UL On The Mark™

The Lithium-Ion Battery Issue | Vol. 1

Charging the future of safety in technology

Welcome to the inaugural edition of On the Mark, a publication created to explore the intersection of safety, science and technology. The pace of innovation rapidly outstrips our understanding on how to best implement, use and integrate technological advancements safely.

On the Mark will explore the issues interwoven in our lives from a practical and scientific perspective. Future editions of On the Mark will explore topics such as supply chain technology, smart cities, data security and more.

The use of lithium-ion batteries continues to grow as the world moves to a connected, alternative future. Lithium-ion batteries provide backup power to solar panels, allow carpenters to work without cords and silently help devices communicate with the world at large. However, advancement comes with challenges as seen by lithium-ion incidents in the news.

A pocketful of change mixed with an e-cigarette—which uses lithium-ion cells to ignite—becomes a fiery combination. Dropping a smartphone too many times could damage it, leading to the possibility of thermal runaway. Improperly packaged lithium-ion cells can increase the risk of a fire or explosion in adverse conditions.

These are issues UL helps work to prevent every day.

I hope readers take away a greater understanding of the technological complexities facing us. Innovation is both a boon and a cautionary tale. As Newton's third law states, for every action, there is an equal and opposite reaction. A thorough understanding of these forces will help us make the world a safer place.

Keith E. Williams

President, chief executive officer and trustee

In 2005, Keith Williams was named the president and chief executive officer of UL. As CEO, Keith has led a profound transformation at UL, guiding its journey from a not-for-profit company to a private, for-profit enterprise and more than doubling its enterprise value while staying true to its 125-year old safety mission. Guided by the clear strategic imperative to lead in science, build client loyalty and be highly relevant, Keith has led a substantial diversification of UL's business, laying the foundation for the company's growth in the 21st century.

For over 125 years, UL has been the leading voice for global safety. UL's mission of supporting safer living and working environments is realized through its work in product safety testing and verification, standards development, certification, research and training. UL continues to respond to an ever-evolving definition of safety, which started a century ago with the public adoption of electricity to more recent breakthroughs in such areas as smart cities, the Internet of Things (IoT), cybersecurity and lithium-ion batteries.

As a partner to organizations across the world, UL offers technical knowledge and business expertise that are invaluable to the collaborative process of developing standards, writing codes, sharing the latest in safety research and helping clients design, produce, package and sell safer and more reliable and sustainable products worldwide.

For more information about our certification, testing, inspection, advisory and education services, visit UL.com.

About the Publication

On the Mark publishes content from various authors and sources both inside and outside of UL. The views and opinions expressed in the articles in the publication are those of the authors and do not necessarily represent the official position of UL.

Featured content

It's a lithium world

Batteries are changing our tethered natures

By Dave Wilson

Lithium-ion batteries are everywhere.

Most of us are familiar with devices powered by lithium-ion batteries, including electric cars, cellphones, laptops and the malfunctioning hoverboards that turned carefree pre-teens and their parents into paranoiacs a few years ago. But in the near future, most major home appliances could be driven by them as well.

The growing use of lithium-ion batteries could change the tethered-to-the-outlet nature of homes (and garages, offices, playhouses, yards, patios and sheds) around the world.

Ibrahim Jilani, business development director of Consumer Technology Product Safety, predicts that soon, microwaves, stovetops and other everyday electrical items could also be powered by lithium-ion batteries.

Greater energy density is one of the biggest advantages of a lithium-ion battery or cell. With the desire for mobile phones and other gadgets to operate longer between charges, there is always a demand for higher energy density. They also offer substantial environmental benefits compared to their alternative — fossil fuels.

But before we get caught up in a future without all the energy sources we're used to, Jilani grounds us in some reality.

"Traditional electrical power is going to remain because you've got to charge everything back up," he says.

Beyond the home, Jilani cites lithium-ion batteries' portable nature as being transformative in the way we will think of travel.

"Being able to go mobile — and being relocatable with your power — is where we are headed," he says.

New products will be eminently trip-friendly, Jilani predicts; charge up your gear and devices and hit the road.

"Go where you want to go," he says. "You've got your fridge; you've got your creature comforts right in front of you."

Seen and unseen

Lithium-ion batteries already power many products in everyday use, from the mundane to the military. Some devices driven by lithium-ion batteries include satellites and medical devices, according to Paul Braun, director of the Frederick Seitz Materials Research Laboratory and the Ivan Racheff Professor of Materials Science and Engineering at the University of Illinois.

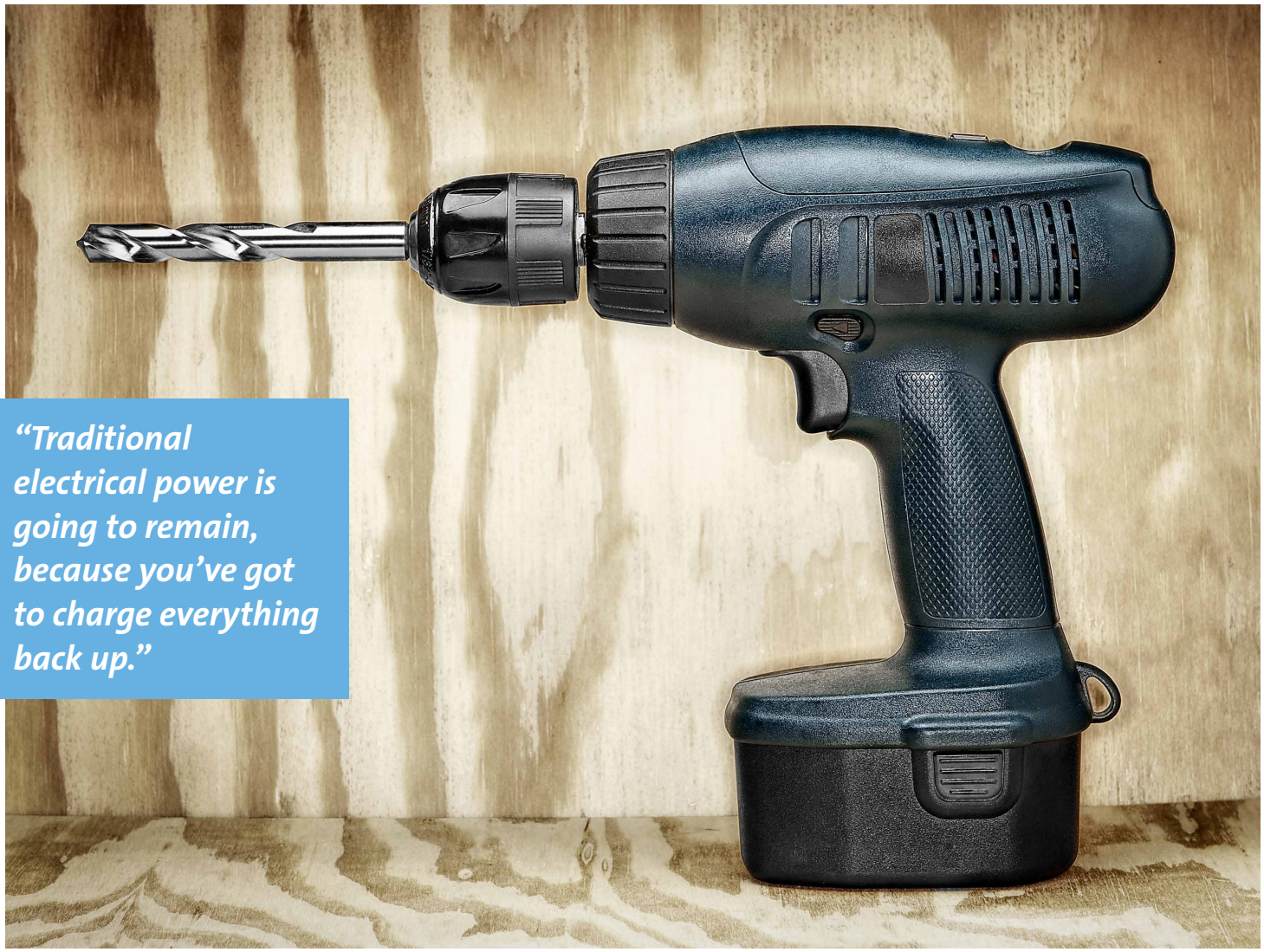
John Horst of the U.S. Department of Energy's Energy Efficiency and Renewable Energy team adds a few more items to the list as well, including roadworthy e-bikes and e-scooters, which have been popping up in many metro areas thanks to battery advances.

Horst also lists lithium-ion-powered stationary energy storage devices for power grid applications; military equipment, including radios, sensors and boats, and space applications, including energy storage and Mars landers and rovers.

UL's Jilani adds a few often-forgotten items to the everyday devices driven by lithium-ion batteries:

- Portable power packs (eco-friendly alternative to portable generators)
- Drones and autonomous/remote-controlled vehicles
- Consumer electronics, power banks and e-cigarettes

Lithium-ion batteries already power many products in everyday use, from the mundane to the military.



"Traditional electrical power is going to remain, because you've got to charge everything back up."

- Wearable technology such as wireless headphones, rechargeable watches and clothing
- E-mobility devices (newer personal transports) as well as e-mobility aids for disabled
- Hospitals and medical applications
- Children's play cars and e-transports (switching from lead to lithium batteries)
- Appliances, power tools, backup and lighting systems

The lithium advantage

The growing popularity of lithium-ion batteries is a result of various factors. Horst says their rechargeable nature, low cost, high-energy and high-power density all contribute mightily to the device's widespread usage.

Braun says lithium-ion batteries' popularity is linked to their ability to be recharged hundreds to thousands of times.

