MAKE LITHIUM BATTERIES SAFE TO SHIP

IATA

Table of contents

1 Introduction 3

2 Why are Lithium Batteries Dangerous? 5

3 Creating Awareness 6

4 Shipper Responsibilities 9

5 Making Lithium Batteries Safe 11

6 What about Sodium-ion Batteries? 13

7 Conclusion 16

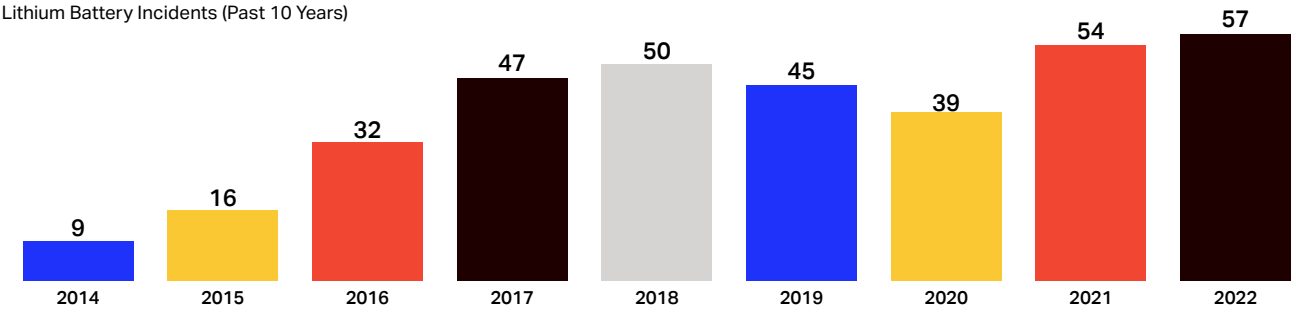
1. Introduction

Lithium batteries continue to present a risk to aviation. Federal Aviation Administration (FAA) figures suggest that, on average, there is more than one incident per week related to lithium batteries in the United States alone[1]. Most are minor, but they can cause flight diversions with all the costs and consequences that are incurred.

And clearly, a fire onboard an aircraft in flight could have far worse outcomes than that.

Lithium Battery Air Incidents

Involving smoke, fire, or extreme heat

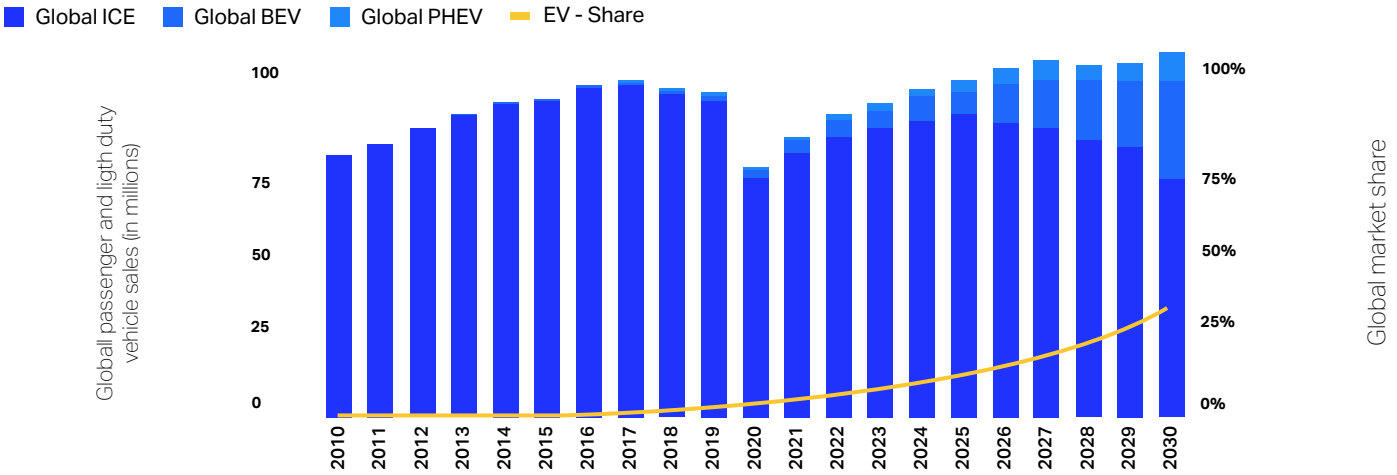


Source: Federal Aviation Administration, Security and Hazardous Materials Safety, last updated February 2023

