

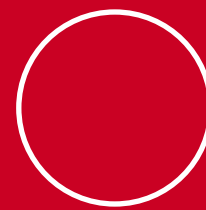
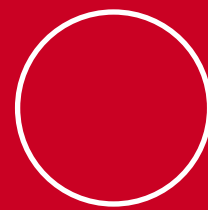
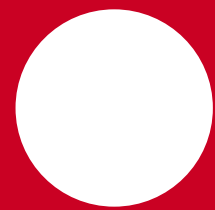
BROCHURE

# Driving confidence in EV battery safety, reliability and performance



Safety. Science. Transformation.™

**CHARGING**



# EV battery innovators, the race is on

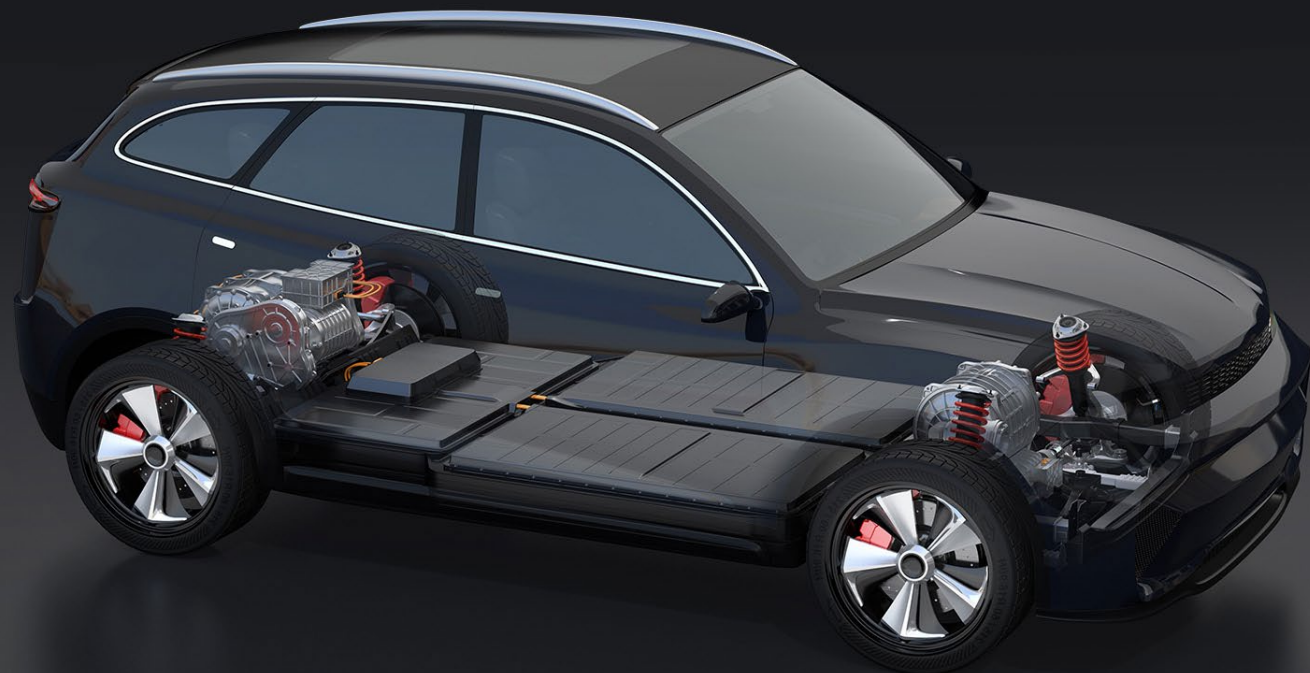
From environmental concerns and government incentives to the improved range, availability and cost-competitiveness of electric vehicles (EVs), diverse factors are driving the global transition to renewable energy.

Critical to success in this highly competitive market is the EV battery. The race is on for original equipment manufacturers (OEMs) and suppliers to launch innovative EV battery designs that offer enhanced safety and performance, increased range, and extended calendar and cycle life — all while reducing costs.

To access global target markets, OEMs and suppliers must test their batteries against applicable regulations and standards, as well as other specifications and requirements. And to stand out in the EV market's deep field of competition, OEMs must be able to validate the key metrics that differentiate their products. If their EV batteries and components don't meet safety and performance requirements, manufacturers could face costly product recalls, launch delays and damage to their brand's reputation.