"Lithium-ion batteries ... store energy by cycling lithium between a metal-like state and a salt-like state," Braun says. "When the lithium is in the metal-like state, the battery is charged. When the lithium is in a salt-like state, the battery is discharged. As the lithium moves from the metal-like state to the salt-like state, electrons move through an external device, powering the device."

History lesson

UL's Jilani notes that early incarnations of lithium-ion batteries were prone to a rather combustible issue.

"The first, original lithium-ion batteries showed up in the late 1980s, but they have a very serious safety flaw—thermal runaway—which is an exothermic reaction that causes device breakdown or an explosion," he says.

In thermodynamics, exothermic refers to the release of energy from a system (such as a battery cell) to its surroundings, in the form of heat, light (e.g., a spark) or sound (e.g., an explosion). Thermal runaway starts from the overheating of the battery system.

To combat this, manufacturers made several design changes including a current interrupting device to terminate battery operation, a separator that could sense an increase in cell temperature and electronic circuitry to control charge-discharge.

These changes increased the lithium-ion battery cell's durability and improved its ability to stay intact, but thermal runaway continues to be a concern for all. Methods to improve battery safety continue to evolve as new materials are formulated and new approaches studied.

A lithium-powered future

Jilani predicts that lithium will remain a dominant power source for the near future, due to the chemical makeup that cements its importance.

"Lithium-ion batteries can retain a charge longer, and the volume of production will keep it in the forefront," he says.

He sees staying power and dominance for many years.

"Lithium-ion batteries are going to stay around for a long time. There are future technologies for the electrical infrastructure world, like sodium-sulfur, flow batteries and nickel-zinc, but in the world of consumer electronics, I see nothing beating lithium-ion at this point. Unless we move to hydrogen as a fuel source, and we start to involve portable fuel cell technology, lithium will remain dominant."

—Dave Wilson is a freelance contributor

Take a look inside

Understanding what powers our essential devices

Lithium-ion: **What is it?**

How can lithium-ion technology power everything from cellphones to electric cars? Here's a quick explanation of the process.

A battery is made up of an anode, cathode, separator, electrolyte and two current collectors: positive and negative. The anode and cathode store the lithium while the electrolyte carries positively charged lithium ions from the anode to the cathode and vice versa through the separator.

The movement of the lithium ions creates free electrons in the anode, which creates a charge at the positive current collector. The electrical current then flows from the current collector through the device being powered, like a cellphone or laptop computer, to the negative current collector. The separator blocks the flow of electrons inside the battery.

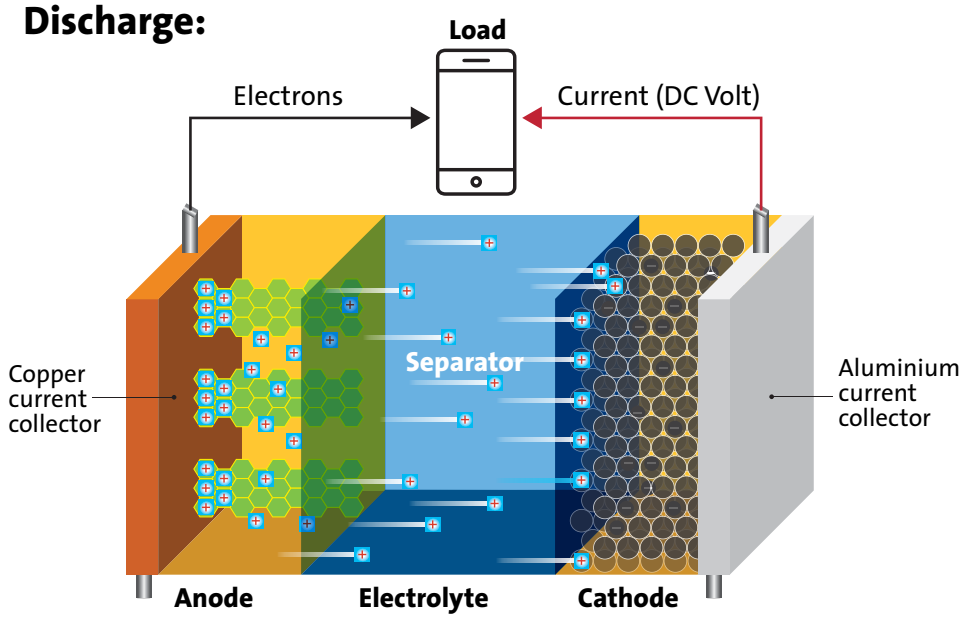
While the battery is discharging and providing an electric current, the anode releases lithium ions to the cathode, generating a flow of electrons from one side to the other. When the device is plugged into an electrical outlet, the opposite occurs: lithium ions are released by the cathode and received by the anode.

Source: The U.S. Department of Energy

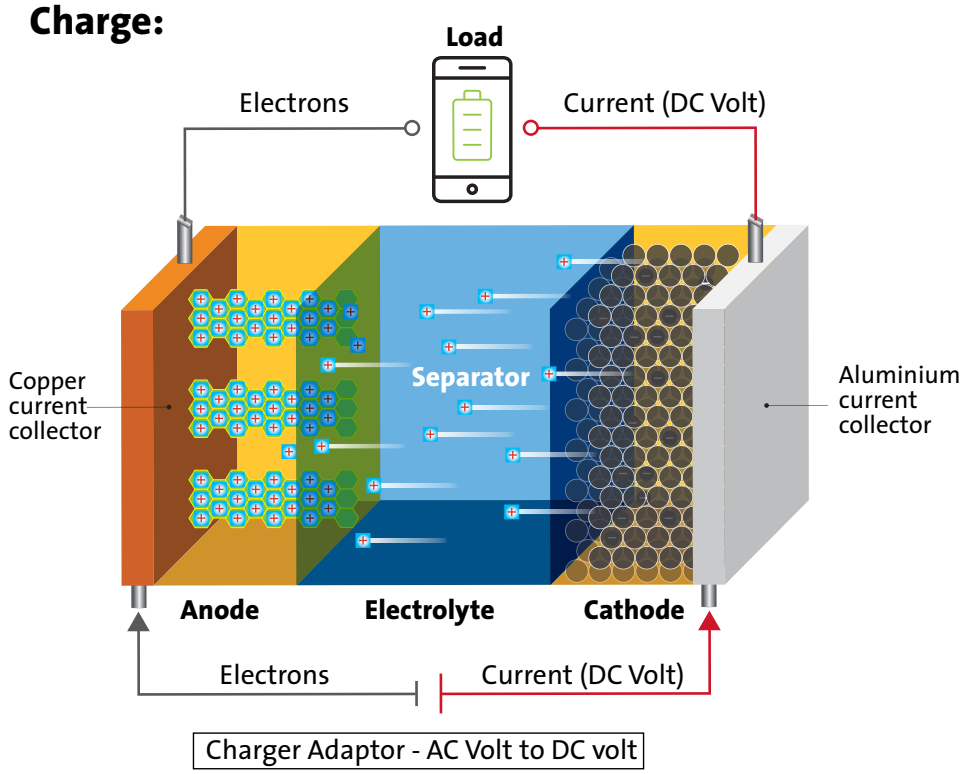
Lithium-ion rechargeable battery

(Discharge / Charge mechanism)

Discharge:



Charge:



Charger Adaptor - AC Volt to DC volt

Cathode	**Anode**	**Cathode**	**Separator**
Lithium Nickel Cobalt Oxide doped with Aluminium	Graphite	Solution of lithium salt	Thin sheet of micro-perforated plastic

LIB-carrying travelers of 2018 and beyond

Our world is increasingly mobile, and our devices go along for the ride. When we go on vacation, we take our digital cameras, tablets and cellphones on the plane, and when we travel for business, we carry our laptops, wear our noise-canceling headphones and strap on our smart watches. These devices often are powered by lithium-ion batteries.

Keeping up with all this technology and how it can affect travel in the U.S. is the job of the FAA. Smoke and fire incidents on aircraft from passengers' malfunctioning lithium-ion batteries have occurred. The issue has been studied extensively by aviation safety experts over the last few years. Where should we store laptops and other devices, taking terror concerns and battery issues into consideration?

"There's a balance here," John Cox, a former pilot and CEO of Safety Operating Systems, an aviation consulting firm, told Consumer Reports. "As we put lithium-ion batteries in cargo holds, they are no longer in an area where the crew can deal with them if they do catch fire. And the fire suppression systems using only (the common extinguishant) halon have not proven to be effective on lithium-ion fires."

The FAA now requires that spare (uninstalled) lithium ion and lithium metal batteries be in carry-on baggage only. When a carry-on bag is checked, all spare lithium batteries must be removed from the bag and kept with the passenger in the cabin.