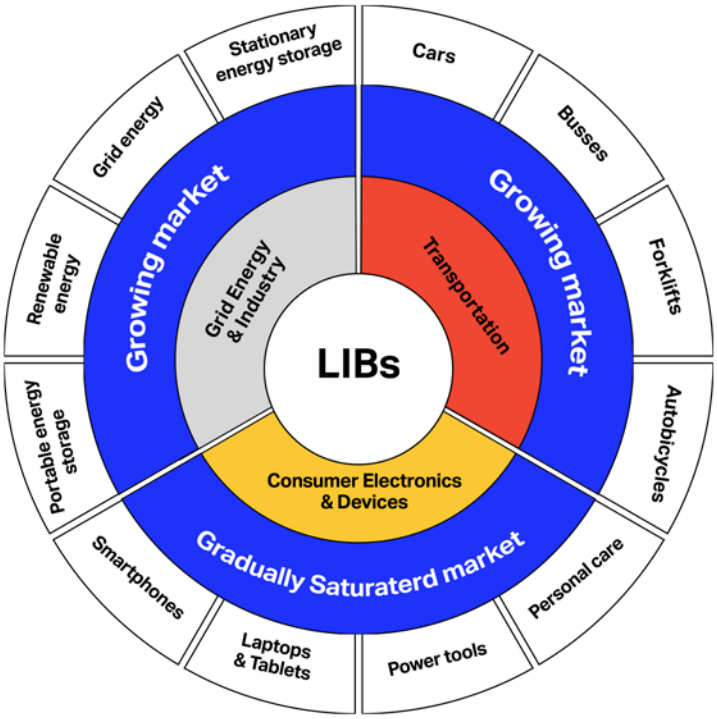
Lithium battery incidents are rising for three main reasons:

1. **The number of lithium batteries is increasing rapidly:** A 2022 analysis by McKinsey suggests that the entire lithium-ion (Li-ion) battery chain, from mining through recycling, could grow more than 30% annually from 2022 to 2030, reaching some $400 billion in value[2]. Lithium batteries are the power source of choice for most modern-day consumer goods, including smartphones, laptops, and numerous toys and gadgets. Because they have a high energy density compared with other battery chemistries, they are also used for most electric vehicles.
2. **There is a corresponding rise in lithium battery shippers:** As the market increases, so too does the number of new players. Unfortunately, some are not always aware of, or compliant with, dangerous goods regulations.
3. **Increasing energy density in lithium batteries:** The rate of improvement in power output is accelerating. Consumers are demanding more from their battery life and capability, and manufacturers are working hard to deliver.

Outlook for annual global passenger-car and light-duty vehicle sales, to 2030[3]



[1] cbsnews.com
[2] mckinsey.com
[3] Deloitte analysis IHS Markiy, EV - Volume.com



- Global lithium-ion battery market is expected to grow from USD 44.billion in 2020 to USD 94.4 billion by 2025.
- Global shift to more renewable, climate friendly energy devices.
- Lithium has become “element” of choice as a portable power source.
- Growth of lithium-ion battery market is mainly driven due to presence of high energy density features of lithium-ion batteries.
- Most lithium-ion batteries used on portable devices are cobalt -based which offers highest energy density.
- Power source for numerous consumer goods including toys, laptops, smartphones, GPS units etc.

This isn’t just a safety issue either. In an era of booming e-commerce, it is vital for airlines to reduce the number of rejected packages. Shippers or freight forwarders may have to pay sizeable fines if a package containing a lithium battery is incorrectly labeled or packed.

Moreover, air cargo has become a vital revenue source to the airline bottom line and in 2023 alone it contributed more than $140 billion. Serving e-commerce effectively will therefore be crucial to the industry’s financial sustainability. According to ICAO and McKinsey, 80% of cross-border e-commerce business-to-consumer shipments are carried by air.

2. Why are lithium batteries dangerous?

In IATA's Dangerous Goods Regulations (DGR), they are separated into lithium metal batteries and lithium-ion batteries.

The former has **lithium metal** as an anode and usually powers such items as watches, calculators, and car key fobs. **Lithium-ion batteries** are rechargeable batteries where the lithium is only present in an ionic form in the electrolyte. These are more common in smartphones and laptops.

