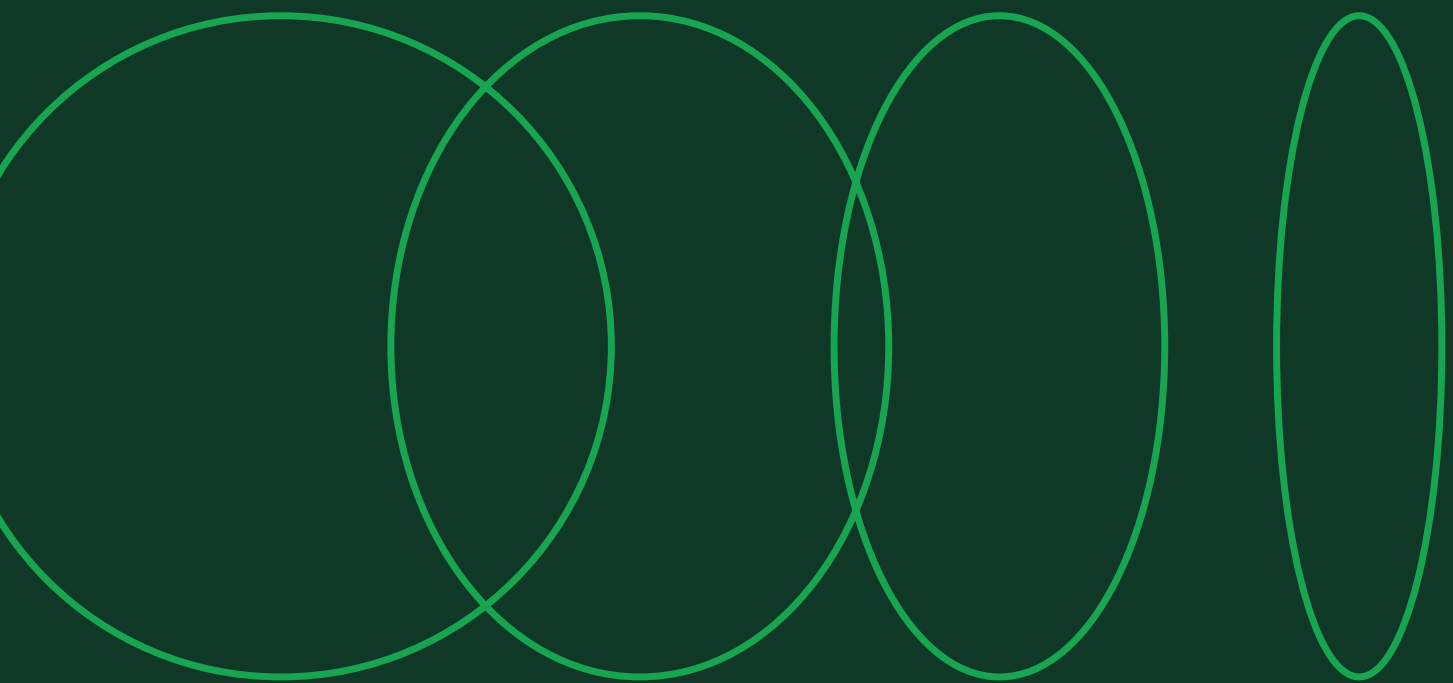


ADDENDUM

# Lithium Batteries in the Aviation Cargo Supply Chain



Thermal runaway is a significant risk that can lead to fire and explosion from rechargeable, lithium-ion batteries if they are damaged, substandard, or malfunctioning. But for stakeholders in the global aviation cargo supply chain, thermal runaway is not solely a battery issue; it's a broader challenge involving trust, transparency, and accountability. In the cargo ecosystem, battery safety is a shared system challenge. There are multiple points of failure in what is a fragmented global supply chain and airlines and operators increasingly bear the burden of detecting and mitigating risks they cannot

fully see or control. Faced with the need to reduce the risk amidst rapid growth of battery commerce, the cargo ecosystem has the opportunity to adopt more consistent oversight and enforcement, better information sharing, and broader adoption of safety standards.

