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# Navigating safety and sustainability in an evolving battery landscape

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LET'S GO

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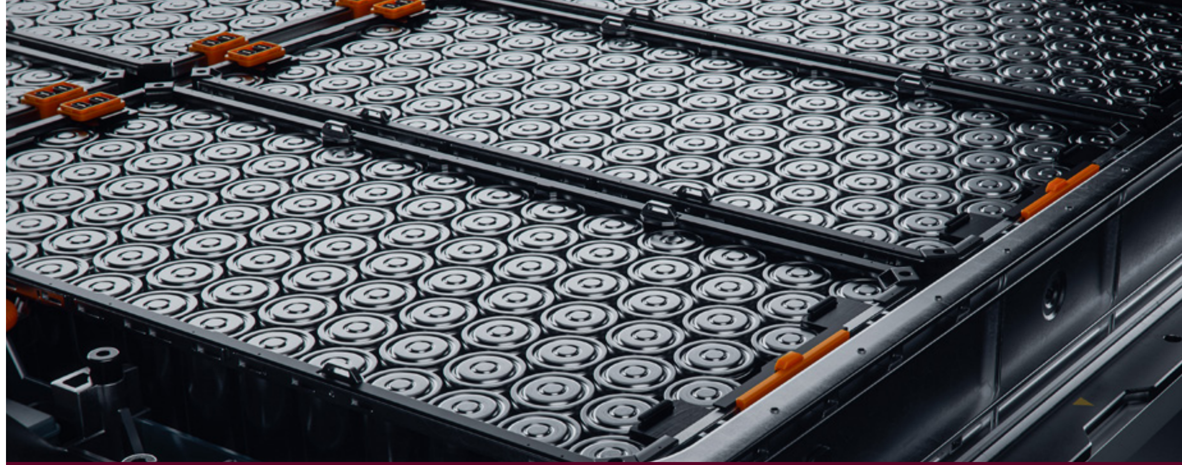
# Battery energy storage systems and the energy transition

Batteries and battery energy storage systems (BESS) are a cornerstone of the energy transition. On global, national and local levels, regulators and private- and public-sector organizations are setting ambitious targets for greenhouse gas (GHG) emissions reductions.



## Balancing safety, performance and speed of deployment

Battery storage will play a crucial role in the world's ability to make good on these targets. The International Energy Agency (IEA) estimates global installed BESS capacity will need to rise from less than 200 gigawatts (GW) in 2023 to more than 1 terawatt (TW) by the end of the decade and 5 TW by 2050 for the world to stay on course with net-zero targets.[1]

As adoption accelerates, stakeholders across the battery value chain — including manufacturers and OEMs, project developers, regulators and more — cannot sacrifice safety and performance for speed of deployment.

Fire safety is a critical example: BESS can be prone to thermal runaway, a self-perpetuating process that can cause a rapid and uncontrollable increase in temperature in battery cells to propagate to entire systems, causing fires and explosions. In New York City alone, lithium-ion battery fires from devices like e-bikes have caused 733 fires, 442 injuries and 29 deaths since 2019.[2] While safety improvements have been made in batteries in recent years, and while BESS used in industrial environments are less prone to catastrophic failures than those used in other devices and environments like in e-mobility,[3] developing and deploying safer, more sustainable BESS will always underpin public trust and market adoption.

In addition to safety, this article explores other critical challenges to more sustainable BESS development and deployment and how key stakeholders can proactively address them.

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# New technologies and new applications breed new challenges and complexities

The BESS product category isn't static or simple; it's made up of a diverse set of technologies used across a growing range of applications and environments.