Lithium metal batteries have lithium metal as an **anode** and usually powers such items as:

Watches

Calculators

Car key fobs

Lithium-ion batteries are rechargeable batteries where the lithium is only present in an **ionic** form in the electrolyte. These are more common in:

Smartphones

Laptops

Scooters

Lithium batteries release energy through an electrochemical reaction as lithium ions move from one electrode to another through a liquid medium known as an electrolyte. The technology provides a relatively high energy density compared with other batteries and so is the preferred product in energy-thirsty goods.

The positively charged electrode contains oxygen and the electrolyte is flammable. Therefore, if a short circuit occurs or if a battery is exposed to excessive heat or pressure, all the constituents for a self-sustaining fire are available. Essentially, reactions occur that give off heat, known as a thermal runaway. This vaporizes the electrolyte, puts pressure on the cell casing, and, when the casing breaks, flammable and toxic gases are released.

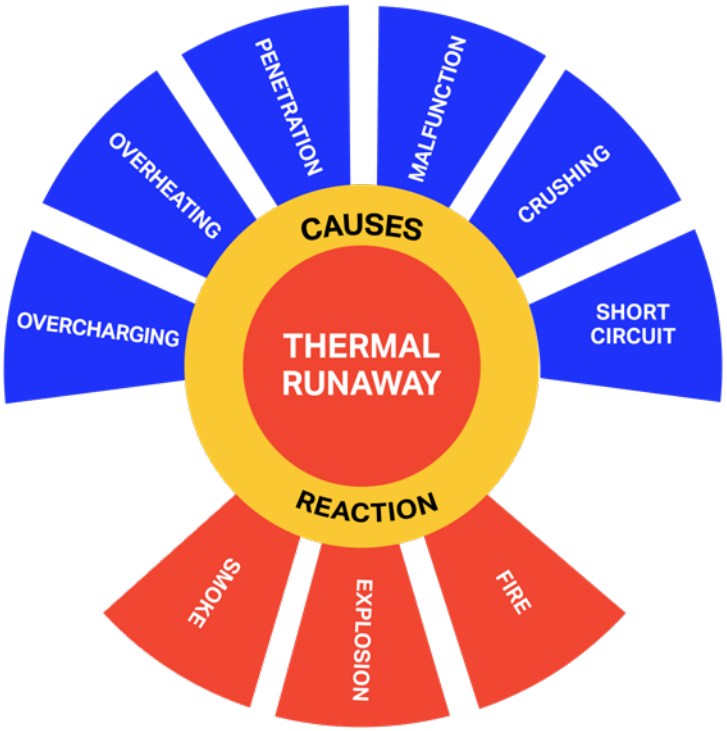
If other flammable materials are nearby, including other battery cells, then a catastrophic fire could result.

Regulations state that the maximum state of charge for the shipment of a lithium battery is 30%, beyond which the risk of fire grows ever larger. However, even batteries with no charge are not "dead" and are still a risk.

Lithium batteries are classified as dangerous goods by the UN Subcommittee of Experts on the Transport of Dangerous Goods and are subject to all relevant aviation regulations.

Incident causation includes, but is not limited to:

- Increasing production of counterfeit lithium batteries with sub-standard safety features.
- Undeclared battery consignments.
- Misuse of refurbished lithium batteries in products.
- Packaging disguised as genuine articles.
- Non-compliance with international regulations when manufactured.
- Poor handling or damage during transportation.
- Lack of proper safety management systems (SMS).
- Inadequate or insufficient training.



3. Creating awareness

Creating awareness among all stakeholders is an important first step in lithium battery safety. The many new shippers in the market must recognize the need to understand and implement IATA's DGR. This will minimize risk and reduce the likelihood of undeclared or mis-declared shipments.

Equally vital is ensuring freight forwarders, handlers, and airline staff perform the correct acceptance checks – and putting in place the certifications, training, controls, and audits to allow that.

When lithium batteries aren't installed in the equipment they power, they must be carried on a cargo aircraft. There is also a weight restriction when the battery is in place, beyond which, again, carriage is restricted to air cargo.

Classification Flowchart - Lithium Ion Batteries

All cells and batteries must be tested in accordance with the UN Manual of Tests and Criteria Part III Subsection 38.3 (DGR 3.9.2.6)

Passed UN?