# A smoother road to battery safety testing, performance validation and compliance



At UL Solutions, we understand the critical importance of EV battery safety, reliability and performance to the future of the automotive industry. We stand committed to supporting EV battery OEMs, automotive manufacturers and materials suppliers as they seize the opportunities and overcome the challenges of navigating the energy transition. That's why we provide comprehensive, end-to-end testing services that help mitigate safety and compliance risks and drive confidence in the value of your products.

By partnering with us, you can demonstrate your EV batteries' critical safety, reliability and performance characteristics and test against applicable regulations, standards and requirements — all with one dedicated testing services provider.

We leverage our wide-ranging offerings to support you through every phase of the product life cycle, from development to repurposing.

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Electrical, mechanical, thermal and environmental testing

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Performance and life cycle testing

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Battery charge/discharge cycling

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Safety and abuse testing for DV/PV and certification

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Testing for regulatory requirements and standards

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Vehicle OEM standards and requirements

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Battery management system certification

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Electromagnetic compatibility testing

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Thermal management system testing

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Battery Enclosure Material Screening (BEMS)

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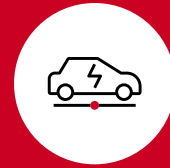
Functional safety and cybersecurity services

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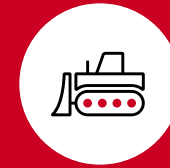
Software for product development support

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The electrification revolution has expanded to virtually every type of vehicle, and UL Solutions offers services for the following:



**Passenger vehicles**



**Construction, agriculture and mining vehicles**



**Commercial vehicles**



**Recreational vehicles**  
Including snowmobiles, golf carts and all-terrain vehicles (ATVs)



**Industrial vehicles**



**Watercraft**



**Buses**



**Aircraft**



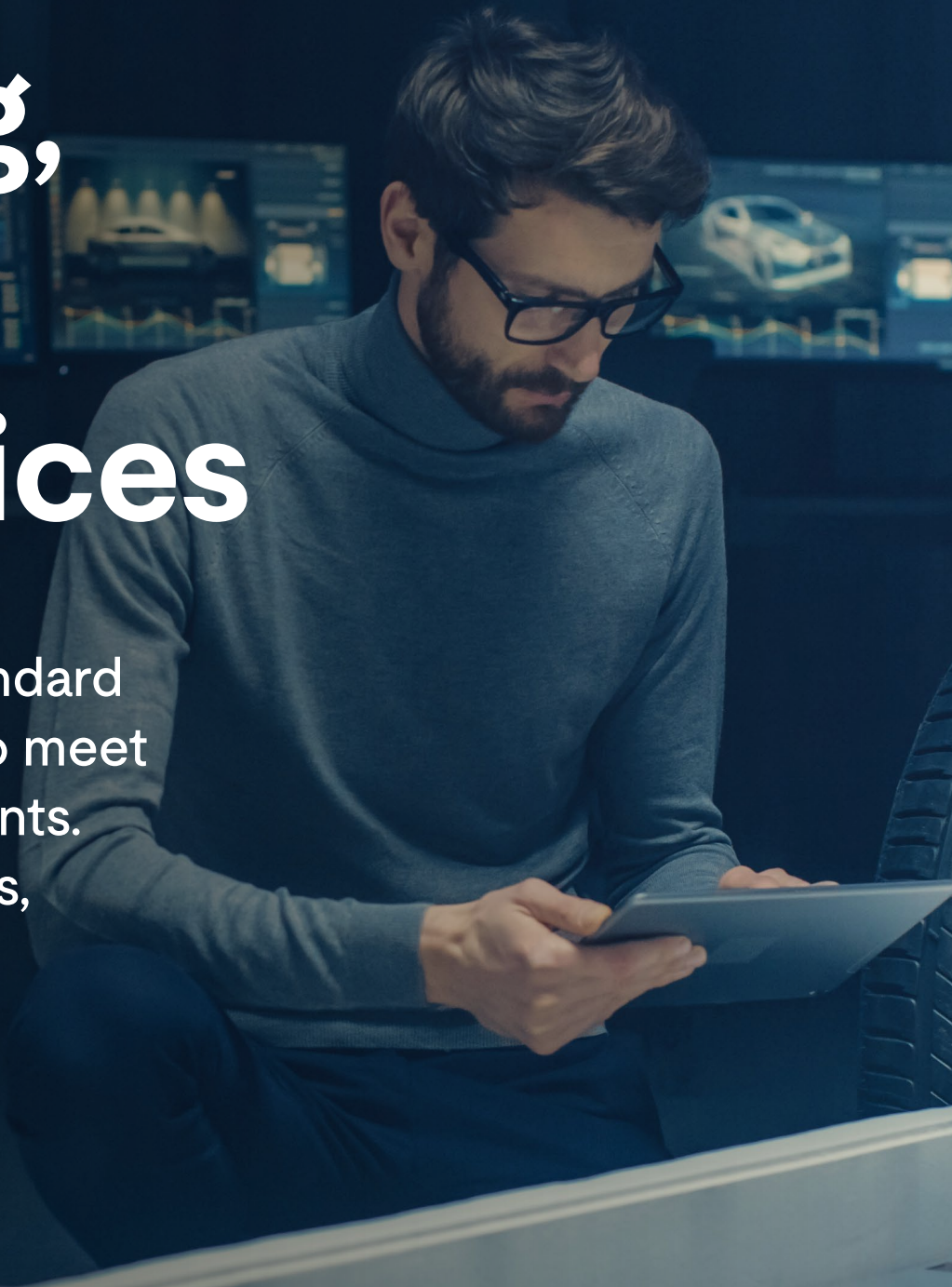
**Two- and three-wheelers**



**Airport ground support equipment (GSE)**

# EV battery testing, validation and certification services

We can test against applicable regulatory and standard requirements, as well as perform bespoke tests to meet customers' and vehicle OEMs' specific requirements. Explore some of our most popular testing services, highlighted in the following pages.





UL Solutions has more than a hundred years of experience in fire and electrical safety. We are well versed in delivering the data you need to make informed decisions about your products.

## Fire exposure and thermal propagation testing

In addition to the thermal abuse testing specified in UNECE R100, ECE R135, and other standards, we also offer bespoke testing programs that include cell-, module- and pack-level calorimetry, off-gassing and detailed analysis reports. We can also evaluate the following battery parameters:

- 1 Total energy output from a single lithium-ion cell
- 2 Fraction of thermal runaway energy transferred through the cell casing
- 3 Fraction of thermal runaway energy ejected through the cell vent
- 4 Gas composition and volume from thermal runaway
- 5 Combustion energy from battery: We collect the gases, analyze them using gas chromatography and estimate the total combustion energy.



## Electrical, mechanical, thermal and environmental testing

We test battery cells, modules and packs to the electrical, mechanical, thermal, and environmental requirements of various industry standards and specifications. Such tests include the following.

- 1 Over-charge testing
- 2 Short-circuit testing
- 3 Over-discharge testing
- 4 Single and double nail penetration testing
- 5 Crush testing
- 6 Damp heat testing
- 7 Drop testing
- 8 Thermal cycling testing
- 9 Thermal stability testing
- 10 Stone impact testing
- 11 Crush testing
- 12 Free fall/drop testing
- 13 Salt spray testing
- 14 IP testing (IPX1 to IPX9K)
- 15 Shock and vibration testing with thermal chamber and electrical cycling
- 16 High-temperature operation endurance (HTOE) life cycle testing