A decade ago, lithium-ion batteries were predominantly used in consumer electronics and in early electric vehicles (EVs). Today, sales of EVs and plug-in hybrid electric vehicles (PHEVs) are skyrocketing; they made up more than half of new car sales in China in July 2024.[4] Similarly, large-scale BESS projects were absent from power grids until 2015. By 2024, California hit a milestone of 13 GW of operational BESS capacity milestone, with more deployed monthly.[5]

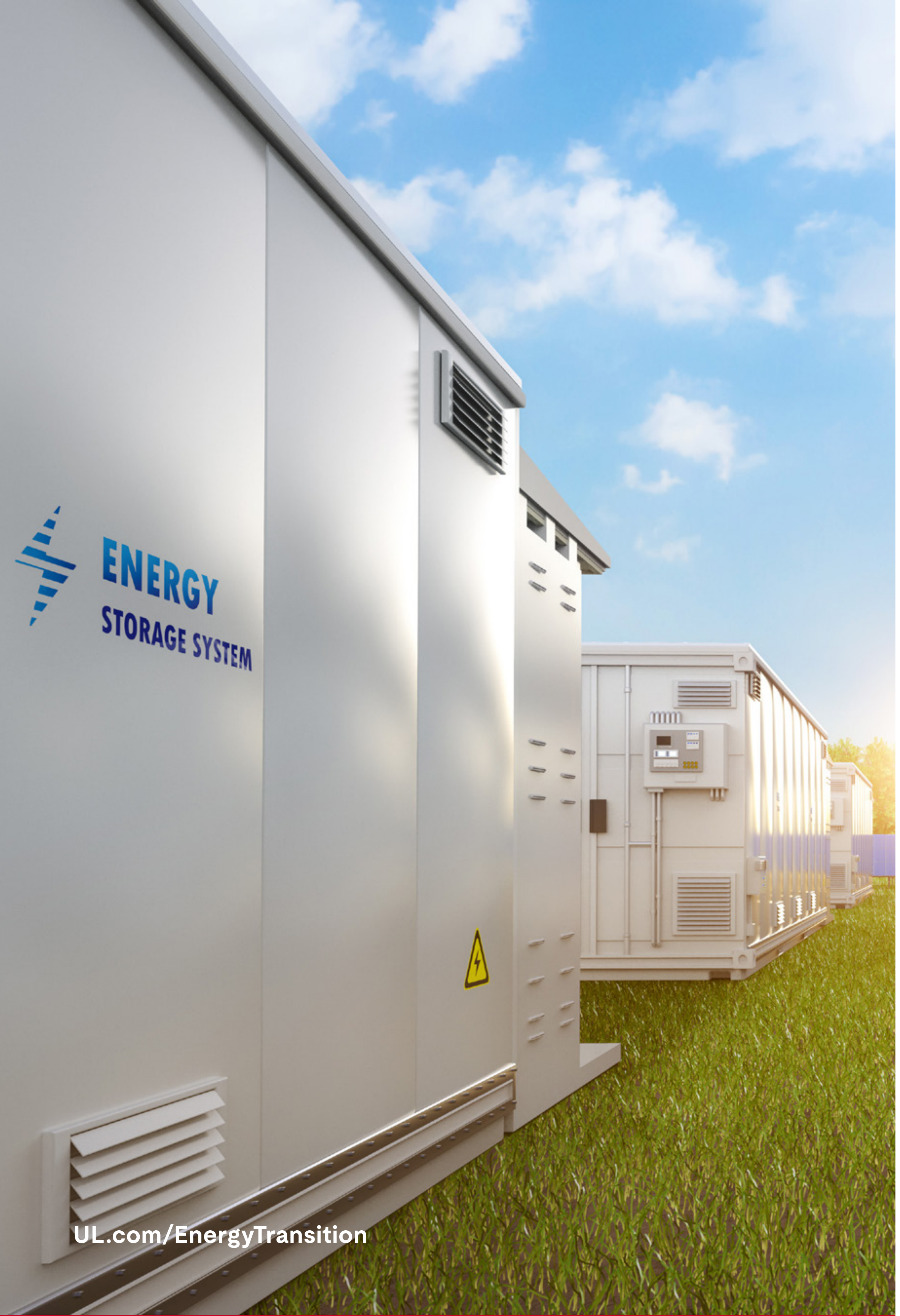
BESS will continue to deploy and gain market share across applications and environments:

**In power generation and grid applications**
BESS use is growing considerably, as they can reduce emissions and increase reliability by regulating grid frequency and voltage.