Through ongoing research and interviews with cargo industry stakeholders, and building on the findings of the 2026 report, [Rising Incidents, Shifting Responsibility: Lithium Batteries in the Aviation Cargo Supply Chain](#), UL Standards & Engagement continues to explore the underlying factors that contribute to noncompliance within the aviation cargo

supply chain while examining opportunities to strengthen safety outcomes. These factors include gaps in shipper awareness and understanding of regulatory requirements and variations in resource and compliance capabilities among small and large brands.

This paper provides a look at these dynamics and offers findings to support industry stakeholders, particularly regulators and airline operators, in improving transparency, accountability, and adherence to established safety requirements, to help advance a safer future in air cargo transportation.

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## Noncompliance and the Risk Across the Lithium-Ion Battery Supply Chain

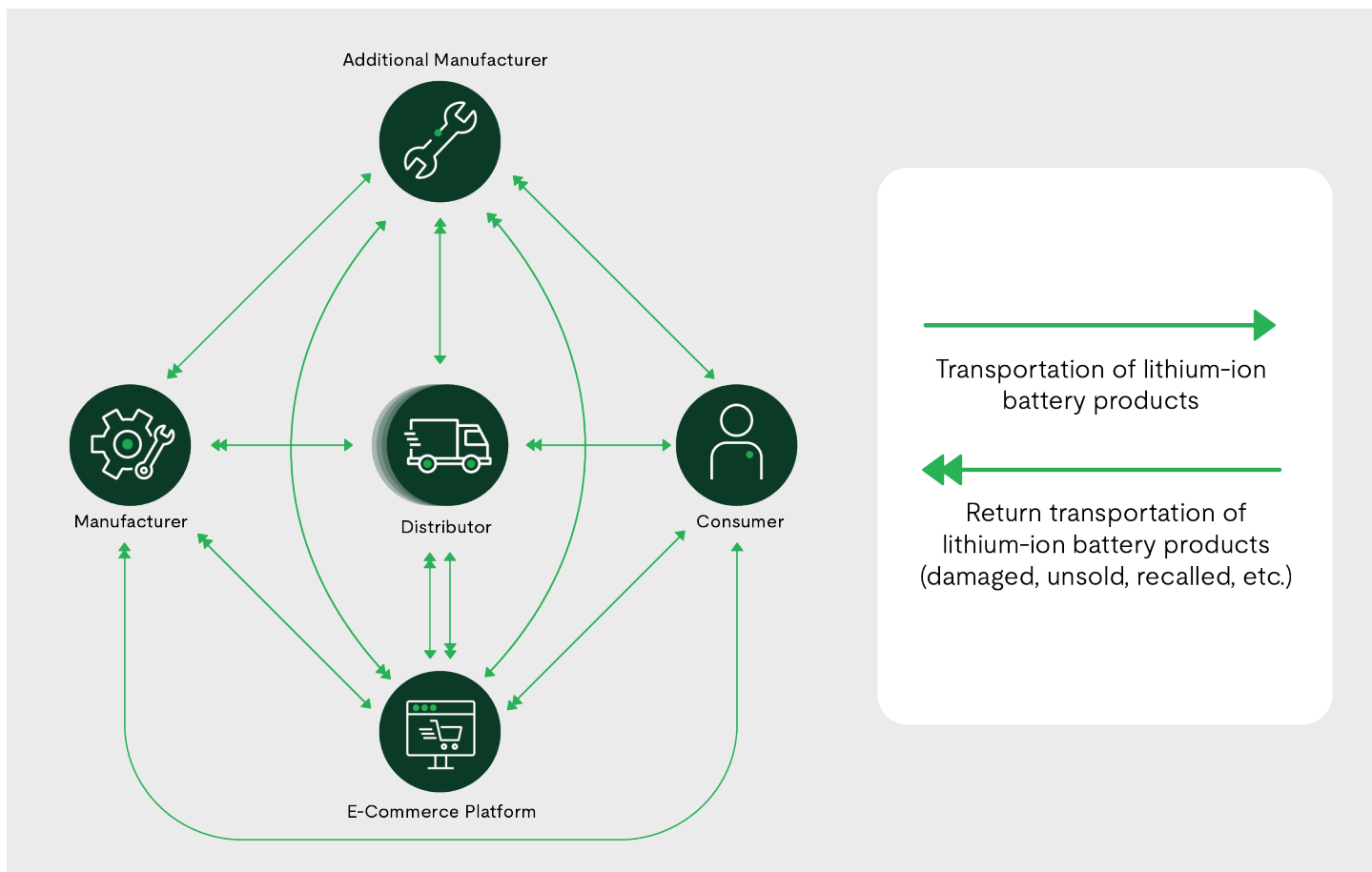
International regulations governing the manufacture, packaging, labeling, and transportation of lithium-ion batteries are designed to minimize the risk of thermal runaway and help ensure batteries move safely through the global supply chain. However, noncompliance with these regulations remains a persistent challenge. In our interviews, stakeholders across the aviation ecosystem reported that violations range from simple mistakes and knowledge gaps to deliberate efforts to bypass requirements. As one regulator noted, noncompliance can stem from a lack of awareness, the complexity of regulations, or intentional disregard for the rules.