Lithium-ion batteries by the numbers

0.0007
The percentage of lithium in the Earth's crust

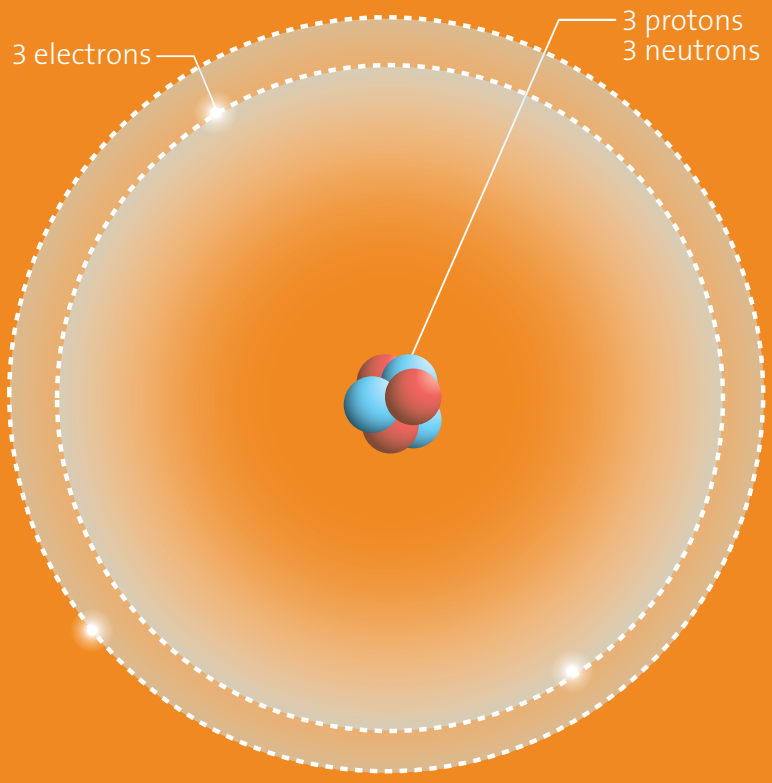
80 Percentage of total power lithium-ion batteries maintain after 1,000 cycles. A cycle is the charging and discharging of a battery's energy load.

1,330 Degrees, in Celsius, at which lithium boils. Water, by comparison, boils at 100 degrees Celsius.

1991 The year lithium-ion batteries were introduced to the market by Sony and Japanese chemical company Asahi Kasei.

10 million
Number of batteries recalled by Sony in 2006, due to structural issues that could cause a short-circuit and damage the devices they were powering. The batteries were used in products produced by Sony, Dell, Sharp, Apple, Panasonic, Lenovo, Hitachi, Toshiba and Fujitsu.

Lithium atom - Li



General properties

Name: Lithium
Symbol: Li
Appearance: silvery-white
Atomic number: 3
Element category: Alkali metal

Physical properties

Phase: Solid
Melting point: 356.9 °F
Boiling point: 2,426 °F

3 The atomic number of lithium, making it the lightest metal on the periodic table. By comparison, lawrencium, the heaviest metal, has an atomic number of 103.

$150 Cost per kilowatt for lithium-ion battery cells, down from $400/kWh in 2012.

1817 The year Swedish scientist Johan August Arfwedson identified lithium while analyzing the mineral petalite.

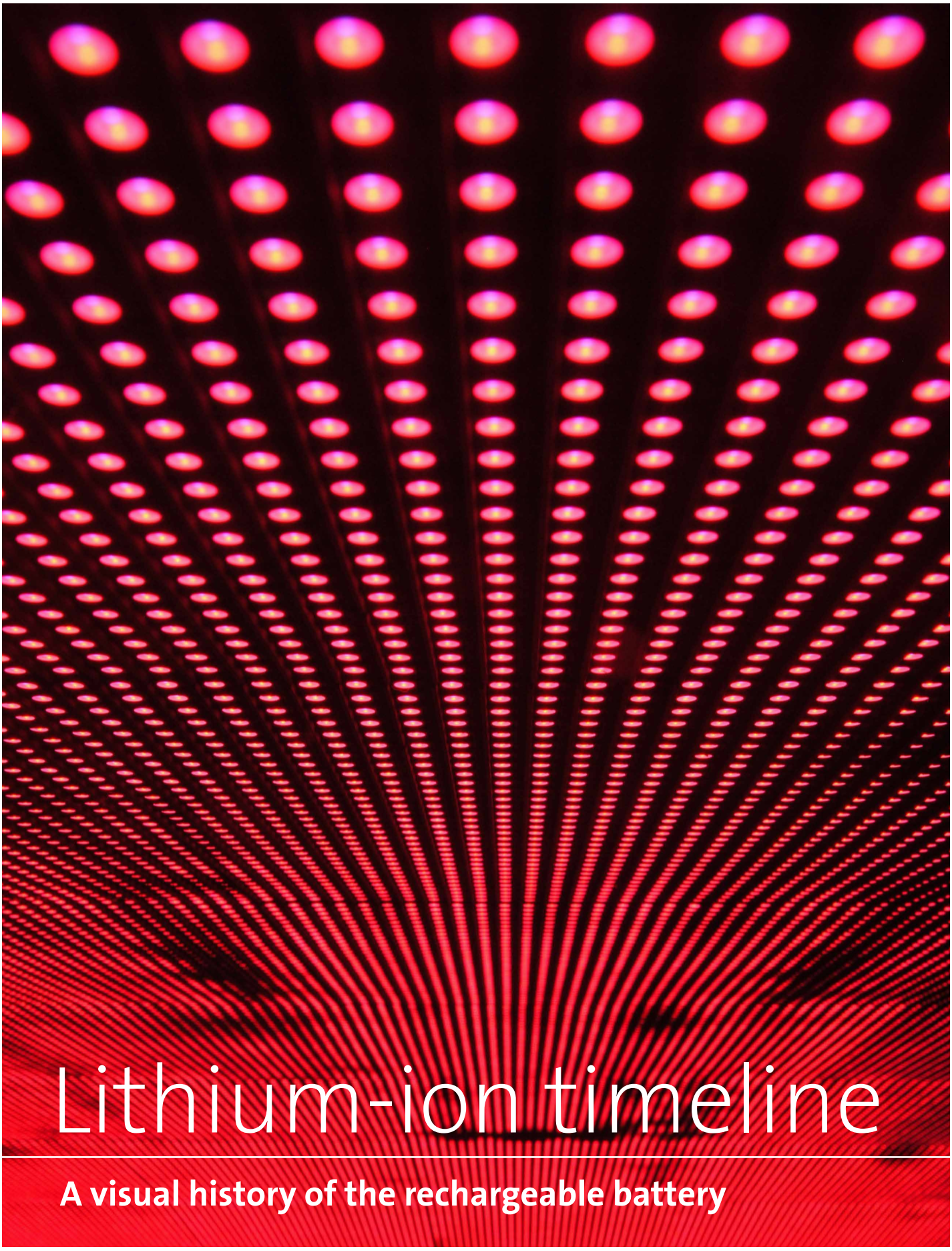
30,000 Number of homes that can use energy provided by Tesla's Powerpack battery for one hour. Powered by wind-farm energy, the 129-megawatt unit is the world's largest lithium battery, which was turned on in December 2017 in South Australia to help during blackouts.

46 million Number of batteries recalled by cellphone manufacturer Nokia in 2007 due to a malfunction that could cause phones to overheat and explode.

1 billion Number of lithium-ion batteries transported through the air each year.

33.9 million Miles separating Earth from Mars, where the rover Curiosity is powered by lithium-ion batteries.

Sources: Scientific American; Los Alamos National Laboratory; Clean Technology; the International Air Transport Association; NASA



Lithium-ion timeline

A visual history of the rechargeable battery

NOTABLE EVENTS IN THE HISTORY OF LITHIUM-ION BATTERIES

1799

Alessandro Volta creates the modern-day battery by building what came to be known as the voltaic pile. The pile was made of zinc and copper plates with vinegar- or brine-dampened pieces of leather or pasteboard placed between each plate.

1800

Brazilian chemist José Bonifácio de Andrada e Silva discovers Petalite in a Swedish mine.

1817

Swedish chemist Johan August Arfwedson discovers and names lithium when examining the elements in Petalite ore.

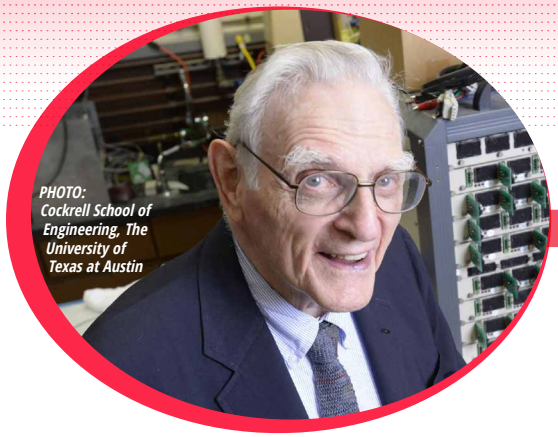


PHOTO: Cockrell School of Engineering, The University of Texas at Austin

Lithium's proud papa

1973

Adam Heller, an Israeli-American engineer, uses his knowledge of the physical chemistry of inorganic oxyhalide solutions to produce the lithium thionyl chloride battery, the precursor to the lithium-ion battery.

1980

John Goodenough develops a rechargeable lithium cell using lithium cobalt oxide as the cell's positive electrode and lithium metal as the cell's negative electrode.

THE NAME JOHN GOODENOUGH may not be familiar to most people, but anyone who's put a mobile phone to his or her ear is very familiar with his work.

Goodenough is credited as the father of the lithium-ion batteries — the ones that power your laptop and iPhone, among other devices — thanks to his work on developing a long-life rechargeable battery.

The fact that Goodenough is well known in scientific circles is an accomplishment in itself, considering the academic struggles he endured when he was younger. Suffering from undiagnosed dyslexia as a young student, Goodenough spent most of his time exploring the woods and rivers near his childhood home near New Haven, Conn.

He labored in the classroom but absorbed enough knowledge to earn a spot at Groton School, a prestigious academic institution in Massachusetts, where he learned to overcome his learning disabilities by mimicking the readings he needed to study. After a teacher told him that Shakespeare's sonnets were probably too much for him to understand, Goodenough began writing his own sonnets to better his comprehension of the form.

"I decided that the only way to understand poems was to try my hand at writing them," Goodenough told The Alcalde, the alumni magazine of The University of Texas, where he's still an active faculty member with the Cockrell School of Engineering — at 95 years old.