**In transportation**
BESS is gaining traction due in part to subsidies and declines in cost to promote greater efficiency and reduce emissions. BESS can also feature in vehicle charging infrastructure to reduce the strain charging places on grids, while BESS in EVs can also deliver electricity back to homes or the grid.

**In the built environment**
The places we live and work and appliances we use every day are now hotspots for BESS integration and can turn into dynamic, interconnected devices. BESS installations are becoming more frequent to provide backup power to buildings or when integrated into devices like induction stoves and hot water heating systems.

Considering the diversity of battery storage applications and continued innovation in the technologies themselves, testing the safety and performance of BESS across all foreseeable operating conditions presents a difficult challenge. Risks to mitigate include existing risks, like thermal runaway, and emergent ones, like cybersecurity risks, which arise as more battery storage connects to grids, expanding the vulnerable surface area for digital attacks.




# The diversity of BESS can require many different assessments

BESS are diverse in their product formulations as well as design, performance attributes and applications. Performance attributes can vary across dimensions including cost, energy density, discharge speed, temperature sensitivity and safety characteristics. Some battery chemistries like lithium-ion may perform better on a metric like energy density, while others may be less costly and others may offer greater safety benefits. Sodium-ion batteries, which may prove less prone to thermal runaway, are not yet widely sold or utilized but are commercializing quickly, with large-scale factories being built in China[6] and the U.S.[7]

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## Testing and compliance

Faced with this diversity of designs, the pace of technological change, adoption demands and decarbonization imperatives, manufacturers, OEMs, regulators and standard development organizations (SDOs) are under pressure to advance testing, inspection and certification to support the design, development and deployment of safer, sustainable battery energy storage.

Other innovations that will challenge testing and certification capacity include the ever-increasing size of battery cells and systems coming to market. Larger cells used in these systems can generate more heat, leading to an uneven temperature distribution within cells. Managing internal temperature variations is critical to prevent hotspots that can degrade battery performance and safety or lead to thermal runaway. These larger cells also require closer evaluation of individual cell health, as failures within a single cell can significantly reduce overall system capacity or cascade to the failure of an entire string of cells. New battery testing and compliance facilities — like the recently opened UL Solutions facility in Auburn Hills, Mich. (U.S.) — test, assess and certify these larger batteries and systems to applicable standards and requirements.

Comprehensive safety standards, such as UL 1973, the Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications, can be used to test and certify a wide range of BESS to applicable safety requirements. While specific testing parameters may be modified for different BESS designs or envisioned applications, standards like UL 1973 help streamline testing and certification, even as BESS and their uses continue to evolve.


North America Advanced Battery Laboratory

# Addressing an evolving compliance environment


The European Commission recently introduced and continues to refine new regulations[8] to protect its domestic manufacturing industry and establish safety and sustainability standards for BESS, battery components and input materials imports. For example, the EU Battery Regulation introduces new requirements, such as reporting on product carbon footprint, which may be difficult for manufacturers to integrate into their design, development, testing and certification efforts.

Variance of regulations, codes and certifications across jurisdictions and geographies can also create compliance risks. If regulations and requirements in one jurisdiction differ from another, and a company operates or wishes to operate in both, the differences between the markets or geographies can complicate quality assurance, testing and certification and development and design plans.

To help alleviate these risks, manufacturers can work with third parties to test and certify products and systems for compliance with diverse standards globally. At UL Solutions, we test and certify BESS to many standards and requirements, including ones that are specific to certain geographies, including UN/DOT 38.3 (United Nations Manual of Tests and Criteria, Lithium Metal, Lithium Ion and Sodium Ion Batteries) and United Nations Economic Commission for Europe (UNECE) R100 and R136 (international requirements for electric road vehicles specific to four-wheel vehicles and two-wheel vehicles).

We also offer performance and reliability testing for standards from other globally recognized standard-setting bodies, including the following from International Electrotechnical Commission (IEC):

- IEC 62619 Safety Requirements for Secondary Lithium Cells and Batteries for Use in Industrial Applications
- IEC 62620 Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Secondary Lithium Cells and Batteries for Use in Industrial Applications
- IEC 63056 Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Secondary Lithium Cells and Batteries, for Use in Electrical Energy Storage Systems

Our team's experience and knowledge — and active participation in standards-setting panels and technical committees — helps our customers stay current with diverse international requirements.