No → Redesign

Yes

Lithium Ion Batteries Contained in Equipment

Cells > 20 Wh; **Batteries** > 100 Wh

UN3481
PI 967 Section I
IMP: RLI

Limit per package:
Pax A/C = 5 kg
CAO = 35 kg

Cells ≤ 20 Wh; **Batteries** ≤ 100 Wh

UN3481

PI 967Section II *
IMP; ELI

Limit per package:
Pax A/C = 5 kg
CAO = 5 kg

Lithium Ion Batteries (limited to a maximum of 30% SoC)

Cells > 20 Wh; **Batteries** > 100 Wh

UN3480
PI 965
Section IA
IMP; RBI

Limit per package:
Pax A/C = Forbidden
CAO = 35 kg

Cells ≤ 20 Wh; **Batteries** ≤ 100 Wh

UN3480
PI 965
Section IB
IMP; RBI

Limit per package:
Pax A/C = Forbidden
CAO = 10 kg

Lithium Ion Batteries Packed with Equipment

Cells > 20 Wh; **Batteries** > 100 Wh

UN3481
PI 966
Section I
IMP; RLI

Limit per package:
Pax A/C = 5 kg
CAO = 35 kg

Cells ≤ 20 Wh; **Batteries** ≤ 100 Wh

UN3481
PI 966
Section II
IMP; ELI

Limit per package:
Pax A/C = 5 kg
CAO = 5 kg

* exceptions exist to the marking requirements - see P1 967 Section II

Classification Flowchart - Lithium Metal Batteries

All cells and batteries must be tested in accordance with the UN Manual of Tests and Criteria Part III Subsection 38.3 (DGR 3.9.2.6)

Passed UN?