### Our labs are equipped with:

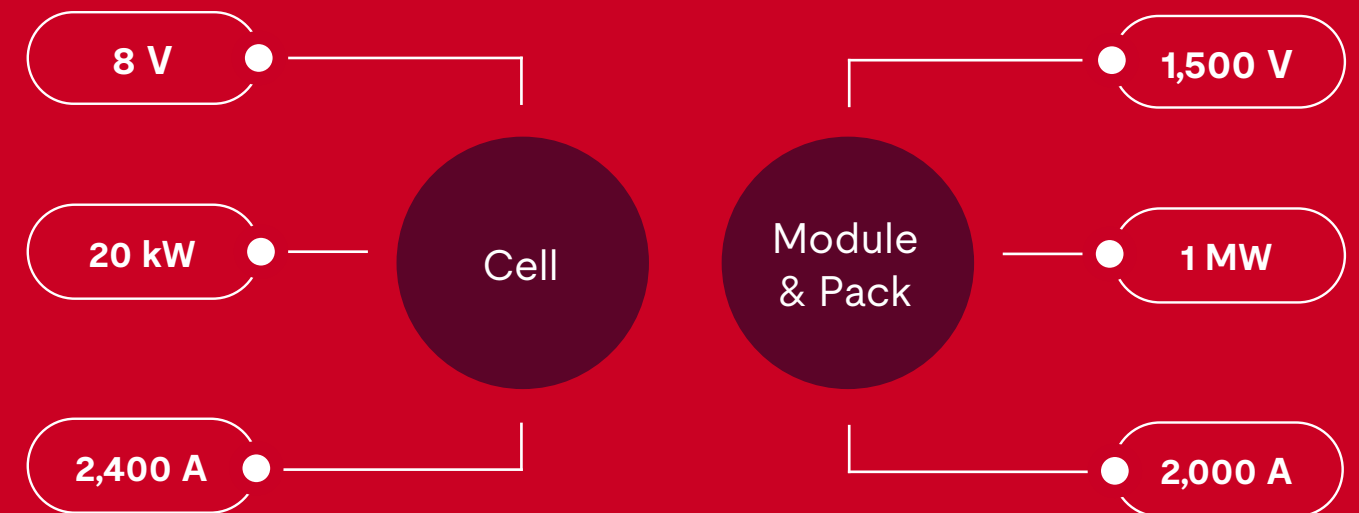
- Fully-automated control system
- State-of-the-art test cells
- Vibration systems with thermal chambers
- Environmental chambers
- High altitude simulation/vacuum chambers



## Performance and life cycle testing

In performance and life cycle testing, our experts create a precise simulation of electrical, thermal or climatic loads and other conditions that your batteries may be exposed to in real-life use to help you optimize the capacity, reliability and safety of your products.

### UL Solutions performance and life cycle testing load capacity





## Battery charge/discharge cycling

EV battery charge/discharge cycling involves charging and discharging the battery at controlled and accelerated rates and combined with environmental stresses to evaluate the safety and reliability of the battery. This helps prevent overcharging and deep discharging, which can lead to overheating, thermal issues and safety hazards. Through cycling, the battery's performance remains consistent and reliable over the design life, helping to prevent sudden drops in capacity or efficiency so that the battery's performance remains consistent and reliable over the life of the battery — crucial for predictable operation.

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## Safety and abuse testing DV/PV and certification

As a leading global testing service provider, UL Solutions offers robust safety and abuse testing services for EV batteries certification and design verification and product validation (DV/PV).

## Testing for regulatory requirements and standards

### **UNECE R100 and R136 — Rechargeable Energy Storage System (REESS)**

United Nations Economic Commission for Europe (UNECE) R100 and R136 are international requirements for the approval of electric road vehicles. They have been formally adopted in Europe and several countries in other regions. R100 applies to four-wheel vehicles (Category M/N); R136 applies to two-wheel vehicles (Category L). Testing to these requirements includes electrical safety, vibration, thermal shock and cycling, mechanical impact and fire resistance testing, as well as external short-circuit, over-charge, over-discharge, over-current and over-temperature protection.

### **UN/DOT 38.3 — United Nations (UN) Manual of Tests and Criteria, Lithium Metal, Lithium Ion and Sodium Ion Batteries**

Products containing lithium or sodium-ion batteries are classified as class 9 hazardous materials that present risks of explosion and fire and can result in injury or loss of life if they are designed or handled improperly. UN 38.3 establishes the criteria for rigorous lithium-ion and sodium-ion battery testing methods to help ensure safety during transport. Enforced worldwide, this standard applies to batteries transported either on their own or installed in a device and at all points in the transportation process. Testing to UN 38.3 includes altitude simulation as well as thermal, vibration, shock, short-circuit, impact, over-charge and forced discharge testing.





## Vehicle OEM standards and requirements

We offer testing services for OEM specifications including VW 80000, GMW 16390, GMW 3172, CS.00056, Ford SDS and TSC3000G.