### **Different Sources of Noncompliance Require Different Solutions**

Noncompliance increases the likelihood that unsafe or unsafely packed batteries enter the transportation system, elevating the risk

of thermal runaway incidents for airlines. The challenge is compounded by the fact that not all noncompliance is equal. Unintentional noncompliance often results from limited awareness, inadequate training, or difficulty navigating complex regulations. Deliberate noncompliance, by contrast, may be driven by economic incentives that encourage shippers or manufacturers to avoid the costs and time burdens associated with proper testing, certification, packaging, or declaration.

Because the underlying causes differ, a one-size-fits-all approach to risk mitigation is unlikely to be effective. In the absence of broader systemic solutions, airlines that carry cargo have largely been left to develop their own mitigation measures, resulting in a patchwork of practices that vary across operators and may not fully address risks originating elsewhere in the supply chain.



[Figure 1.1] Battery movement in the supply chain contributes to oversight difficulties, as batteries move both forward to distributors and consumers, and backward due to return, repair, and recycling.

## Key Finding: Targeting Awareness Gaps, Incentives, and Enforcement

Reducing thermal runaway risk requires a coordinated approach that addresses both unintentional and deliberate noncompliance. This includes improving awareness and education among shippers, strengthening incentives for manufacturers and shippers to comply with regulations, and evaluating whether existing oversight and enforcement mechanisms are sufficient to deter violations.

The lithium-ion battery supply chain extends far beyond manufacturers and includes distributors, e-commerce sellers, freight forwarders, repair providers, recyclers, and individual shippers. As batteries move through these multiple layers, compliance responsibilities become less visible and more difficult to oversee. Research identified three primary awareness-related challenges contributing to unintentional noncompliance. These challenges appear to increase as products move farther from the original manufacturer, where institutional knowledge and accountability for regulatory compliance often diminish.

- 1 Limited understanding of battery shipping requirements.** Some shippers are unaware that lithium-ion batteries are regulated dangerous goods, or do not fully understand packaging, labeling, documentation, and transport requirements.
- 2 Complex and evolving regulations.** Dangerous goods regulations are subject to change and can differ across jurisdictions and transport modes. Even well-intentioned shippers may struggle to remain current and compliant.
- 3 Training and guidance gaps.** Stakeholders reported that inconsistent training, varying levels of operational expertise, and insufficient regulatory guidance can result in declaration, packaging, and documentation errors, even among organizations actively attempting to comply. These gaps can greatly affect shippers, particularly small and medium-sized businesses, e-commerce sellers, distributors, and other stakeholders farther removed from battery manufacturing.

# The Influence Incentives have for Behavior Change Across the Battery Cargo Supply Chain

Stakeholders consistently reported that safety and compliance decisions are shaped by the incentives different actors face across the supply chain. Large manufacturers and established shippers are often motivated to invest in compliance to protect brand reputation, maintain customer trust, and reduce liability. In contrast, smaller manufacturers, sellers, and shippers frequently operate with narrower margins and face greater pressure to reduce costs and move products quickly, creating competing priorities that can make compliance investments more difficult to justify.

Training exemplifies this challenge. Stakeholders expressed differing views on whether current dangerous goods training requirements strike the right balance between cost and effectiveness. While some operators worry that cost pressures lead organizations to underinvest in training, others question whether existing programs effectively support long-term compliance. Our research also identified concerns about deliberate noncompliance, particularly in rapidly expanding

e-commerce markets. Stakeholders reported that some manufacturers and sellers may intentionally circumvent testing, declaration, or shipping requirements to lower costs or gain a competitive advantage.