No → Redesign

Yes

Lithium Metal Batteries Contained in Equipment

Cells > 1g; **Batteries** > 2 g

UN3091
PI 970
Section I
IMP: RLM

Limit per package:
Pax A/C = 5 kg
CAO = 35 kg

Cells ≤ 1g;
Batteries ≤ 2 g

UN3091
PI 970
Section II *
IMP: ELM

Limit per package:
Pax A/C = 5 kg
CAO = 5 kg

Lithium Metal Batteries

Cells > 1g:
Batteries > 2 g

UN3090
PI 968
Section IA
IMP: RBM

Limit per package:
Pax A/C = Forbidden
CAO = 35 kg

Cells ≤ 1g;
Batteries ≤ 2 g

UN3090
PI 968
Section IB
IMP: RBM

Limit per package:
Pax A/C = Forbidden
CAO = 2.5 kg

Lithium Metal Batteries Packed with Equipment

Cells > 1g;
Batteries > 2 g

UN3091
PI 969
Section I
IMP; RLM

Limit per package:
Pax A/C = 5 kg
CAO = 35 kg

Cells ≤ 1g;
Batteries ≤ 2 g

UN3091
PI 969
Section II
IMP; ELM

Limit per package:
Pax A/C = 5 kg
CAO = 5 kg

* exceptions exist to the marking requirements
- see P1 967 Section II

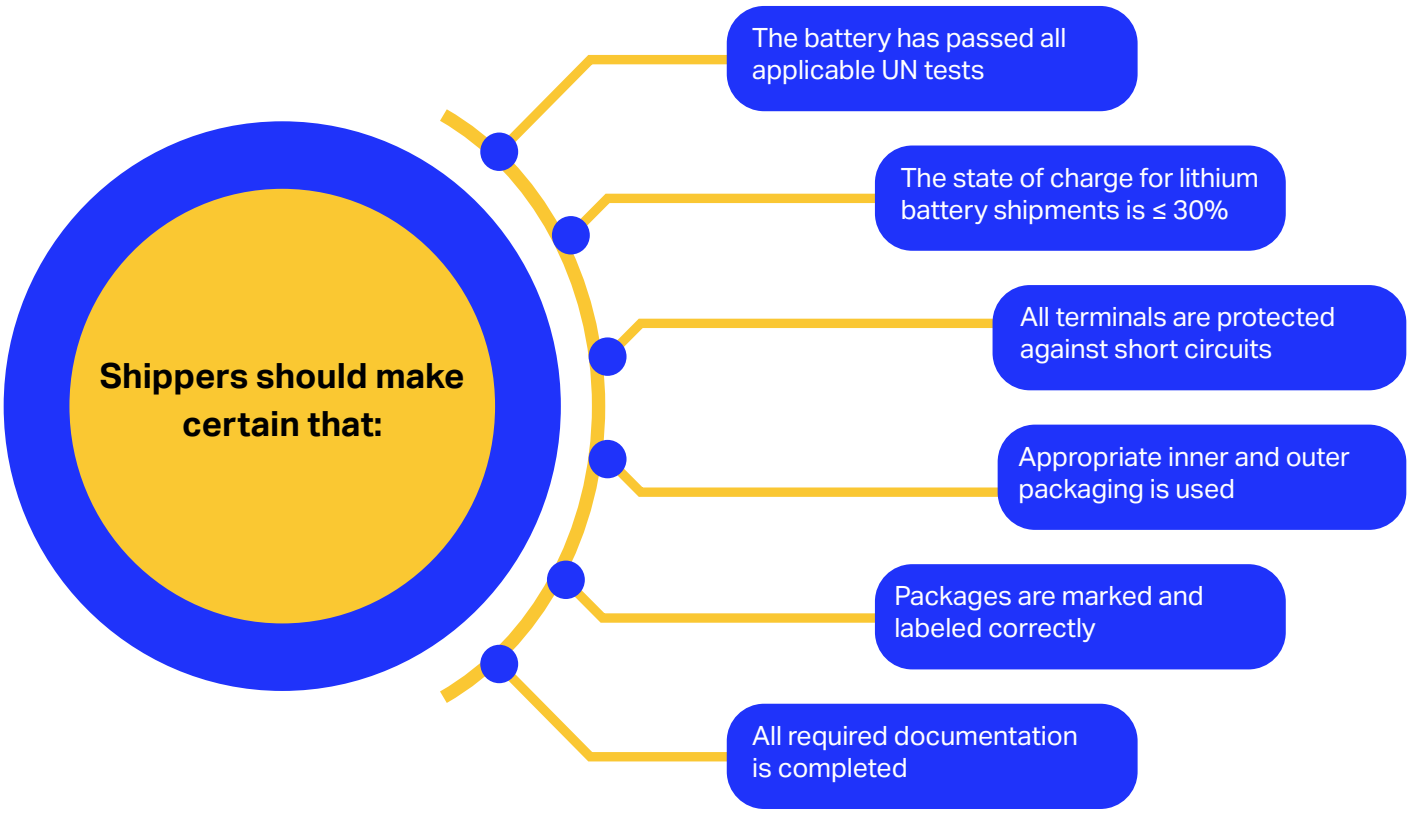
Any disregard for the rules must be penalized. IATA calls for stiffer penalties for rogue shippers and the criminalization of dangerous or willful offenses. Any complexity resulting from international jurisdictions must be resolved so that effective deterrents for potential offenders are in place.

And should an incident occur, better protective measures are essential. Work on fire resistant containers and blankets - over and above the mandatory cargo compartment fire suppression systems - and the associated standards is encouraging. Airlines need to know fire containment is possible.

Given the increasing incidents brought on by the proliferation of lithium battery-powered goods and new shippers, raising the safety bar is essential. But this is a joint responsibility. Governments, airlines, manufacturers, and freight forwarders all have a role to play to ensure that there are more effective tools, that harmonized standards and training are implemented, and that all lithium batteries are safely transported.

4. Shipper responsibilities

It is the shipper's responsibility, as with all dangerous goods and as per the DGR, to sign a declaration that all applicable standards and regulations regarding lithium batteries have been met.



Since 1 January 2019, manufacturers and distributors of lithium cells and batteries must make available a test summary that provides evidence that the cell or battery type has met the requirements of the UN Manual of Tests and Criteria, Part III, subsection 38.3.

These tests include an altitude simulation where the batteries are subjected to reduced air pressure and a thermal test that subjects them to extended periods of heat and cold. There are also vibration, shock, short circuit, and crush tests.

All dangerous goods, including lithium batteries, must be identified by the applicable UN or ID number and proper shipping name and all marks and labels must be clearly visible on the exterior of the packages.

The watt-hour rating for a lithium battery or the lithium metal content dictates the type of packaging required. In some cases, certain specifications must be met and in others it is simply a case of ensuring strong packaging. Care should also be taken with other products that may be in the same packaging or stored nearby.

There are quantity limits, and these are available in the IATA's Lithium Battery Shipping Regulations (LBSR).