### **UL 2580**

The Standard for Batteries for Use in Electric Vehicles

### **UL 1973**

The Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications

### **UL 2271**

The Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications

### **LV 124**

German Automotive Manufacturer Testing Standards

### **GB 38031**

National Standard of the People's Republic of China, Electric Vehicles Traction Battery Safety Requirements

### **IEC 63057**

Secondary Cells and Batteries Containing Alkaline or Other Non-acid Electrolytes — Safety Requirements for Secondary Lithium Batteries for Use in Road Vehicles Not for the Propulsion

### **ISO 6469-1**

Electrically Propelled Road Vehicles — Safety Specifications — Part 1: Rechargeable Energy Storage System (RESS)

### **Regulatory tests**

Including Federal Motor Vehicle Safety Standards (FMVSS), Korea Motor Vehicle Safety Standards (KMVSS) and others

### **SAE J2380**

Vibration Testing of Electric Vehicle Batteries

### **SAE J2929**

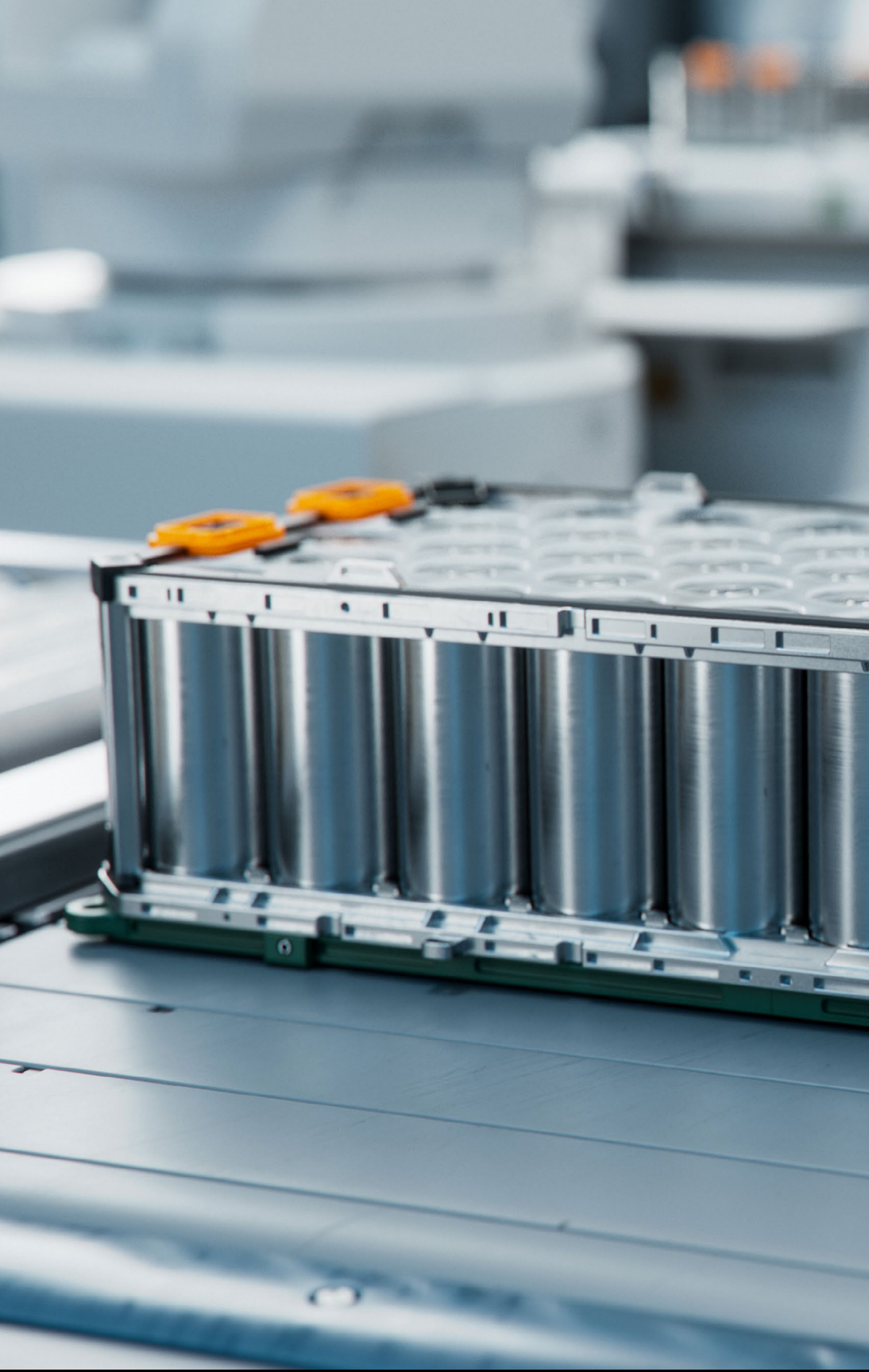
Electric and Hybrid Vehicle Propulsion Battery System Safety Standard — Lithium-based Rechargeable Cells

### **IEC 62660-3**

Secondary Lithium-ion Cells for the Propulsion of Electric Road Vehicles — Part 3: Safety Requirements

### **SAE J1798**

Performance Rating of Electric Vehicle Battery Modules



## Battery management system certification

To help mitigate the potential fire, explosion and electric shock risks during EV batteries' real-world use, testing the battery management system (BMS) — often referred to as the brain of the battery system — is critical.