# Environmental impact and end-of-life management

Manufacturing and sourcing inputs for batteries and energy storage systems present their own environmental issues. While battery storage can help reduce greenhouse gas emissions over the lifecycle of their use, mining, material refining and manufacturing needed for production can introduce significant environmental impacts and may also be subject to new regulations.

Cobalt is one example of a core material input to many lithium-ion batteries with ethical and environmental concerns. Most of the world's cobalt globally comes from the Democratic Republic of Congo (DRC), which is home to mining operations that can employ child labor.[9] Large companies have faced considerable scrutiny as to whether and to what extent cobalt used in their batteries originates from mines with negative ethical and environmental externalities. These companies have committed to phasing out cobalt from their supply chain by moving to batteries with different chemistries that omit cobalt or using 100% recycled cobalt by 2025.

Lithium iron phosphate (LFP) cathode chemistries have become more popular, in part because they omit cobalt, rising from 3% to 27% market share between 2019 and 2023[10] in the light-duty vehicle sector. But the cobalt example illustrates that issues persist in BESS supply chains and that products that use them, like EVs — which offer significant environmental benefits — can come with environmental and ethical concerns for manufacturers, OEMs and regulators to manage. Failing to adequately and proactively address these challenges and concerns can expose companies to reputational damage, force changes to design and development and slow time to market in the face of any new regulations or requirements and reduce trust with other stakeholders.

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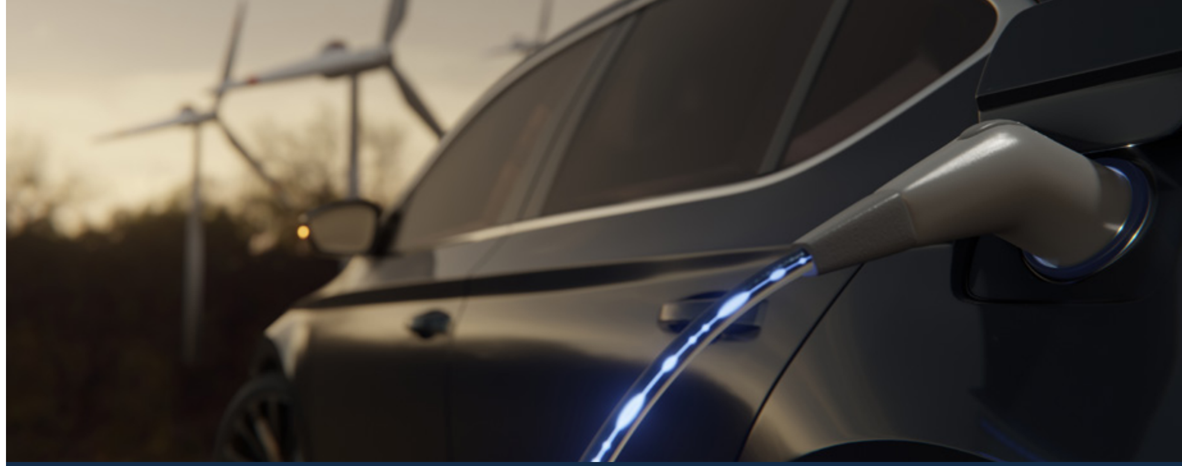
## End-of-life management

The same is true for end-of-life management. Considering the value of many metals and minerals in BESS and the systems themselves, significant opportunities to recycle and repurpose BESS are coming to the fore as we speak and will continue to develop as more BESS is deployed and reaches the end of its useful life in any given application. For example, when EV batteries reach the end of useful life in their automotive application, they can still retain up to 80% of their storage capacity,[11] making them potentially useful for deployment in other applications, such as power grids. Hence, repurposing efforts are underway. For example, in May 2024, a 53 megawatt-hour (MWh) grid-connected BESS installation using entirely repurposed EV BESS began providing power to the grid in West Texas.[12]

Projects like this demonstrate thoughtful reuse of used BESS but also introduce new safety and performance concerns. When BESS is redeployed in secondary applications, they may require additional testing and certification. At UL Solutions, we offer services to certify large battery repurposing facilities by assessing how battery cells are sorted and graded, the processes used to identify their continued viability and rating mechanisms for future use. Once we determine the viability of a facility's processes, it can achieve a second-life battery facility certification, such as certification to UL 1974, the Standard for Evaluation for Repurposing or Remanufacturing Batteries.