Going forward, it is also worth noting that "smart luggage" may contain small lithium batteries for locks or tracking. Regulations state that devices containing lithium batteries must be completely turned off in checked baggage. However, there is an exception for devices where the lithium battery does not exceed 0.3g of lithium metalor a watt-hour rating of 2.7 and the tags only use low energy Bluetooth.

5. Making lithum batteries safe

The aviation industry has long been active in promoting lithium battery safety, but the increasing number of products relying on the technology and the associated proliferation of manufacturers and shippers, has given industry efforts renewed focus.

The Safety Risk Management Framework further refines the safe carriage of lithium battery shipments and a Dangerous Goods Occurrence Reporting Alert System provides a mechanism for airlines to share information on incidents.

The foundation of lithium battery safety efforts, however, is IATA's Dangerous Goods Regulations (DGR). But to assist stakeholders further, there is also the Lithium Battery Shipping Regulations (LBSR) and the Center of Excellence for Independent Validators (CEIV) Lithium Batteries, as outlined below.

Manuals and Regulations

Industry guidance on the subject is plentiful. The LBSR contains all the information the supply chain needs to follow recommended practices and ensure compliance when shipping lithium batteries. The LBSR covers all aspects of the shipping process from packaging requirements, labeling, and marking to planning for potential problems enroute.

Lithium batteries are also covered by the DGR, which provides all relevant information and is equally useful to a new shipper or an experienced handler.

The DGR is updated annually and the 65th edition is now available. The manual contains elements crucial to every partner in the aviation value chain. In terms of lithium batteries, this includes:

- Shipper and operator responsibilities
- Classification
- Packing Instructions
- Documentation
- Handling

The manuals combine regulatory and operational input from industry and government experts to ensure lithium battery safety standards are met in manufacturing, testing, packing, labeling, and documentation.

DG AutoCheck

Airlines and handlers can also make use of DG AutoCheck, an innovative digital solution that automatically cross-references a dangerous goods declaration (DGD) with the latest IATA DGR, providing more detailed and accurate acceptance processes for dangerous goods. It can also be used by freight forwarders as a pre-check of a package.

DG AutoCheck:

- Provides guidance for physical checks
- Automates routine tasks
- Is e-DGD ready
- Provides powerful business intelligence reports
- Provides data for NOTOC (notification to Captain) via Connect API

Reducing manual and paper-based processes by using this digital solution helps decrease incorrect rejections, fines and penalties, shipments delay, and subsequently all associated costs.

Implementing DG AutoCheck will improve safety, cargo digitalization, data usage, and environmental sustainability. In 2022, more than 130,000 acceptance checks were conducted by DG AutoCheck and the solid growth trend continued in 2023.

CEIV Lithium Batteries Certification and Training

CEIV Lithium Batteries was launched in October 2021 and is driven by the DGR and the LBSR. The program establishes baseline competency and quality management in the handling and carriage of lithium batteries throughout the supply chain.

Certification is internationally recognized and denotes compliance with the highest standards and best practice. To achieve certification, organizations must train all relevant personnel, be assessed by an independent validator, and then close any findings. A second validator will validate that the program's standards have been met.

Certification lasts for two years, highlighting the commitment to the safe transport of lithium batteries. Re-certification involves refresher training and a re-validation to verify continued compliance.

Freight forwarders, airlines, and ground handlers are now active in CEIV Lithium Batteries, and more than 30 companies have achieved CEIV Lithium Batteries certification.
A CEIV Lithium Batteries Refresher course helps with re-certification and training is also available in:

- Lithium Battery Logistics Safety Management (Classroom, 3 days)
- Shipping Lithium Batteries by Air (Classroom, 2 days).

Dangerous goods courses are also offered.

Fire-Resistant Standards

Prevention is better than cure. Although the regulations are designed to stop incorrectly packaged dangerous goods getting on the aircraft, it is vital to prepare for that eventuality. Should a lithium battery fire occur, it is important to have the best possible suppression tools available.

Work is ongoing to establish standards in fire resistance for containers, nets, and other coverings that are supplementary to the existing cargo compartment fire suppression systems.

There are fire resistant containers (ULDs) available and fire containment covers for palletized cargo that can contain a fire, providing enough time to get an aircraft safely on the ground. Better products that can contain more severe fire-loads for longer and different fuels and battery mixes are also being evaluated.

These fire containment innovations should meet agreed international standards. Lithium batteries can be loaded differently, in varied quantities, and be surrounded by a multitude of materials. More importantly, the state of charge, the cells, and the chemistries differ.