We can evaluate the BMS's electrical, mechanical and environmental aspects, as well as functional safety, which can help reduce BMS risks so that systems perform safely in the event of an electrical or electronic malfunction. We can test BMS functional safety to several standards, including:

### **UL 991**

The Standard for Tests for Safety-Related Controls Employing Solid-State Devices

### **UL 1998**

The Standard for Software in Programmable Components

### **UL 60730**

The Standard for Automatic Electrical Controls for Household and Similar Use — Annex: Requirements for Electronic Controls

### **IEC 61508**

Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems

### **IEC 62061**

Safety of machinery — Functional Safety of Safety-Related Control Systems

### **ISO 26262**

Road Vehicles — Functional Safety

### **ISO 13849-1**

Safety of Machinery

## Electromagnetic compatibility testing

For low-voltage (LV) and high-voltage (HV) electronic components, electromagnetic compatibility (EMC) testing is an essential part of a component's DV or PV validation program. UL Solutions offers electronic sub-assembly EMC testing to regulatory, OEM-specific and vehicle-level testing requirements in several convenient locations around the world.

In the laboratory setting, our experts recreate the component's in-vehicle operation modes while measuring emissions and susceptibility/resistance (immunity) to electrical disturbances transmitted over the air or along the wiring harness according to the OEM's EMC test specification.\*

UN ECE Regulation 10 is an example of a vehicle/sub-assembly EMC regulation adopted by countries around the world. UL Solutions can conduct other applicable regulatory EMC tests for EVs and EV sub-assemblies during charging mode when the sub-assemblies are coupled to the grid (AC power mains). Regulatory requirements and the applicable compliance testing can vary by country.

*\* Please note that testing to OEM EMC validation test methods is not equivalent to regulatory compliance testing*



## Thermal management system testing

Thermal management is key to EV safety, performance, efficiency and reliability. The EV battery thermal management system comprises the battery, cabin and power electronic thermal systems, which include heaters, pumps, valves and heat exchangers.

Because thermal management systems are complex and have non-serviceable components, they require comprehensive reliability, safety and service life testing. This includes accelerated testing through mechanical vibration, shock, pressure cycling, thermal/humidity cycling and fluid thermal shock.







## Battery Enclosure Material Screening (BEMS)

EV batteries typically cover the entire base of a vehicle. The enclosure in the vehicle must protect the battery from outside elements and accidents while also containing the risks it could pose to the vehicle and its occupants.

As the EV industry looks to decrease the weight of many components, manufacturers are increasingly changing battery enclosure materials to plastics and composites. The enclosure materials must be exceptionally strong as well as heat- and pressure-resistant — all while remaining relatively lightweight. Choosing the appropriate enclosure material before building an expensive prototype plays a crucial role in minimizing safety hazards and other costly issues.

Together with industry stakeholders, we developed our Battery Enclosure Material Screening (BEMS) services to help OEMs and suppliers choose the most suitable EV battery enclosure materials. In BEMS, we evaluate the safety and performance of different battery enclosure materials in response to

a thermal runaway event, outlined in UL 2596, the Test Method for Thermal and Mechanical Performance of Battery Enclosure Materials. UL 2596 includes the following test methods:

- The Torch and Grit (TaG) test for impact and heat performance
- The Battery Enclosure Thermal Runaway (BETR) evaluation for impact, pressure and heat performance

Our experts can also help create bespoke enclosure material test programs for your specific product development requirements and needs. We leverage our leading-edge laboratory equipment, research and testing expertise as well as a deep understanding of standardizing test methods to help you determine optimal test procedures.