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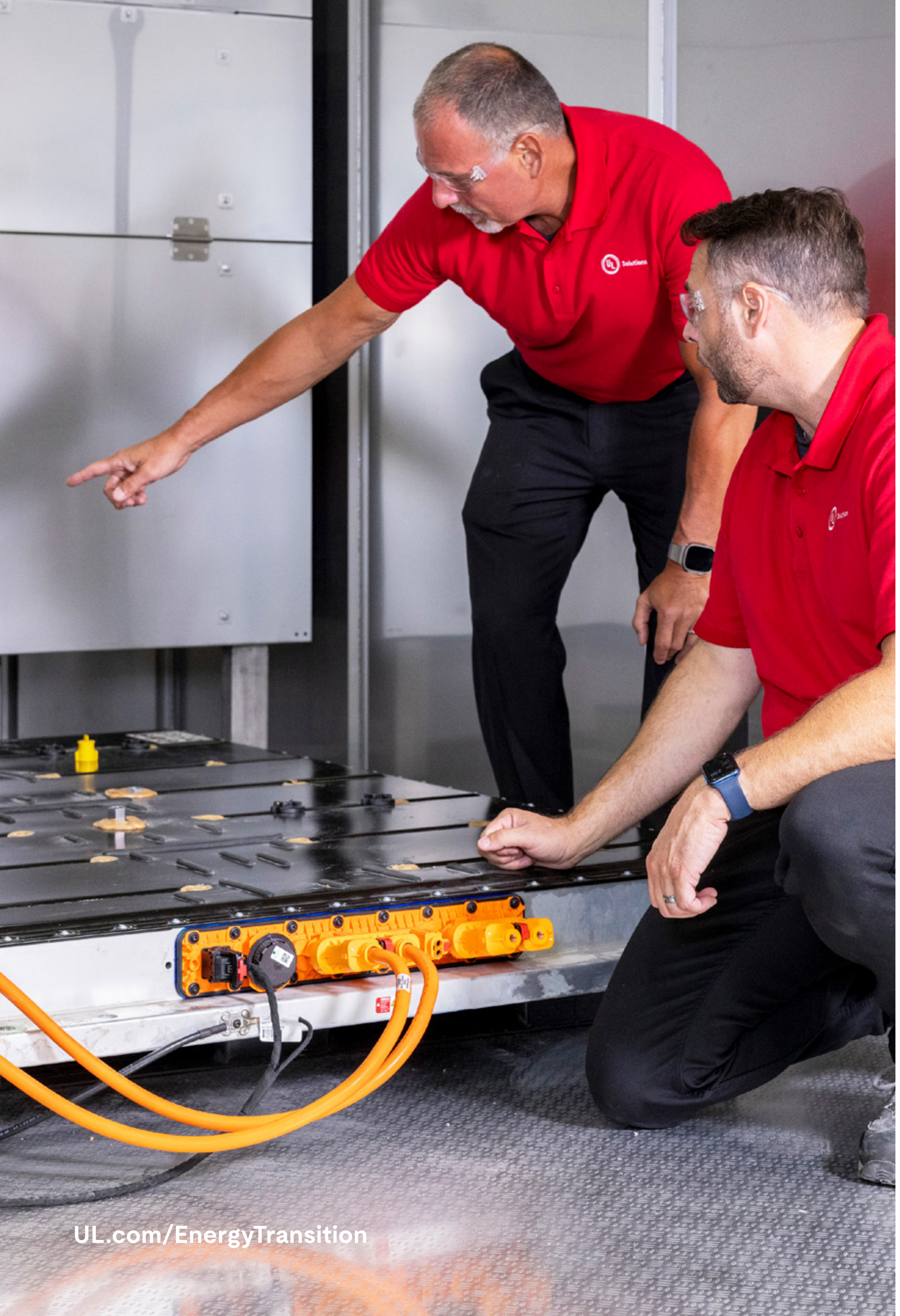


# UL Solutions’ role in advancing safer, more sustainable BESS

Regardless of the innovation, the scale of deployment or the application, battery safety and performance cannot be compromised in favor of speed. In the long term, deficiencies in safety or performance hinder sustainability and the success of the energy transition more than near-term speed to market or deployment of installations that enable it.

