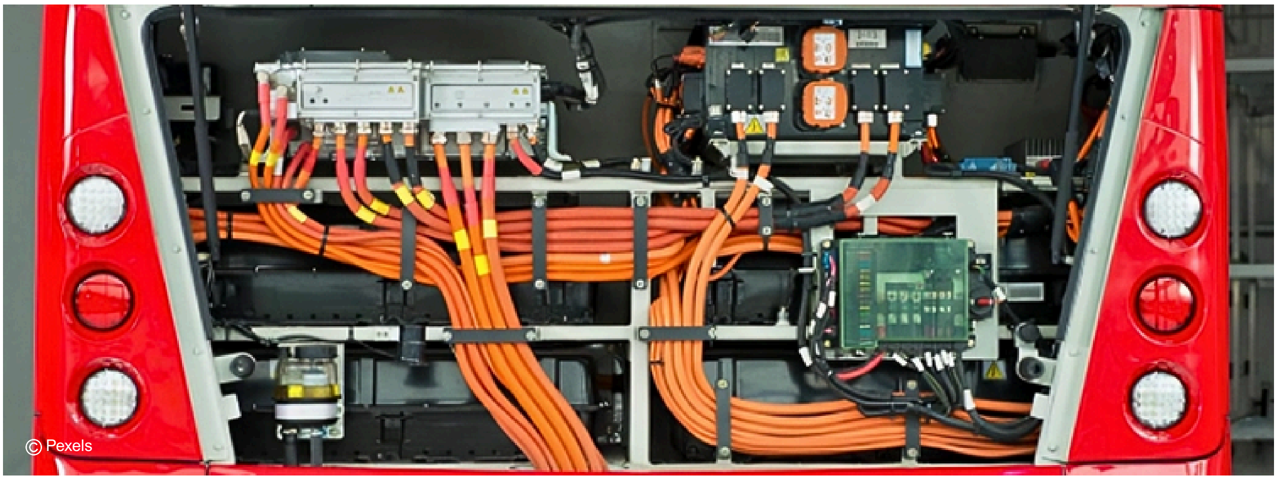
- The protective end cover of the charging socket must be intact and undamaged. The socket interior should be clean, free from foreign objects and moisture, and maintain good insulation performance. The inner waterproof ring, if visible, must be in place and undamaged.
- The cover and locking buckle of the charging socket should not show any signs of damage or breakage. The conductive parts must be free from oxidation, abnormal heating, or burn marks.
- The charging socket should be securely fixed with no looseness. Terminals must not be blackened or broken, and the internal spring must be intact and properly positioned.
- After 30 minutes of vehicle charging—or at least 10 minutes for fast charging—the temperature of the charging socket should not exceed the ambient temperature by more than 10°C.

D. Safety requirements for repair and maintenance of high-voltage connector

- High-voltage connectors must be free from damage or deformation.
- There should be no rust at the socket that could cause difficulties during disassembly.
- All high-voltage connectors must be securely installed without any signs of loosening.
- Seal rings should remain properly positioned within the sheath and must not be removed.
- The insulation resistance between the terminal and the shielding layer of the high-voltage connector must be at least 220 MΩ.
- The connector casing must be free from corrosion, damage, foreign objects, or internal moisture.
- No signs of oxidation, abnormal heating, or ablation should be present on the conductive parts of the connector.
- After any repair work, the high-voltage connector must be fully inserted and locked in place to avoid virtual or incomplete connections.
- Following any repair or maintenance, insulation testing must be conducted using appropriate testing equipment. Any detected insulation faults must be resolved immediately.
- If a connector fault is identified, the entire high-voltage harness assembly must be replaced. The correct replacement procedure is detailed in the vehicle's Maintenance Manual.

E. Safety requirements for repair and maintenance of high voltage wiring harness

- The high-voltage harness must be free from fractures, aging cracks, discoloration, ablation, insulation damage, or exposed conductors, and must maintain proper insulation performance.
- The harness should be securely fixed without any signs of loosening or detachment and must include a vibration margin of 30 to 50 mm to prevent wear or damage from sharp edges.
- There should be no defects in the electrical terminal connections between the high-voltage harness and B-level voltage components.
- After repair activities, the conductive surfaces of the terminals must be thoroughly cleaned to prevent increased contact resistance or abnormal heating due to dust or oil residue.
- The insulation resistance between the high-voltage wire and ground must exceed 2 MΩ, and the grounding resistance of the shielding layer must be less than 0.5Ω.
- Upon completion of any repair or maintenance work, insulation testing must be performed using vehicle-grade insulation testing equipment, and any identified insulation faults must be promptly resolved.