Goodenough earned a scholarship to Yale University, where he graduated summa cum laude, receiving a bachelor of science degree in mathematics. Goodenough then served as a meteorologist in World War II, eventually returning home to earn his Ph.D. from the University of Chicago in 1952. He headed to MIT afterward, continuing his A-list journey through the finest academic institutions in the country.

At MIT, Goodenough began researching computer memory in Lincoln Laboratory, eventually leading a team that developed a magnetic-core system that stored computer data on magnetic rings. It was cheaper, faster and more reliable than previous methods — think vacuum tubes, lightbulbs and computers the size of a one-bedroom apartment. Goodenough's work led to a series of rules that explained magnetism at the atomic level: the Goodenough-Kanamori Rules. Those guidelines would become the bible for engineers across the world as they worked to develop smaller, faster computers.

Goodenough eventually moved to England to head the inorganic chemistry lab at Oxford University and continue his research into batteries, which had taken on increasing importance after the oil crisis of the early 1970s. Although a lithium-ion battery, largely developed by chemist M. Stanley Whittingham, was commercialized in 1976 by Exxon, it had a high explosion rate.

Goodenough and his team worked with metal oxides to create a more stable battery, eventually developing cobalt oxide, which led to the lithium-ion battery as we know it today, albeit bigger and less powerful. Rapid development led to smaller, more powerful batteries, which are used in countless devices large and small. While companies make busloads of money from the technology, Goodenough receives no royalties and doesn't receive any financial benefits. Oxford never applied for a patent, and Sony quickly snatched up the rights to the technology.

You might think that financial injustice would have embittered Goodenough toward science, but it hasn't in the least. In fact, he's focused on improving upon his life's work. "What we need is not an incremental improvement, but a step improvement," Goodenough told The Alcalde. "Our society is still completely dependent on fossil fuels, and we've got to find an alternative soon."

Goodenough is already making good on that promise. Last year, he and his team introduced a glass electrolyte-sodium battery that recharges faster, is potentially less expensive and is three times as powerful as lithium-ion batteries.

1991

Sony develops a smaller lithium-ion battery that can be used to power smaller devices like cameras and CD players.

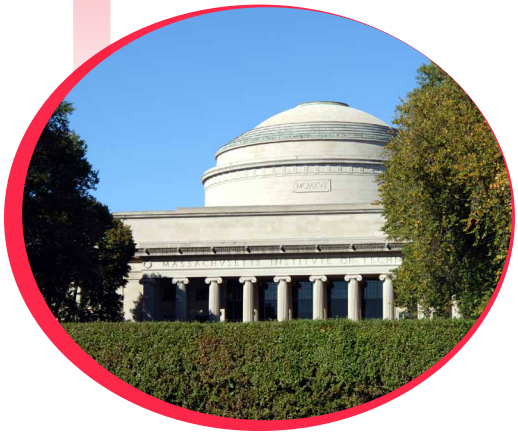
1992

The Chattanooga Area Regional Transportation Authority tests a fleet of 20 electric, rechargeable buses.

Sony adds a rechargeable lithium-ion battery as a $60 option for the Handycam CCD-TR1 8mm camcorder.

2002

Yet-Ming Chiang and his associates at MIT boost lithium-ion's conductivity by combining it with aluminium, niobium and zirconium, greatly improving the performance of lithium batteries.



2003

Marc Tarpenning and Martin Eberhard found Tesla, an electric-car company.

2006

2008

Tesla delivers the Roadster, the first mass-produced, all-electric car to use lithium-ion battery cells. The Roadster can travel 200 miles on a single charge.

2013

Lithium-ion batteries catch fire in Boeing 787 Dreamliners and Tesla automobiles. The Dreamliner fleet is grounded for review.

A Dell laptop bursts into flames in Osaka, Japan. After other incidents, Dell offers free replacements for 4.1 million laptop batteries.

2015

Tesla CEO Elon Musk unveils the Tesla Powerwall, a combined set of high-powered batteries that can be used for home energy.

2016

British transportation officials test a Class 379 Electrostar, a multi-car passenger train powered by lithium-ion batteries on the Mayflower Line in Essex, England.

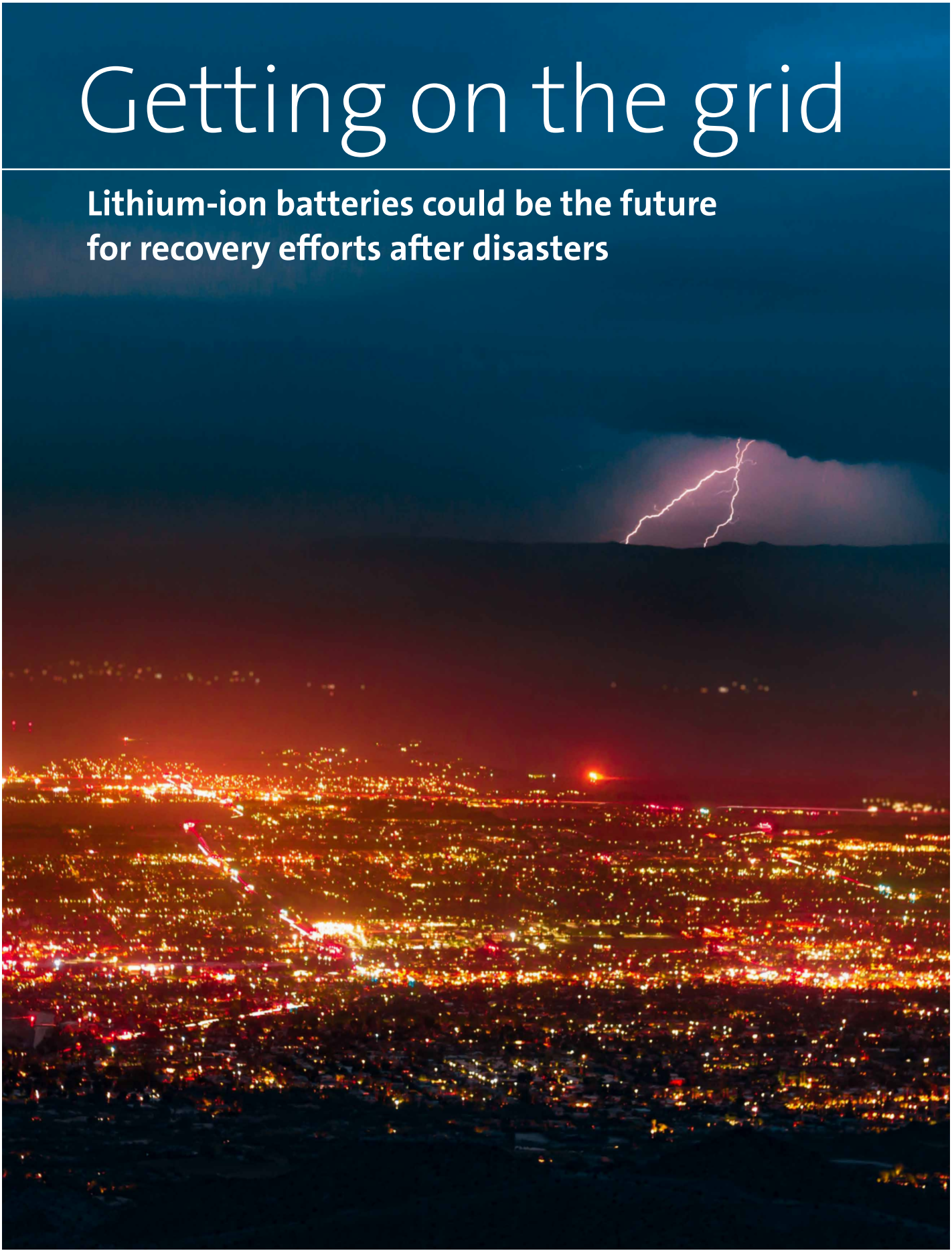
Samsung Electronics recalls 2.5 million Galaxy Note 7 smartphones after a flaw in the battery cell caused some of the phones to catch fire.

The Consumer Product Safety Commission recalls more than 500,000 hoverboards after the lithium-ion batteries overheat and cause at least 60 fires.

The U.S. Department of Transportation bans e-cigarettes in checked baggage on aircraft, citing the possibility of fire during the flight.

Getting on the grid

Lithium-ion batteries could be the future for recovery efforts after disasters



By Kathleen Furore

Several months after hurricanes dealt a one-two punch to Puerto Rico, recovery still floundered in many areas.

"In Puerto Rico, roughly 150,000 homes and businesses are still waiting for electricity. That's 11 percent of the island's customers," NPR reported in March. "Many have been waiting since before Hurricane Maria when Hurricane Irma grazed the island."

Houston was struck by nearly $200 billion worth of damage caused by Hurricane Harvey in August 2017. More than 100,000 homes were damaged in historic flooding and hundreds of thousands were left without power in the wake of the storm.

The onslaught of last year's hurricanes and wildfires was unprecedented. But severe weather events will continue, as will more common events such as thunderstorms and ice storms, which also can wreak havoc on an area's electrical supply.

Can cities avoid long-lasting outages that can have a debilitating impact on the families, schools, hospitals and businesses in a storm's path?

A microgrid — "localized grids that can disconnect from the traditional grid to operate autonomously and help mitigate grid disturbances to strengthen grid resilience," according to the U.S. Department of Energy — is one solution that holds promise, whether on the mainland or in more remote locales.

"Microgrids, including energy storage systems with lithium-ion batteries, can be important and resilient energy sources," says Kenneth Boyce, principal engineer director for Energy and Power Technologies at UL. "They are especially impactful when used to help hard-hit locations withstand and recover from events causing severe or long-term power outages."

Why lithium-ion?

Lithium-ion technology, the same technology used to power laptops and cellphones, is the most popular chemistry used in batteries today, because of the advantages it offers — the amount of energy in its footprint chief among them, Boyce says.