Simultaneously, navigating ways to promote safer, more sustainable BESS development, deployment and reuse requires proactivity in testing and certification. Keeping pace with industry shifts, including engagement with a third-party provider, is essential to evaluating impacts on existing and future design and development plans as well as needed updates to testing and certification.

At UL Solutions, we have long-standing relationships with many manufacturers, OEMs and other stakeholders who design, develop and deploy a wide range of energy transition technologies, including BESS. Our extensive expertise in safety science, testing and certification can help manufacturers and OEMs bring safer, more sustainable BESS to market. Specifically, the comprehensive testing, inspection and certification services we offer for BESS include:

- Battery cell and module testing
- Battery pack and system testing
- Fire safety and thermal runaway testing
- Electrical safety and performance testing
- Grid integration and interoperability testing
- Environmental testing and durability testing
- Cybersecurity testing as software plays a growing role

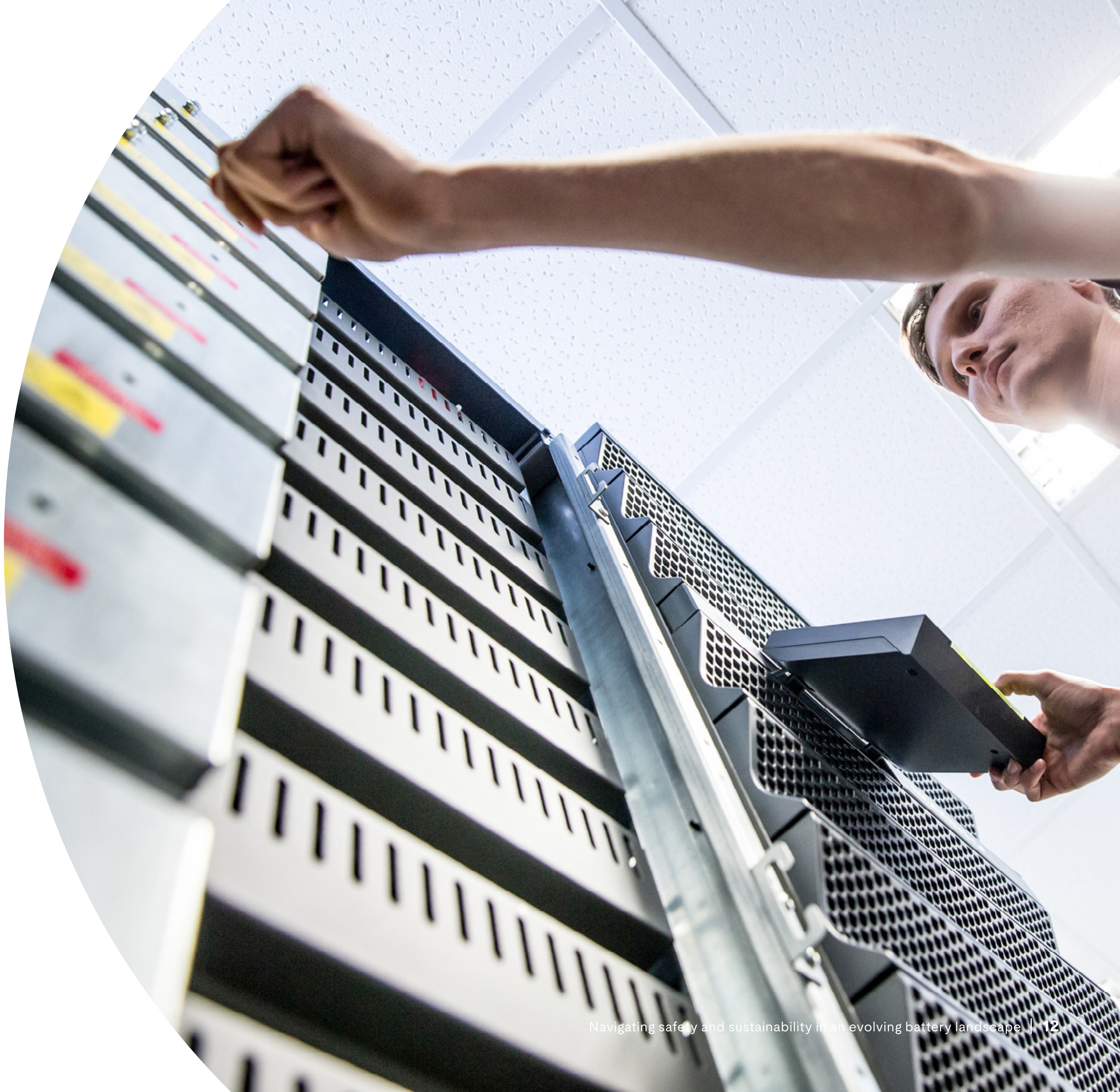
Demonstrate compliance by testing and certifying to standards such as UL 9540,[13] the Standard for Energy Storage Systems (ESS) and Equipment, which covers safety for BESS, other types of energy storage systems, offers a comprehensive assessment of system attributes ranging from charging and discharging to protection, control and communication between devices, fluids movement and more.