## Misaligned Incentives Can Undermine Supply Chain Safety

Compliance is not driven solely by regulations. It is also influenced by the economic incentives that shape behavior throughout the cargo ecosystem. When safety, compliance, and business objectives align, organizations are more likely to invest in testing, training, documentation, and quality controls. However, when competitive pressures reward speed and lower costs over compliance, safety risks can increase. This dynamic creates an uneven risk landscape. Larger organizations often have stronger incentives to prioritize compliance because the reputational, legal, and financial consequences of a

| Attentives                                                                                                                                                                                                                             | Pragmatists                                                                                                                                                                                                                                             | Passives                                                                                                                                                                                                                                                | Cynics                                                                                                                                                                                                                                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"><li>• High safety awareness and accountability</li><li>• Strong compliance practices</li><li>• Formal training/resources</li><li>• Safety and regulatory compliance are core to operations</li></ul> | <ul style="list-style-type: none"><li>• Aware of regulatory guidelines and support compliance</li><li>• Offloads accountability to upstream</li><li>• Rely on brands/suppliers for compliance</li><li>• Balances compliance with cost savings</li></ul> | <ul style="list-style-type: none"><li>• Limited understanding</li><li>• Safety is not top of mind</li><li>• Low shipping volume relative to total business</li><li>• Rely on transactional platforms (e.g. Shopify) or suppliers for guidance</li></ul> | <ul style="list-style-type: none"><li>• High technical knowledge</li><li>• Believe manufacturing safety has improved but enforcement is weak or outdated</li><li>• Skeptical of low-cost imports</li><li>• Believe bad actors undermine safety and compliance efforts</li></ul> |

[Figure 1.2] represents the groupings of respondent types from our study of small- and mid-sized US-based battery shippers. These groupings emerged from focus groups and in-depth interviews in which shippers described their approach to cost versus safety.

failure can be significant. Smaller organizations, particularly those operating in fragmented global markets, may have fewer resources and face stronger pressures to reduce compliance-related costs. In the absence of explicit oversight of the manufacturing quality of battery outputs from individual factories, experience has led industry stakeholders to recognize that economic incentives can create risk.

A battery industry stakeholder identified that this risk occurs consistently: “Are there weird accidents that happen to good companies? Of course, that happens to everybody, but if there are these [manufacturers] that are just pumping out products that are repeatedly seeing the same [safety] issues over and over, there’s only one way to deal with that after a few infractions. And that is, they have to go away.”

A regulator echoed this sentiment: “The large manufacturers, they’re not the ones that give us a problem. They might reach out to us six, nine months before the next set of regulations is about to change just to see what we think things are going to evolve to... they’re trying to... prepare for it.”

Operators, too, report seeing this difference in their own experience: “Where you have either small businesses or people with seemingly little experience in preparation of dangerous goods... and sometimes inadequate knowledge of regulations... we found issues with quite a few of those companies.”

Based on the concerns raised by cargo industry stakeholders, ULSE also conducted research with small- and mid-sized U.S.-based lithium-ion battery manufacturers, retailers, and distributors. These focus groups reinforced the experience of industry-level stakeholders. More than one U.S.-based battery shipper admitted that they believed all responsibility for safe shipping is situated upstream from them, with one stating, “We try to be responsible retailers but ultimately we feel like the responsibility lies on the manufacturer.” Another reported, “We’d rather just trust the manufacturer. Nine times out of 10, it is working.”

Across this group of shippers (which industry stakeholders believe may present greater risk due to lower awareness of shipping regulations), we identified four broad categories, each of which takes a different approach to regulatory compliance:

## **1 Attentives**

These are shippers who tend to have deep experience in the battery industry. They are often original equipment manufacturers or are engaged in battery production and sales for larger applications. These shippers tend to be well aware of the risks of thermal runaway and prioritize safety over cost, preferring to be in compliance with all regulations.

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## **2 Pragmatists**

These are shippers who are aware of regulations and often do enough compliance activities to meet the letter of the law, but in general, they see shipping safety as an upstream responsibility of the carrier. The shippers in this group typically distribute larger format batteries embedded in equipment.