Lithium has unique properties that make it especially useful for batteries. According to PowerScout, a California company that designs smart-home products that help conserve energy: "Lithium is the lightest of the six alkali metals, has the greatest electrochemical potential and provides the largest energy density for its weight."

In other words, "it is a very powerful and effective way to have energy stored," Boyce says.

Grid benefits

Because they can operate while the main grid is down, microgrids can help mitigate grid disturbances; they also can function as a grid resource for faster system response and recovery.

Another plus, microgrids "support a flexible and efficient electric grid by enabling the integration of growing deployments of distributed energy resources such as renewables like solar," the U.S. Department of Energy notes.

"The idea of coupling an energy source like solar and an energy source like lithium-ion creates a synergy so you can locally generate and store power," Boyce says. "It can be a stationary product — solar panels on a roof for example — or it can be a mobile storage system, so you have more flexibility in case of a catastrophic event."

Clearly, microgrids of lithium-ion

"Microgrids, including energy storage systems with lithium-ion batteries, can be important and resilient energy sources."

batteries can be powerful energy sources that facilitate recovery in the event of severe, long-term power outages due to their high energy density, as well as their charging and discharging efficiency.

But recent reports of smartphone fires, exploding laptops and smoldering hoverboards, all of which involved lithium-ion batteries, have raised safety concerns about the batteries' potential for unwanted ignition.

Just how big is the risk of fire in lithium-ion battery-powered microgrids? And what steps can be taken to ensure the safety of the batteries when used in a microgrid application?

"Lithium-ion batteries are very effective and generally have a low failure rate. However, they can be susceptible to faults that can cause ignition or explosion, as we have seen in the news many times," Boyce says. "UL has been diligently working for many years in many ways to expand battery safety science, so we understand what causes those faults and how we can proactively assess battery systems to demonstrate that hazards have been addressed."

Safety testing

UL has engaged in extensive scientific research, testing to rigorously assess battery systems, and development of many standards, which "include the world's first safety standard for energy storage systems" — all in an effort "to promote the safe and sustainable use of batteries and energy storage technologies," Boyce says. "Products that bear the familiar UL Mark have been assessed to show compliance with those important safety requirements."

Fire departments across the country are proactively preparing for any fires caused by lithium-ion batteries, although the size of an emergency recovery system can present a new set of problems.

Ronald Spadafora, the New York Fire Department's chief of fire prevention, says that today's large-scale power supplies should be approached cautiously, even during a recovery effort.

"We have to prepare for these new systems because we know that they're going to be the future for large buildings, but we have to make sure we're considering how we can keep these systems safe," Spadafora says. "Even a temporary system needs to be properly installed and operated. We can cut down on incidents by making sure that we're following proper procedure."

Spadafora says the issue with lithium-ion batteries is that an overheated cell can cause nearby cells to overheat at various rates. A large system of batteries can be destroyed in a small amount of time or can take hours, meaning it's important to put the fire out as quickly as possible.

Peace of **mind**

AN EMERGENCY POWER supply isn't just for large-scale emergency efforts. It can also be a key component of individual recoveries.

After losing power last year, Joseph Marion bought a solar-powered power pack, an eco-friendly alternative to portable generators, for his home in Fort Myers, Fla. These power packs can cost anywhere from $150 to $3,000.

For Marion, who purchased a $1,500 model, the cost is a small price to pay for a little extra peace of mind.

"I'm not someone who holds out during storms, but I'm not going to head out of town if there's a bunch of thunder and lightning," says Marion, 72, a retired pipefitter from Franklin Park, Ill. "Having a power pack gives me a little extra time to get my things together and to make sure everything is secure if I have to head up to Georgia or something."

Private power

In the aftermath of the 2017 hurricanes in Puerto Rico, private firms stepped in to help by creating microgrids to restore power to remote areas. Boyce says these microgrids are good examples of the incredible potential at play here.

"There was a lot of damage to the infrastructure there, so energy storage systems and solar panels were used in a Lego-style approach to find solutions where power was most needed," Boyce says. "Puerto Rico shows how you can customize these systems to meet a particular need."

Last year, Tesla used its batteries and solar panels to restore power to a children's hospital in San Juan. Tesla tweeted that it was "the first of many" solar plus battery projects going live in Puerto Rico.

In February, sonnen, a Los Angeles-based company that manufactures renewable-energy products, announced the commissioning of a solar and battery storage microgrid in collaboration with Pura Energía, its local energy partner in Puerto Rico. Together, the two companies worked to power a school in the remote town of Orocovis. Sonnen and Pura Energía also installed microgrids on the island in community and relief centers, food distribution centers and other locations.

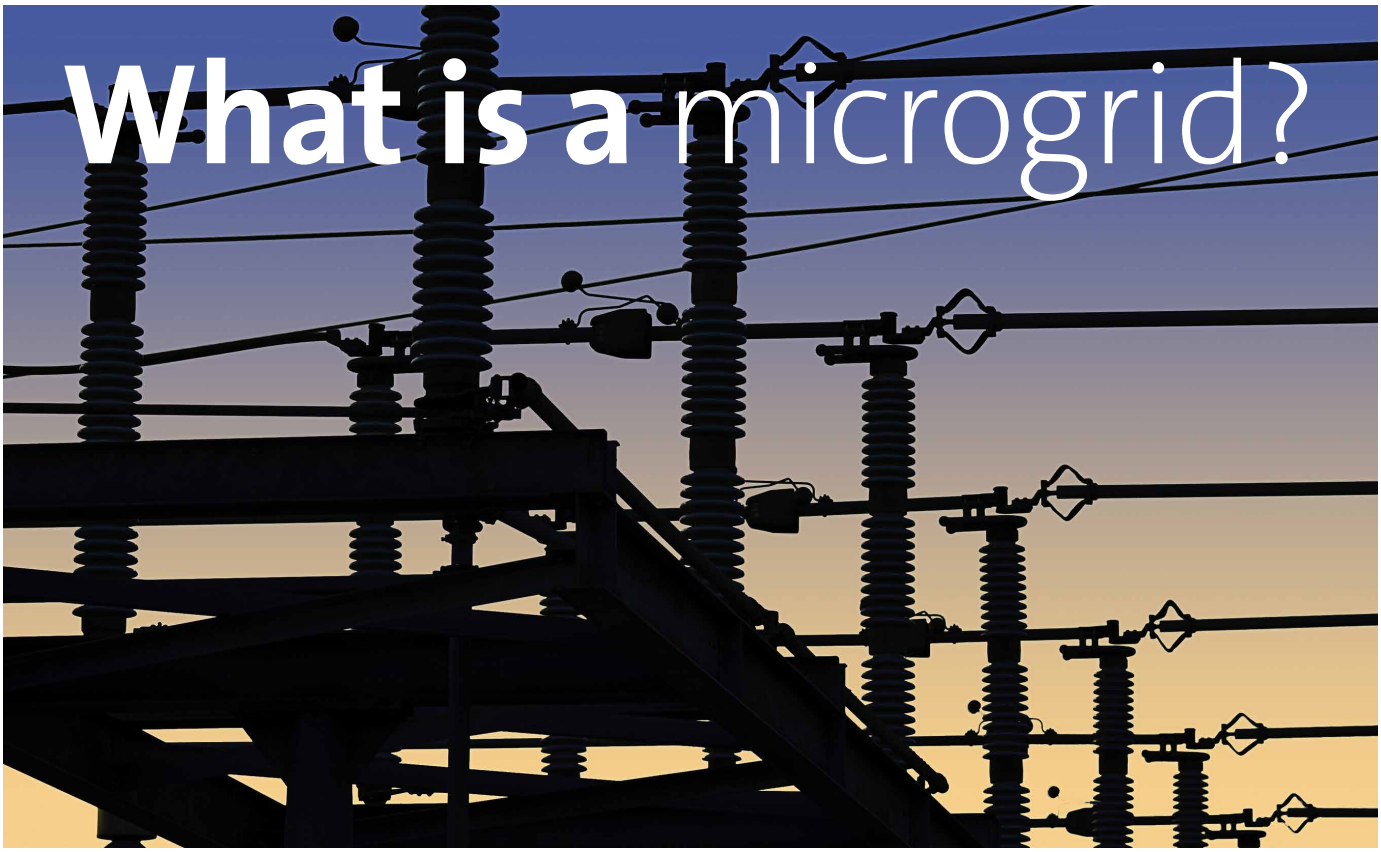
The examples showcase the potential integrated renewable energy systems have when catastrophes strike and beyond.

"These microgrids effectively form the blueprint for more than just recovery, but for preparation for islands and regions around the world that are susceptible to natural disasters and power outages," Adam Gentner, sonnen's director of business development, Latin American expansion, said in a statement.

—Kathleen Furore is a freelance contributor

Tesla battery bank in Ontario. The bank was installed in three months.

What is a microgrid?



A MICROGRID IS A LOCAL ENERGY GRID with control capability, which means it can disconnect from the traditional grid and operate autonomously.

How does a microgrid work?

The grid connects homes, businesses and other buildings to central power sources, which allow people to use appliances, heating/cooling systems and electronics. But this interconnectedness means that when part of the grid needs to be repaired, everyone is affected.

This is where a microgrid can help. A microgrid generally operates while connected to the grid, but importantly, it can break off and operate on its own using local energy generation in times of crisis like storms or power outages.

A microgrid can be powered by generators, batteries and/or renewable resources like solar panels. Depending on how it's fueled and how its requirements are managed, a microgrid might run indefinitely.

How does a microgrid connect to the grid?

A microgrid connects to the grid at a point of common coupling that maintains voltage at the same level as the main grid unless there is some sort of problem on the grid or other reason to disconnect.