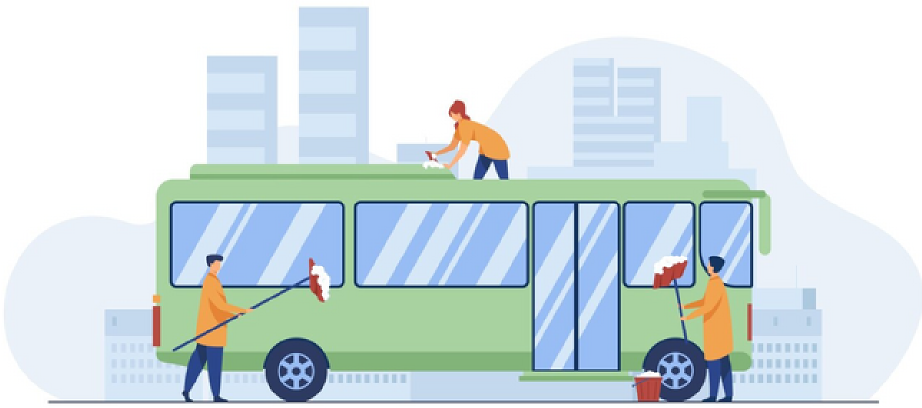


F. Procedure for transportation of a damaged/defective battery

- The Manual Service Disconnect (MSD) or serviceable fuse(s), if equipped, should be removed.
- This will typically split the battery potential in half and divide the potential energy in the pack.
- Responsible organisation service manual or service bulletin should be consulted.
- Package any damaged battery in a container compliant with relevant national or international hazardous materials and dangerous goods regulations.
- The battery should be surrounded by a non-conductive, non-combustible, absorbent cushioning material, such as vermiculite.
- Avoid using plastic wraps, duct tape, or other combustible materials to surround damaged batteries.
- A flame-retardant bag may be used around the inner packaging.
- The completed package should be closed, secured, and maintained.
- Only one battery is permitted per outer package during transportation to ensure safety and compliance with regulations.
- The outer package must be marked with damaged/defective lithium-ion battery with characters at least 12 mm high.

G. Safety requirements for repair and maintenance of power batteries

- Control the charging frequency according to the ordinary operating frequency and driving mileage.
- Please charge the vehicle in time to avoid over discharging of the battery.
- Vehicles must be charged regularly when they are stationary for a long time
- Repair of power batteries must be carried out by certified professionals
- Repair personnel shall wear insulation gloves and insulating shoes.



H. Safety requirements at repair site

- High voltage power battery repair sites must be clean (without grease, stain, or metal waste), dry (without liquid leakage), and free of sparks.
- It should not be maintained in the vicinity of the vehicle cleaning area or body repair area, and a movable partition should be used when necessary.
- Repair sites shall be well-ventilated (indoor) or as open as possible (outdoor), with clear signs that fireworks, waterproof and high-voltage hazards are strictly prohibited.
- Non-repair personnel are prohibited from entering repair sites.

I. Safety requirements during repair process

- Tools with sharp edges/corners shall not be used at/or near high-voltage components or lines.
- Failed or damaged high-voltage lines must be discarded to avoid reuse.
- Tools shall not be left inside the power battery.
- Before closing the shell cover, check the integrity of the tools in the toolbox
- It is recommended to use general magnetisation tools so that bolts will not be left in the power battery when repairing.
- If the repair process is interrupted, cover the shell cover and screw several bolts to prevent from accidental opening.
- The air tightness of the power battery system and battery liquid cooling system shall be checked at the end of the repair.
- Repair sites shall be equipped with fire safety measures to deal with emergencies such as smoke, open fire, etc.

J. Recommended practices for water washing of e-buses

- High Voltage components of e-buses come with ingress protection degree IP 65 or Higher
- Use lukewarm or cold water. Do not use hot water.
- Do not apply water directly on the high voltage and low voltage cables and connector areas.
- Avoid direct water spray from hoses and pressure washes directly onto air intakes, electrical compartments, enclosures and connectors.
- Use a dry cloth if needed to clean the dirt particles in the connector areas.

K. Recommended practices for welding operations on e-buses

- Before performing any welding or plasma cutting operations, first disconnect the 12/24V battery and the Manual Service Disconnect (MSD) of the high-voltage battery pack.
- All the critical control units like body control module, vehicle control module and other electronic control units shall be disconnected before performing any welding operation anywhere on the body or chassis.
- After completion of welding operations, do not forget to reconnect all the electronic control units.

© Unsplash

4.5 Considerations of policy and regulations

This section outlines recommendations for developing policies and regulations to ensure the safe and efficient operation of e-bus systems. It focuses on creating tailored guidelines for e-bus depots, charging infrastructure, and safety protocols, while promoting collaboration among key stakeholders. These measures aim to enhance infrastructure, safety, and training, supporting a sustainable and secure e-bus transportation system.