Further, we also help customers identify preventative and corrective actions and offer custom research that can help reduce risks across the development and deployment life cycle, including battery aging studies, forensic failure analyses and on-site field evaluations.

As a global safety science leader, our testing and certification services and participation in working groups and in industry boards across the BESS and energy transition landscape position us to help our customers turn complexities into competitive advantages.

Connect with us to learn more about how we support innovators as they advance safer, more sustainable energy storage technologies.

CONTACT US



# References


[1] Batteries and Secure Energy Transitions, World Energy Outlook Special Report, International Energy Agency (IEA), April 2024, https://www.iea.org.

[2] Mayor Adams takes new actions to prevent deadly lithium-ion battery fires, promote safe e-bike charging and usage, July 22, 2024, The Official Website of the City of New York, https://www.nyc.gov.

[3] Claims vs. facts: Energy storage safety, American Clean Power, accessed October 2024, https://cleanpower.org.

[4] EVs, hybrids set to exceed 50% of China car sales for first time, Bloomberg News, Aug. 7, 2024, https://www.bloomberg.com.

[5] California now has more than 13GW of battery storage, Energy Storage News, October 2024, https://www.energy-storage.news.

[6] World's largest sodium-ion BESS comes online in China as it seeks to diversify away from lithium, Energy Storage News, July 4, 2024, https://www.energy-storage.news.

[7] Natron Energy to invest $1.4 billion in new sodium-ion battery gigafactory, IndustryWeek, Aug. 19, 2024, https://www.industryweek.com.

[8] Circular economy: New law on more sustainable, circular and safe batteries enters into force, European Commission, Directorate-General for Environment, Aug. 17, 2023, https://environment.ec.europa.eu/news.

[9] Combatting child labor in the Democratic Republic of the Congo's cobalt industry (COTECCO), U.S. Department of Labor, Bureau of International Labor Affairs, accessed October 2024, https://www.dol.gov.

[10] Trends in batteries, International Energy Agency (IEA) Global EV Outlook 2023, https://www.iea.org.

[11] EV battery capacity retains over 80% even after 200.000 km: How residual value evolves across lifecycle phases, EV Boosters, November 2024, https://evboosters.com/ev-charging-news/ev-battery-capacity-retains-over-80-even-after-200-000-km-how-residual-value-evolves-across-lifecycle-phases/

[12] The biggest grid storage project using old batteries is online in Texas, Canary Media, November 2024, https://www.canarymedia.com.

[13] UL 9540 energy storage system (ESS) requirements — evolving to meet industry and regulatory needs, UL Solutions.

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