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## **3 Cynics**

These shippers are familiar with shipping regulations, but they believe the lack of oversight and enforcement renders regulations relatively ineffective. They may also tend to believe product certification is too costly, but will often seek to comply with regulations while expressing doubt that other shippers are in compliance.

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## **4 Passives**

These shippers tend most frequently to be resellers/distributors and drop shippers. They are only vaguely, or often not at all, familiar with regulatory requirements. This group tends to ship smaller consumer electronics such as children’s toys and everyday rechargeable products, often connected to social media trends.

## Safety/price tradeoff may be correlated to business identity



Attentives

"The thing we need to do as an industry...is to **promote the quality of safety, not the advantage of cheap.**"



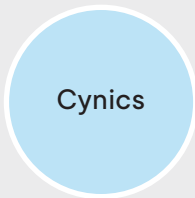
Pragmatists

"I can't control impact and crushing and shipping...I can't control a truck that may be not maintained...**you're still relying on that [carrier]** to make sure they're following these things."



Passives

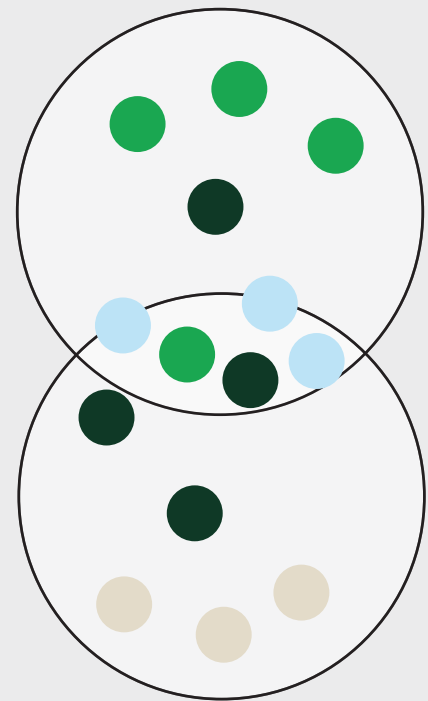
"We try to be responsible retailers but ultimately we feel **like the responsibility lies on the manufacturer.**"



Cynics

"Regulation, transport, safety concerns, safety treatment, fire management, everything to do with **this is a rapidly evolving business.** And whatever you are looking at now, by the time we finish this phone call, there'll be something new."

Safety more important



Price more important

[Figure 1.3] represents the sentiments expressed by each shipper type, along with a depiction of where each shipper fell in the cost versus safety spectrum.

The result is that unsafe products or improperly declared shipments can enter the supply chain, increasing the likelihood of thermal runaway incidents and creating risk for airlines, cargo operators, crews, and passengers. As battery sales continue to expand through online marketplaces and international distribution channels, these incentive-driven risks become increasingly difficult to identify and manage. Consumers also influence these outcomes. Demand for lower-cost products and faster shipping speeds can reinforce market pressures that encourage manufacturers and distributors to prioritize price and speed over safety investments.

### Key Finding: Incentives Can Be Aligned to Reward Compliance and Discourage Risky Behavior

Reducing battery cargo risk requires policies and programs that make compliance the easier and more economically attractive choice. Key opportunities include:

**Increasing accountability for deliberate noncompliance** through stronger oversight, enforcement, and penalties that reduce the competitive advantages of violating regulations.

**Creating positive incentives for compliance**, such as recognition programs, preferred shipper status, streamlined processes, or other mechanisms that reward strong safety performance.

**Increasing consumer awareness** of battery safety and compliance issues so purchasing decisions reinforce, rather than undermine, investments in safe manufacturing and transportation practices. Ultimately, unsafe batteries in the supply chain are much more likely to negatively impact the end user.

# Airlines Have Built Strong Risk Mitigation Systems, but They Cannot Eliminate the Risk of Noncompliance

To reduce the risk of thermal runaway, cargo airlines have developed layered safety systems that combine both proactive and reactive mitigations. Proactive measures typically include shipper vetting programs, surveillance systems, proprietary screening technologies, shipper education initiatives, and dangerous goods training. Reactive measures often include fire-resistant unit load devices, specialized containers, and fire suppression or containment capabilities.