A switch can separate the microgrid from the main grid automatically or manually, and it then functions as an island.

Why would a community choose a microgrid?

A microgrid not only provides backup for the grid in case of emergencies but can also be used to cut costs or connect to a local resource that is too small or unreliable for traditional grid use. Microgrids empower energy consumers to use energy in the best way to suit their needs and priorities.

A microgrid allows communities to be more energy-independent and, in some cases, more environmentally friendly.

—U.S. Department of Energy

A microgrid not only provides backup for the grid in case of emergencies, it can also be used to cut costs.

Towers of power

Evolving energy sources poised to be big part of cities of the future

By Sarah Newkirk

Your office building, home or even city may be powered by lithium-ion — or another evolving energy source — in the near future.

Known for their use in electric cars and cellphones, lithium-ion batteries are becoming increasingly prevalent in other areas of our world, including alarm systems, city power grids and office and apartment buildings.

One of the biggest barriers to their widespread use right now is the cost. Lithium-ion batteries for electric cars, for instance, are expensive. Moreover, as with other batteries, lithium-ion ones eventually wear out. They can be recharged, but not an infinite number of times. However, one advantage of lithium-ion cells is that their rate of self-discharge, a chemical reaction that reduces the cell's stored charge, is much lower than that of other rechargeable cells such as nickel-cadmium and nickel-metal hydride.

In a push to improve this power source, researchers are working on boosting the energy density, the price, the safety, the environmental impact of disposal and the lifetime of lithium-ion batteries, as well as designing new types of batteries, Smithsonian magazine reports.

"Lithium-ion is increasingly being used in stationary applications such as data centers, replacing the lead-acid battery," says Laurie Florence, principal engineer for stationary and motive batteries at UL. "UL is seeing an increase of submittals of these devices."

There are several advantages to the use of lithium-ion power, Florence says.

"There's less maintenance associated with it," she says. "It's a higher-energy technology, so it takes up less space."

It's also a much lighter battery, which is why it's being used for vehicles. There is less need for replacement, and there's more energy with a smaller footprint, she says.

Reducing reliance on the grid

Lithium-ion power may be particularly useful in high-rise buildings because it helps to reduce reliance upon the power grid. Pairing solar photovoltaics with battery storage can help support critical power needs and contribute to fossil fuel reduction.

There are a variety of ways in which lithium-ion systems are being used in larger structures.

One of the critical considerations is that power during certain times of the day is very expensive, or buildings may have periods of heavy energy usage. During times of peak cost or demand, a building might power its activities using the energy that's been stored in the battery pack.

Cautious approach

However, one factor influencing the potential for lithium's growth is ongoing safety concerns.

Lithium-ion is a safe technology, but when things do go wrong, it can be dramatic because there's a lot of energy.

"If you look at New York, the city has set a target of 100 MWh of storage citywide by 2020," says Pravin Gandhi, a research director for UL, where he focuses on fire safety. "However, as the policy is being implemented, local authorities, like the fire department and the department of buildings, have the responsibility to approve installation of battery storage products going into buildings."

"The industry as a whole was not aware of the potential of fire – they were looking at it from an electrical capacity perspective," says Bob Backstrom, manager of the fire research and development group for UL. "They did not consider the rare occasion for when a fire does occur, what could be the potential size of the event; and how that may impact the building and its occupants?"

While lithium-ion batteries can help provide cleaner energy, they are inherently complex regarding their cellular make-up. One of the challenges with lithium-ion batteries is thermal runaway, a chain reaction fueled by the reactive nature of lithium-ion chemistry. Thermal runaway can be difficult to extinguish as the reaction generates additional heat, which causes the cycle to intensify until the reactive agents within the cell are exhausted.

"As the chemical reaction proceeds, the temperature increases, and the chemical reaction becomes even faster," Gandhi says. "You can have a pretty rapid temperature increase with lithium-ion batteries, especially in these large systems."

Location counts

The concept of backup power is not new. Many critical infrastructures have three levels of power — the utility provider, batteries and a gas generator. What is new is the concept of using chemistries other than lead acid for battery storage.

"We now have a product which is electrical in nature, and it has within its storage capability a large amount of electricity," Backstrom says. "And, these power containment systems used to be outdoors, but they're being moved indoors."

The National Fire Protection Association Standard calls for each battery unit to be separated from another unit by three feet, including a three-foot separation between a unit and the wall.

"What we don't want is the radiated energy to increase the temperature in the surrounding units," Sean DeCrane, a former Cleveland fire chief and industry relations manager for UL's Building, Life and Safety division. "Once thermal runaway starts, it is difficult to stop. What the fire service wants to do is to try to prevent the propagation of thermal runaway to the other battery units. Even when these systems are disconnected from a power source, the amount of stored energy is of great concern to responders and must be dealt with appropriately."

Additionally, the thermal environment can impact the health of the battery.

If the environment is too cold, this can lead to lithium dendrite formation during the charging process; and if the environment is too warm, this can lead to the decomposition of electrolytes and the destabilization of electrodes.

"The need to understand the operational, mechanical and environmental impacts on lithium-ion battery modules is very significant and very challenging when you have really large systems. This is the challenge for the fire service."

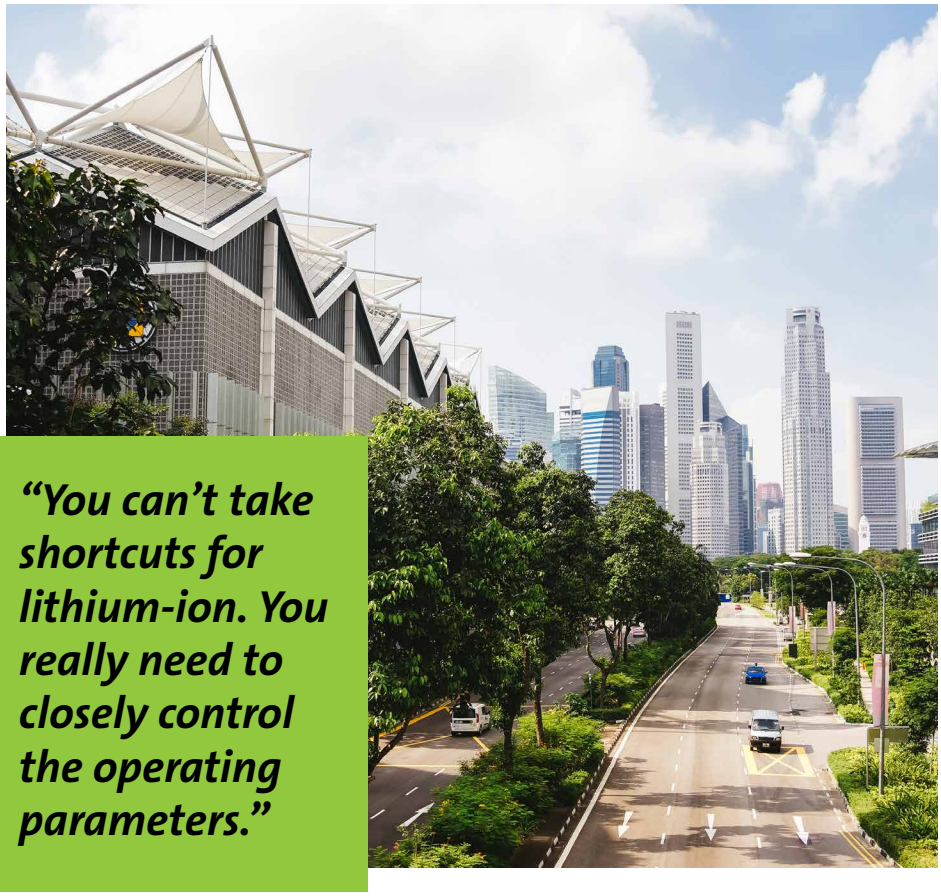
To enable broad adoption of energy storage systems in its many applications, UL has developed a set of battery storage system standards to assist industry and safety stakeholders with data and certification programs.

"Not only will the research that went into the UL Standard educate the fire service, it will also lead to the appropriate modifications of our codes and standards," DeCrane says.