The challenge, therefore, is to find consensus on a standard that will consider the variables, given that multiple tests would be prohibitively complex and costly.

A draft framework of the fire test parameters and pass criteria is being evaluated by the European Aviation Safety Agency (EASA) and the FAA. Following any amendments, the framework will then be presented to the SAE AGE-2 committee (which covers standards in air cargo) so that it can be considered in the development of a new fire test standard.

While fire-resistant ULDs and containment covers are available today, there isn't an international standard for them to be tested against. Setting an international standard will help product development in a critical area of safety.

As it stands, the Fire Safety Branch of the FAA recommends:

- The use of halon, halon replacement or a fire extinguisher to prevent the spread of the fire to adjacent battery cells and materials.
- Water, or other non-alcoholic liquid to be poured from any available source over the cells immediately after extinguishing the fire. Only water or other non-alcoholic liquid can provide sufficient cooling to prevent re-ignition and/or spreading of the fire to adjacent batteries.

Regulatory Developments

Safety issues related to the transport of lithium batteries are constantly being evaluated by the Dangerous Goods Board (DGB). There are several ongoing projects.

The IATA Incident Data Exchange (IDX) system is being expanded. Airlines share incident data related to dangerous goods and cargo safety with IDX to support analyses on dangerous goods and other cargo incidents, including lithium batteries.

New UN numbers and proper shipping names for vehicles powered by lithium batteries and sodium-ion batteries are also being adopted. Three new UN numbers and proper shipping names have been agreed and new packing instructions for vehicles powered by lithium batteries or sodium ion batteries have been added.

The new entries are:

- UN 3556, Vehicle, lithium-ion battery powered
- UN 3557, Vehicle, lithium metal battery powered
- UN 3558, Vehicle, sodium ion battery powered

In essence, from 1 January 2025 there will be a standard to identify vehicles, such as hover boards, e-scooters, and e-bikes throughout the transport process.

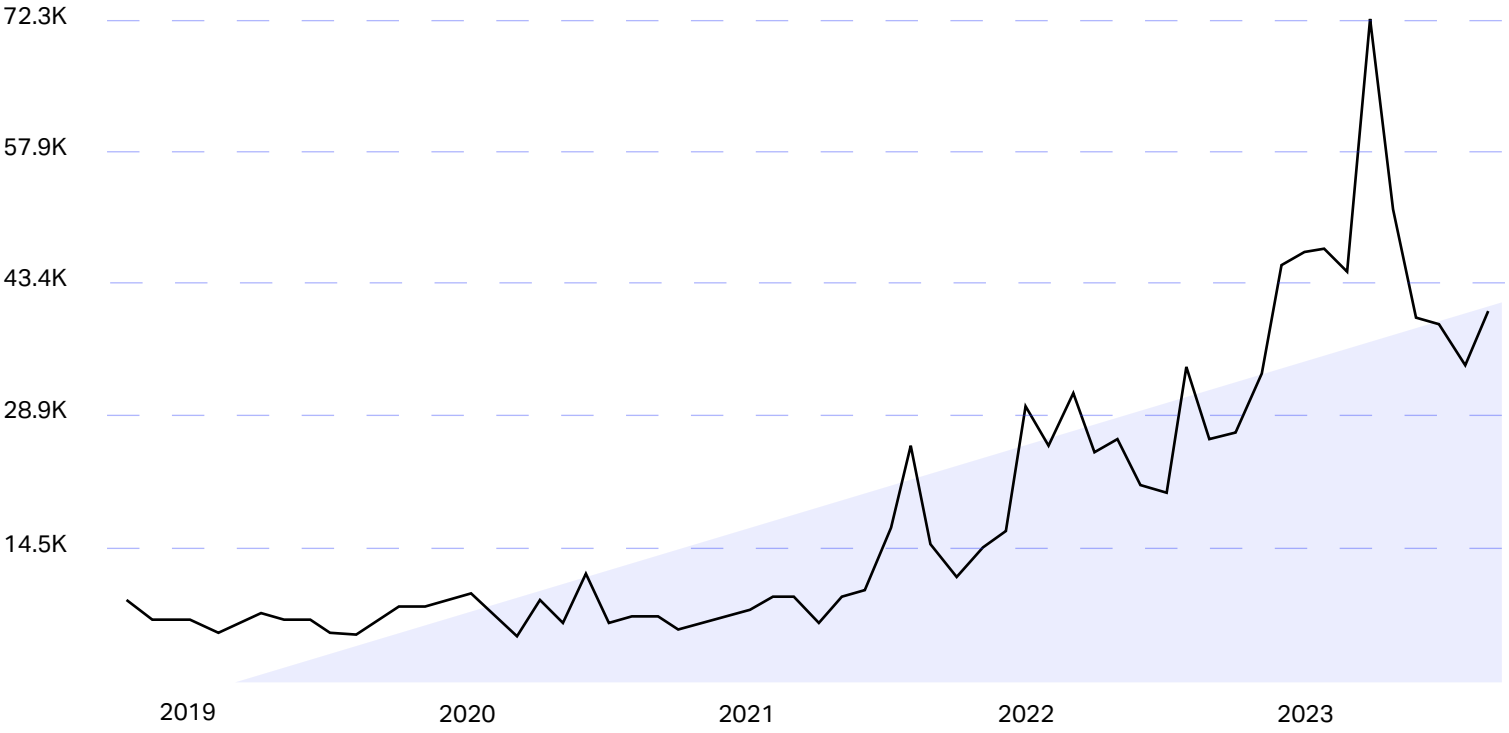
6. What about sodium-ion batteries?