Together, these efforts create multiple opportunities to identify unsafe shipments before they reach an aircraft, and to respond effectively if a thermal runaway event occurs in flight. However, stakeholders consistently emphasized that no single mitigation is sufficient, and that airlines are developing and implementing these measures independently. A fundamental challenge is that many risk controls rely on information provided by manufacturers and shippers. Because airlines cannot fully verify the contents or compliance status of every shipment, they often rely on indicators of shipper reliability and trustworthiness rather than direct verification.

## Key Finding: Current Mitigations Are Managing Uncertainty Rather Than Eliminating Risk

The aviation industry's current approach has helped reduce risk, but it remains constrained by limitations in both compliance oversight and regulatory frameworks. Stakeholders overwhelmingly agreed that preventing unsafe shipments from entering the supply chain is more effective than intervening after thermal runaway begins. Once an event occurs, options for detection, suppression, and containment remain limited, making prevention the most effective safety strategy. At the same time, airlines argue that significant responsibility for identifying noncompliant shipments has shifted from regulators to operators. As a result, airlines often operate with incomplete information and must make conservative shipment acceptance decisions that can affect operational efficiency, costs, and the movement of goods.

Regulators likewise recognize challenges within the current system. Stakeholders identified several factors that can limit effective oversight, including:

- Inconsistent enforcement approaches across jurisdictions.
- Limited penalties that may not adequately deter noncompliance.
- Unclear accountability when shipments move through multiple parties and countries.
- Resource constraints that make it difficult to monitor growing shipment volumes.
- Multiple, and sometimes conflicting, regulatory frameworks across transportation modes.

Collectively, these challenges make it difficult for regulators and operators to fully address the risks associated with noncompliant battery shipments.



**The Benefits and Limitations of the 30% State-of-Charge Requirement:** Stakeholders unanimously support international regulations limiting state-of-charge in batteries and batteries packed with equipment. At the same time, they acknowledge that these limits are extremely difficult, if not impossible, to enforce within the supply chain. Many see enhanced screening technologies and stronger interagency cooperation as key opportunities to improve compliance and close oversight gaps.



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## Opportunities to Reduce Risk

The findings suggest that industry stakeholders view regulation, oversight, and enforcement as critical components of improving battery safety, while seeing fewer opportunities to address risks through shipper-controlled measures such as labeling and packaging alone. This points to a broad industry stakeholder belief that meaningful risk reduction will require systemic, top-down solutions.

At the same time, stakeholders emphasize that reducing thermal runaway risk requires more than additional regulations. Improving awareness, strengthening accountability, and sharing best practices are equally important. While perspectives differ on the root causes of noncompliance, there is broad agreement that better information sharing, stronger product safety standards, improved screening capabilities, and more coordinated oversight could help close existing safety gaps.

### Our recommendations include:

- 1 Clarifying shared responsibility and accountability for oversight:**

Greater clarity around the roles of regulators, operators, manufacturers, and shippers could help strengthen accountability across the cargo ecosystem. Clear regulatory guidance on risk mitigation, screening, and appropriate penalties (both financial and operational) for intentional and unintentional noncompliance, would support more consistent decision-making and reduce reliance on individual organizations to fill oversight gaps. Opportunities for clarification and better oversight include shifting the focus upstream toward prevention, enhancing regulatory coordination, and establishing clearer international guidance, accountability, and best practices for thermal runaway detection.
- 2 Adopting product safety standards:**

Preventing unsafe batteries from ever entering the supply chain remains the most effective reduction strategy. Broad adoption of battery safety standards, such as UL 1642 for Lithium Batteries, UL 2054 for Household and Commercial Batteries, UL 2056 for Power Banks, and the international standard IEC/UL 62133-1 for Secondary Cells and Batteries, can help reduce the likelihood of thermal runaway events and provide greater confidence throughout the supply chain. Because supply chains are global, international standards can play a key role in helping mitigate risk around the world.
- 3 Requiring a connected approach across the supply chain:**

Greater international harmonization could help strengthen compliance and reduce opportunities for noncompliant actors to exploit inconsistencies. Addressing awareness gaps, improving oversight, advancing screening capabilities, and strengthening data sharing, can help create a more resilient cargo ecosystem. No single intervention will eliminate risk, but a coordinated approach across regulators, operators, manufacturers, and shippers can significantly help improve the safe transport of lithium-ion batteries worldwide.