## Functional safety

The purpose of functional safety is to reduce risk in systems so that they perform safely in the event of an electrical or electronic malfunction. As more automotive products incorporate complex microelectronics and software into their designs, it becomes increasingly challenging to implement functional safety at the process and system level. UL offers personnel training, independent confirmation reviews, audits and assessments to relevant standards such as ISO 26262.

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## Cybersecurity

We can help you develop cybersecurity requirements at the vehicle, system, hardware and software levels. Digital security training and advisory around the ISO/SAE 21434, UNECE R155/R156 and ISO 24089 standards help you successfully deploy innovations that safely connect people and technology.





## Software for product development support

### ParkView Analytics

ParkView Analytics, our cloud-based research and development data analytics software, enhances your ability to work with big data. ParkView Analytics reduces the need for manual processing, simplifies storage, offers continuous access and facilitates analysis during each stage of the product life cycle. Build your own technology-neutral data visualization and processing platform in the cloud, customized for your business needs.

With ParkView Analytics, you can create a visualization of EV batteries' individual state of health. This powerful software can track battery cell voltages and currents against motor power, temperature, time, usage patterns, GPS location and more.

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### Stages

Help ensure your battery development program meets regulatory and other requirements. Our Stages process management tool supports complex processes — including product development process (PDP), homologation, embedded software, agile transformation and more — all tailored to your specific project or program's needs. Stages helps accelerate the rollout of an agile process landscape by applying a predefined process framework, such as Scaled Agile Framework® (SAFe®).



## **Automotive SPICE®**

Automotive SPICE® (Software Process Improvement and Capability Determination) is an established quality management framework and industry standard that helps assess and improve processes in automotive electronics software, hardware, mechanical and systems development. We can help determine gaps in your development processes and apply Automotive SPICE to help improve the maturity of your processes and the quality of their outcomes.

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## **Agile**

Today's demands for accelerated timelines, greater productivity, product safety and security call for optimized development processes. Our experts can help you develop a tailored approach to agile transformation that works for your business's unique needs.

# Why choose UL Solutions?

## **Long-standing expertise**

With more than 100 years of experience in fire and electrical safety and over 30 years of experience in battery and energy storage system safety, UL Solutions has a deep heritage of helping innovators in these spaces demonstrate and communicate the safety, quality and performance of their products.

## **Comprehensive end-to-end services**

We offer comprehensive services at the battery cell, module and pack level to validate performance, reliability, safety and other key characteristics. We support both EV and EV battery manufacturers and suppliers throughout the entire product life cycle, can test against applicable regulatory and standard requirements, and also offer customized services to meet your unique needs.

## **Global presence and dedicated local service**

We leverage our highly equipped testing laboratories and global network of experts to provide high-quality, efficient, local service to our customers. Our facilities are located near major vehicle manufacturing epicenters in the U.S., Germany, France, Sweden, China, Taiwan, Japan and Korea to offer dedicated support close to your business.

## **Cutting-edge testing technologies and methodologies**

At our advanced testing laboratories, we use state-of-the-art equipment, technology and methodologies. Our laboratories also meet all information security management standard requirements relevant to the industry.

## **Committed to supporting the energy transition**

The race for EV adoption has spurred manufacturers to seek a knowledgeable and trusted third party to test for compliance with performance and safety requirements. Our expanded portfolio of EV battery services demonstrates our commitment to operating at the forefront of the industry. We apply our safety science expertise to help facilitate innovation and speed to market.

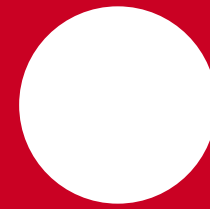
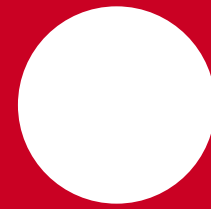
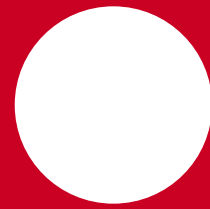
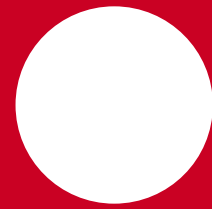
# The journey starts now

During this transformative era, success in the automotive industry hinges on the ability to balance speed to market, performance and compliance in dynamic supply chains. We can help you solve these critical challenges and achieve shorter development cycles critical to competitive positioning in the global marketplace.

Visit [UL.com/EVbattery](https://www.ul.com/EVbattery) to learn more and connect with our experts.



READY. SET. GO!





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