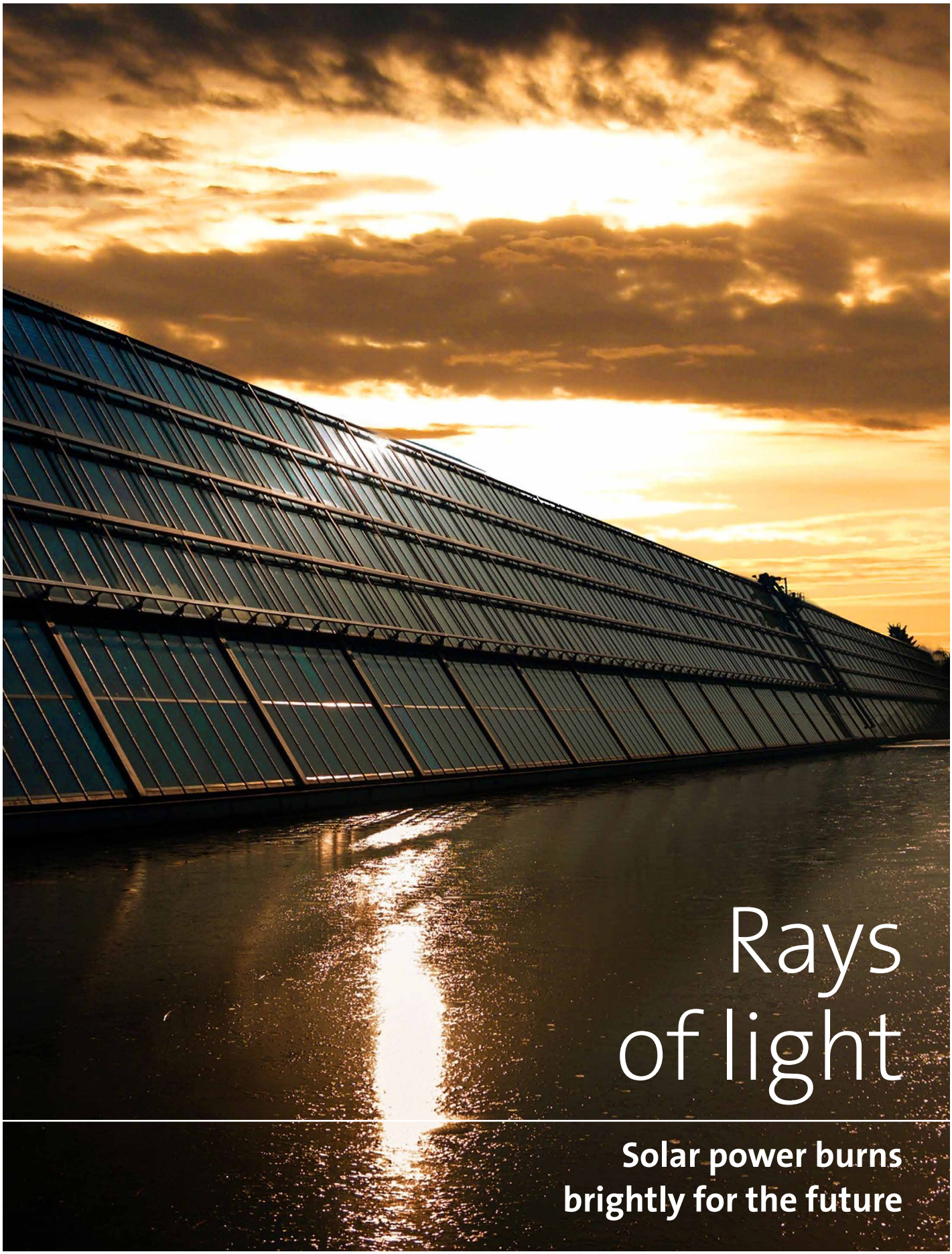
Ultimately, the use of lithium-ion batteries will come with a sophisticated set of standards and controls.

"This requires a multi-tiered safety approach that includes performance testing and certification at cell and system levels; and also, the ability to mitigate abnormal events that may occur in any installation," Gandhi says.

—Sarah Newkirk is a freelance contributor



"You can't take shortcuts for lithium-ion. You really need to closely control the operating parameters."



Rays of light

Solar power burns brightly for the future

By Robert Snarski

Our concept of solar panels may need some updating.

Steve Perez bought a house in Chicago last year that has two solar panels on the roof, but the panels were disconnected after Perez's home inspection.

"Something about the wiring to the battery cells and the house not being up to code," he says. "I was told it would cost me a hundred bucks to fix it, but when I jobbed it out, everyone quoted me $1,000 or more. I wasn't sure it was worth it."

So, Perez decided to track sunny days from his desk at home, where he works as an online translator. "My desk is right under the panels, so I figured that would be a good way to see how much direct sunlight was hitting the panels," he says.

Perez's plan sounds good in theory, but Donald Beldon, a certified energy consultant in Santa Clara, Calif., points out that direct sunlight is not necessary to charge the cells that make up solar panels.

The panels convert photons, or sun particles, to direct current, or DC power, in natural daylight, which means that most homes get enough light to run on solar panels. However, you may have to wait a little while to earn back the cost of purchasing and installing them.

"I've seen systems installed for as little as $12,000 and as much as $20,000," says Beldon. "If you're saving $2,000 a year, you'd need to commit to 10 years in the house. If that's part of your plan, then it's something you should consider."

Beldon adds that many cities and states are offering rebates and incentives to make the solar switch. "Most states or cities will offer something," he says. "Even a $3,000 grant can help justify the switch."

'Powered by the sun'

Michael LoPresti, a tax attorney in San Jose, Calif., says he weighed the costs of installing a solar system 12 years ago and decided to go for it.

"My wife is a tree-hugger by nature and we were lucky to have the incomes to afford it, so we did it," said LoPresti, who says he paid about $35,000 for the installation. "Prices have dropped pretty significantly since then, so I'd tell anyone to do it. We've already paid for our system and then some, since our electric bills used to run about $350 a month, and that was before we installed a pool and a pool house. Everything on our lot is powered by the sun."

California this year became the first state to require all new homes to have solar power. California law requires that at least 50 percent of the state's electricity come from non-carbon-producing sources by 2030.

Packing power

Going off the grid is now a reality for many. In the past, "even if your house ran on solar power during the day, it was likely you had to tap into the grid at night, especially for heat," says Beldon. "But like everything else solar, that's changing quickly, too."

Now the energy is stored and then used when needed.

For private homes, companies are now selling energy storage systems as well. When the solar panels produce more electricity than an owner can use in the home, the excess is stored in the battery pack, and when the panels aren't churning out enough electricity, the electricity stored in the system is tapped, instead of having to buy it from the utility.

Most of the new home energy storage technologies use some form of lithium-ion chemical composition. Beldon says lithium-ion batteries offer longer lifespans at less weight than their lead acid counterparts.

"It's a technology that's already here but is always being improved," Beldon says. "Lithium-ion batteries, depending on their capacity, are light, so they can be attached to the home or stacked with other similar-sized batteries."

As prices continue to go down, solar-powered homes will become more widespread.

"There will be a day when entire subdivisions are built with solar power and backup batteries," says Melissa Rhome, an energy consultant who previously worked for Sargent Lundy in New York and Accenture in Dublin, Ireland. "I don't know if that's a future of houses that are off the grid and running on their own power, or houses with equipment installed and maintained by the same companies that sell electricity and natural gas today."

Moving forward

At a recent solar symposium in Chicago, representatives from solar equipment companies, consulting firms and energy suppliers agreed that despite a new emphasis on coal and fossil fuels, U.S. companies would move ahead with plans to improve and expand solar power. Beldon agrees.

"The genie is out of the bottle," he says. "People have dollar signs in their eyes."

Beldon says prospective profits will drive solar energy's expansion more than the thousands of homeowners who want to "chip in to save the Earth," which is why companies will forge ahead with more efficient solar panels and stronger, smaller batteries.

Like its business-based partners, UL also keeps moving ahead despite some uncertainty in the country's energy policies.

"If anything, there's movement that starts in a certain state and that movement may cascade to the rest of the country," says Diana Pappas Jordan, a senior programs manager at UL. "California now has a set of requirements for more solar power in new homes, so we'll create a new set of standards for manufacturers, which eventually will be adapted by companies in other states. There's no real slowdown. Things just keep moving forward."

—Robert Snarski is a freelance contributor. Marco Buscaglia contributed to this story.

On the road

Battery-powered wanderlust lifestyle helps recharge spirit, self and stuff

"Live, travel, adventure, bless, and don't be sorry."

—Jack Kerouac, "On the Road"

By Robert Snarski

The first time Adam Platt enjoyed a taste of freedom — "a true taste of freedom, like no constraints," he says — he was 8 years old.

"I ran away from home for about an hour," says the former building material sales representative. "My dad was a writer, and he had rented a house near Willard Beach in Maine one summer when we were kids. We were from Ventura, Calif., and I knew we lived by a beach, like the one in Maine. I was upset one day with my mom, so I figured I could walk down Willard Beach and get to our beach."

A short time later, he turned back. Although it was a brief adventure, Platt, 34, says something "opened up inside" of him.

"I really can't explain it, but to this day, I remember that feeling of absolute exhilaration," he says. "Seeing nothing behind me but beach and nothing in front of me but beach — I felt like I was in a movie."

Fast-forward about 20 years, and Platt's life was still like a movie, but "one of those ones where a man finds himself in a horrible life and decides to lash out at society," he says.

So, Platt gave his two-week notice at work, subleased his apartment in Portland, Ore., and decided to go on "an open-ended road trip." That was six years ago.

The great escape

When he began his journey, Platt loaded his Ford Escape with everything he thought he'd need for a month.

"I knew I couldn't live like this forever in parking lots and at rest stops," he says.

"When you work at a certain job and have a certain lifestyle, it's hard to just walk away from that, so I made a deal with myself — six months on and six months off. Work for six months, save enough to go on a trip, travel for six months and then find a place to work until you can afford to take the next leg of the journey."

Platt says his travel timeline expanded after his father died in 2014.

"My father was not a prominent author by any means, but the little money that he did make and the money that he had inherited from his family had been wisely invested, so when he died, there was a substantial amount of money," Platt says. "Since I'm an only child, that money went to me."

Platt says he invested a portion of the funds for his retirement — although he admits "retirement" is a relative term when you spend the bulk of your year roaming the continent — and decided to upgrade a bit. He purchased a new Jeep and several rechargeable devices, and he invested in a small auto shop in his adopted hometown of Portland.

"I know pretty much nothing about cars, but I helped set it up and got it running," he says. "That's how I make my living now."

Lithium life

Platt says he has simplified his life to the point that he no longer carries a laptop or a cellphone. He has rechargeable lights, an MP3 player, a battery-powered TV and several other lithium-battery-powered devices.

Platt says people likely would be surprised at the various mindsets and lifestyles of a lot of people who travel.

"The nomadic lifestyle isn't exactly synonymous with dirty hippie or anti-establishment socialist, not at all," he says. "There are people with a lot of money who decided to take a break from society for a few months. ... It's a little piece of connection with America."

Jane Gomez, who is traveling with her husband and 2-year-old son on a one-year coast-to-coast trip, agrees.