Sodium-ion batteries work in much the same way as lithium batteries. Instead of lithium ions there are sodium ions and sodium salts are exchanged for lithium salts inthe electrolyte. The technology is not new but has been dominated by the greater energy capacity of lithium batteries.

Sodium-ion battery use over time (2019-2023)

40.5K
Volume

+367%
Growth



Pros and Cons of Sodium-Ion Batteries [4]

Pros

- Sodium is at least 500 times more abundant than lithium and much cheaper
- The battery uses aluminum instead of copper, which is again more cost-effective
- The battery has a higher operating temperature range, mitigating the risk of thermal runaway
- The battery charges faster

Cons

- The technology is still in its infancy
- There isn't yet a mature supply chain
- They have less energy density than lithium-ion batteries
- They are structurally less flexible and so are difficult to mold into different shapes

The raw materials for sodium-ion batteries are considerably cheaper, more widely available, and less chemically reactive, which makes them safer. Lithium prices have risen enormously, and lithium is only available in a handful of countries. China dominates the manufacturing process.

Importantly, sodium-ion can be transported with zero charge. Lithium-ion batteries always have a minimum charge, increasing the fire risk. Furthermore, sodium-ion batteries have a higher temperature range, meaning they can withstand more heat and so are less susceptible to thermal runaway. Finally, from a practical point of view, sodium-ion batteries are quicker to charge and have a longer lifecycle.

Whether sodium-ion batteries will have a meaningful share of the market is unknown and a mature supply chain doesn't yet exist. Even so, the industry is preparing for their use, and they will be included in the DGR from 1 January 2025.

[4] www.gep.com

7. Conclusion

This paper explored why lithium batteries are dangerous and the various strategies and tools available to mitigate the risk of shipping them.

The amount of lithium batteries being transported by air has increased and will continue to grow for the foreseeable future. They are safe if tested, packaged, handled, and labeled correctly. To ensure that is the case and that shippers always comply with the latest regulations and best practices, IATA is coordinating industry-wide activities, including:

- Lithium Battery Shipping Regulations (LBSR)
- Training in Shipping Lithium Batteries by Air
- Promoting fire resistance standards
- Dangerous Goods Regulations (DGR)
- Training in Lithium Battery Logistics Safety Management
- Supporting initiatives in data sharing
- DG AutoCheck
- Dangerous goods courses
- CEIV Lithium Batteries
- Participation in the Dangerous Goods Advisory Council

Aviation safety demands shippers follow the standards and regulations in this plentiful guidance. If they do not, they should be heavily and publicly penalized to act as a deterrent to other who may choose to operate unlawfully.

This also makes business sense. It benefits all stakeholders to reduce the number of rejected packages containing lithium batteries and to ensure there are no safety incidents.

Lithium batteries have become the preferred energy source to power a wide variety of consumer goods, ranging from smartphones to children's toys to various e-vehicles. Although they can pose a safety risk if not prepared and shipped in accordance with regulations, a multitude of IATA tools are available to ensure compliance and their safe transport on every journey.