A. Regulatory framework for e-bus depots

- Developing specific standards and regulations for e-bus depots was deemed imperative for providing clear guidance to stakeholders.
- The existing guidelines primarily catered to diesel and CNG buses, highlighting the need for specialised regulations to address the unique requirements of e-buses.
- These standards aimed to ensure that e-bus depots adhered to stringent safety protocols.
- The regulations were designed to incorporate cutting-edge infrastructure to support the safe and efficient operation of EVs.

B. Regulatory framework for e-bus depots charging infrastructure

- It is strongly recommended to establish specific regulations, or at least detailed guidelines, for e-bus charging stations and their associated infrastructure.
- These regulations cover critical aspects such as grid connectivity and comprehensive fire safety measures.
- There is a need to enhance the current technical specifications provided by the Central Electricity Authority (CEA).
- The enhancement includes broader and more detailed coverage of key operational and safety areas, such as:
    - Electrical load management
    - Power quality requirements
    - Monitoring and control protocols
    - Ventilation specifications
    - Fire safety protocols
    - Periodic inspection and maintenance procedures for electrical installations
- Refining these technical specifications ensures the safe, efficient, and compliant operation of electric bus charging infrastructure.
- In addition, it is recommended to develop a comprehensive document addressing the following aspects:
    - Delineation of responsibilities among emergency response agencies
    - Establishment of emergency training and drill protocols
    - Implementation of prevention measures and emergency preparedness plans
    - Creation of monitoring frameworks for e-bus operating organisations

The document is to outline procedures for:

- Reporting emergencies
- Implementing on-site emergency response measures
- Organising operational emergency responses
- Releasing pertinent information
- Conducting emergency response assessments and summaries
- Ensuring resource support and guarantee
- Such a document is intended to provide essential guidance for e-bus operating organisations in India, contributing significantly to the safety and security of drivers and passengers.

C. Building a collaborative network: Inclusive stakeholder engagement

Following the "Mastering Electric-Bus Fire Safety in India" training programme, it became clear that expanding stakeholder outreach was essential for future initiatives. In addition to engaging top management, mid-level personnel, and ground staff, GIZ involved a broader range of stakeholders, including disaster management services, city traffic police, emergency medical responders, and regulatory bodies like CERC, IRDAI, CPCB, and SERC. The inclusion of stakeholders from NASSCOM, bus body builders, RTOs, and insurance surveyors provided diverse perspectives, helping to develop comprehensive safety protocols. This collaborative approach aimed to enhance understanding of e-bus fire safety and promote sustainable and safe operations.

D. Regular e-bus safety trainings

It is recommended to implement regular training sessions on e-bus safety to ensure ongoing education and preparedness among stakeholders. These sessions were to cover evolving safety protocols, emerging technologies, and best practices in e-bus operation, maintenance, and emergency response. By conducting regular trainings, stakeholders would be able to stay updated on the latest developments and reinforce their skills, ultimately enhancing the safety and efficiency of e-bus transportation systems.

E. City-level master trainers for e-bus safety

To build a culture of safety and operational excellence in e-bus systems, regular capacity-building programmes are essential. These sessions should serve as dynamic platforms for stakeholders to engage with the latest safety standards, technological innovations, and practical approaches to maintenance and emergency handling. By institutionalising ongoing training, operators, technicians, and support personnel can sharpen their competencies and adapt to the rapidly evolving landscape of electric mobility—ensuring safer, smarter, and more resilient public transport networks.

5. Outcomes

5.1 Integration of fire safety in PM E-bus Sewa scheme

Fire safety was not originally a formal requirement in the operation of e-bus depots in India. However, it has now been recognised as a critical component under the PM E-bus Sewa scheme.

As part of capacity-building efforts, targeted fire safety training sessions were organised for key stakeholders, including officials from the Ministry of Heavy Industries (MHI), the Ministry of Housing and Urban Affairs (MoHUA), and Convergence Energy Services Limited (CESL). These sessions improved awareness and understanding of fire risk assessment, emergency response protocols, and best practices for managing fire-related incidents in electric bus depots.

As a direct result of the capacity building and training initiatives, the PM E-bus Sewa scheme now mandates that all newly developed or upgraded e-bus depots in participating cities secure formal fire safety clearance from the respective fire departments. This policy integration has significantly strengthened fire risk mitigation, enhanced operational safety, and contributed to the overall resilience of India's electric bus infrastructure.

The Ministry of Heavy Industries (MHI), Government of India and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH are jointly implementing the Indo-German Development Cooperation project “Promotion of transformation to sustainable and climate-friendly E-mobility”, commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ). As part of the Green Urban Mobility Partnership (GUMP) between India and Germany, the project aims to improve the conditions for coupling the transport and energy sectors for climate-friendly electric mobility and achieve sustainable, socially balanced, and inclusive urbanisation (SDG 11). The project works with Surat (Gujarat) to promote systematic, safe, and sustainable adoption of electric mobility solutions to reduce the emission intensity of the transport sector.