"We see families, retired couples, singles, siblings — any combination you can think of," says the 24-year-old Iowa City, Iowa, resident. "It's a mix of all cultures

"We see families, retired couples, singles, siblings — any combination you can think of. It's a mix of all cultures and backgrounds."

and backgrounds."

Still, Gomez says she does find one commonality with her fellow travelers.

"I think we're all people who really appreciate nature and appreciate each other," she says. "Sometimes I look up at the stars at night and think about how sad I'm going to be when I get back to Iowa and have to go to work. ... I hope I can find a way to keep this magical essence inside of me even if I'm out living in the suburbs somewhere."

These modern wanderers often rely on devices powered by lithium-ion batteries that make living easier and keep them connected to the world. Living away from the rat race is often possible because of battery-powered devices.

Portable solar panels, head lamps, flashlights, water purifiers, hand warmers, camp stoves, power banks, charger kits, generators, water heaters, fans, coffee makers and more can keep nomads going as they're connecting with nature and reducing their reliance on the grid.

More time with nature

"Rechargeable batteries have opened up camping in new and exciting ways," says Luiz Benitez, director of the Colorado Office of Outdoor Recreation Industry. "They've allowed families, couples and individuals to spend a little more time with nature. We don't have to do without some of the small but important items we count on to help get us through our day-to-day lives just because we want to spend more time outdoors."

Pittsburgh resident Anna Rinella agrees. A mother of three children, Rinella says she and her husband camp with their twin 6-year-old sons and 9-year-old daughter far differently than she used to camp with her father.

"When I was a kid, we roughed it — I mean, really roughed it — and it turned my sister and brother off from camping for a long time," Rinella says. "I always liked it, but I was a bit of a tomboy, so catching fish for breakfast was exciting for me. All of it was. I was the kind of kid who thought it was hilarious to dig a hole in the forest and use it as a bathroom."

It's important for Rinella to give her children the best of camping.

"It gets dark when we camp, obviously, and that used to terrify me as a kid so I make sure we have lanterns and nightlights so there's always some light, so having things that run on rechargeable batteries make a big difference," Rinella says. "My kids can go stare at the stars and we can sit around a campfire and I don't necessarily mind if they want to play on my phone for 15 minutes before they go to bed."

Rinella says her kids also love using rechargeable portable fans and head lamps. And Rinella herself also admits she likes some of the comforts from home while she's sleeping under the stars.

"I have a portable espresso machine," she says. "Yes, that sounds pretentious — camping with an espresso machine. We have a portable coffee machine, too, a one-cup coffee maker. So, I have my coffee in the morning and then a shot of espresso with lunch or dinner. ... My husband makes fun of it and says my dad would roll over in his grave if he saw me drinking espresso after cooking steaks on the fire, but he'd probably love it."

Benitez says that comforts like Rinella's espresso maker, which is powered by a lithium-ion battery, is why many newbies try camping.

"There are people who love roughing it,

who can go out with minimal equipment and enjoy the experience, but that's not for everyone," he says. "It's entirely possible to enjoy some of the comforts from home and still have an amazing, outdoor experience. The setting is what matters to most people, not the logistics."

See the world

Matthew Kepnes, founder of NomadicMatt.com and author of "How to Travel the World on $50 a Day: Travel Cheaper, Longer, Smarter," says traveling — especially map-your-own-journey traveling — isn't just for people looking to disconnect from society for a while. In fact, he says, it's a great learning experience for people of all ages, including new college graduates before they embark on their careers.

"For a lot of people, once you're out of school, you're going to work until you're dead, so why not go have some fun while you're young?" Kepnes says. "When you're 50 and you have four kids, you can't just quit your job and travel. When you're 22, you can say, 'I'm going to go have fun for a little bit.'"

Kepnes says young travelers are sure to pick up life skills while traveling around the globe.

"You learn to go with the flow and deal with situations," he says. "You learn how to talk to people from different cultures. You learn things you can't learn in school. You become a more well-rounded person."

Have batteries, will travel

Platt doubts he'd be able to take his long excursions if there weren't portable versions of his favorite items available.

"Everything's rechargeable: rechargeable lights, rechargeable MP3 player, rechargeable power for my TV and Roku — I'm not anti-technology, just anti-being-bothered-by-people-for-no-reason," he says, further explaining his no-phone-or-laptop position. "I have a rechargeable blender and a rechargeable water purifier. I have a couple of rechargeable flashlights and a rechargeable hot-water heater I use for showers."

When he first went on the road, Platt relied on campsites with electrical hookups. Then he "graduated" to a jerry-rigged car battery he used to power devices like his electric shaver and hot plate.

"Really, it probably was incredibly dangerous," he says. "I remember one time I was shaving and it was hooked up to this battery, and the shaver started to get really hot ... and I started smelling burning metal. I unhooked the shaver and ditched it and the battery at a truck stop along I-80 in Nebraska. When I got back to Portland a few weeks later, I had this ZZ Top beard."

He opts for safety now.

"I'm pretty sure there's a rechargeable version of anything you would ever need to live a nomadic lifestyle."

Safety first

Before clicking "purchase" on the cheapest item, consumers should be sure they're getting more than just a good price.

"It's easy to buy things that may be dangerous. You see something that's less expensive than similar items and it draws you in," says Matthew Thomas, senior engineering technician at UL's testing lab in Northbrook, Ill. "As a consumer, though, you have to make sure you're buying from a legitimate manufacturer and that the product you're buying has been tested."

Thomas and other members of his team take the batteries through a litany of tests, making sure the batteries and cells can handle heat, pressure, drops and other rough-and-tumble elements of portable flashlights, phones, coffee makers and more.

"We replicate what could happen in real-life situations," says Thomas. "Anything left in the sun could overheat, so we test for that. Anything can be dropped or can fall off a shelf or table, so we test for that. We want to make sure the batteries that bear the UL Mark adhere to the standards."

In addition to having the right gear and devices, Platt says the right expectations are important for such a lifestyle.

"It helps being a loner," Platt says, "but make sure you define that like I do: a person who enjoys his alone time, not a person who hates everyone."

—Robert Snarski is a freelance contributor

Packing list

If you want to enjoy life off the grid, grab the right gear

By Marco Buscaglia

NO, THAT DOG-EARED COPY of "On the Road" by Jack Kerouac isn't going to help you survive life off the grid for a few months. Let's face it: Even a few hours without some of life's necessities can be pretty taxing, no matter how much you want to be one with the earth.

Thanks to the marvels of rechargeable lithium-ion batteries, there are numerous options if you're looking to gear up before hitting the road. Here are some suggestions:

Let there be light

A solar-powered flashlight and a solar-powered lantern — or a combination of the two — are camping essentials. Not only will you use them to find your way back after that midnight trip to the bathroom, you can plant one on a table so no one accidentally knocks over the bowl of chips and hand-crafted guacamole. And really, what else are you going to use to make scary faces at your kids when it's pitch black outside?

Voices from beyond

While the chances of things going wrong when you're off the grid depend on your setting, your circumstances and your luck, it's always smart to plan for the worst — and to know when the worst is coming. Look for a multi-purpose radio, which includes a flashlight, phone charger and AM/FM/WB radio. You'll be able to keep track of pending thunderstorms and the Cubs' winning streak while doing the environment some good.

Heading out

There are headlamps that throw off 300 lumens of bright light and are Bluetooth-friendly, which means you can customize your beam of energy with an app. Why would you do that, you ask? By adjusting the app, you can set a certain distance to illuminate or control the strength of the beam, depending on your remaining battery power.

Drink up

Challenging the voice in your head that asks, "You're not going to drink that, are you?" can be a bad idea. Use a water purifier instead. Look for a purification process that involves ultraviolet technology to cleanse the water and a unique reservoir system to speed the process.

Charging ahead

Harness the power of the sun, or something like that, with a weatherproof phone and tablet recharger that gains a full charge from the sun. They can help you stay charged in potentially dangerous situations when you really need to make a call while in the wild.

—Marco Buscaglia is a freelance contributor

Lithium-ion issues

The flip side of being an energy powerhouse

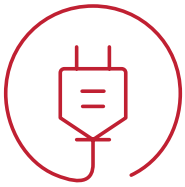
Headline-grabbing reports of exploding headphones, hoverboards, laptops and e-cigarettes parade across our consciousness in a seemingly unconnected din. So frequently do these reports occur that only the most sensational incidents are deemed worthy of our attention.

But as investigators review individual occurrences, a common thread reveals several different factors surrounding these events. Lithium-ion batteries and thermal runaway, a chain reaction which can be fueled by the batteries' nature, remain at the center of each explosion, injury or, on the rare occasion, death, but the cause is varied.

Here are several conditions that contribute to thermal runaway:

Device misuse

Life's mishaps can damage the device's interior design. Actions such as the repeated dropping of a device over time, leaving a device in a hot car or setting it in bedding, can cause the battery to overheat, and can lead to thermal runaway. Lithium-ion batteries that have been exposed to stresses may function normally but be damaged internally. Think of it in terms of your brain — stresses such as heat exhaustion and repeated hits can irreparably damage structure and functioning.

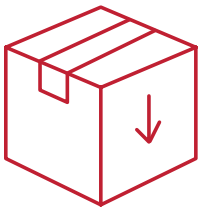


Non-certified batteries, chargers and other contributors

Lithium-ion technology is generally safe when quality battery manufacturers take exhaustive steps to minimize design flaws, vet material suppliers and control quality of production. Manufacturers of battery powered products can then use established protocols to integrate those batteries safely into their products. However, some companies and consumers continue to purchase and use non-branded and non-tested batteries, cables and, as if often the case with consumers, chargers.

Design flaws

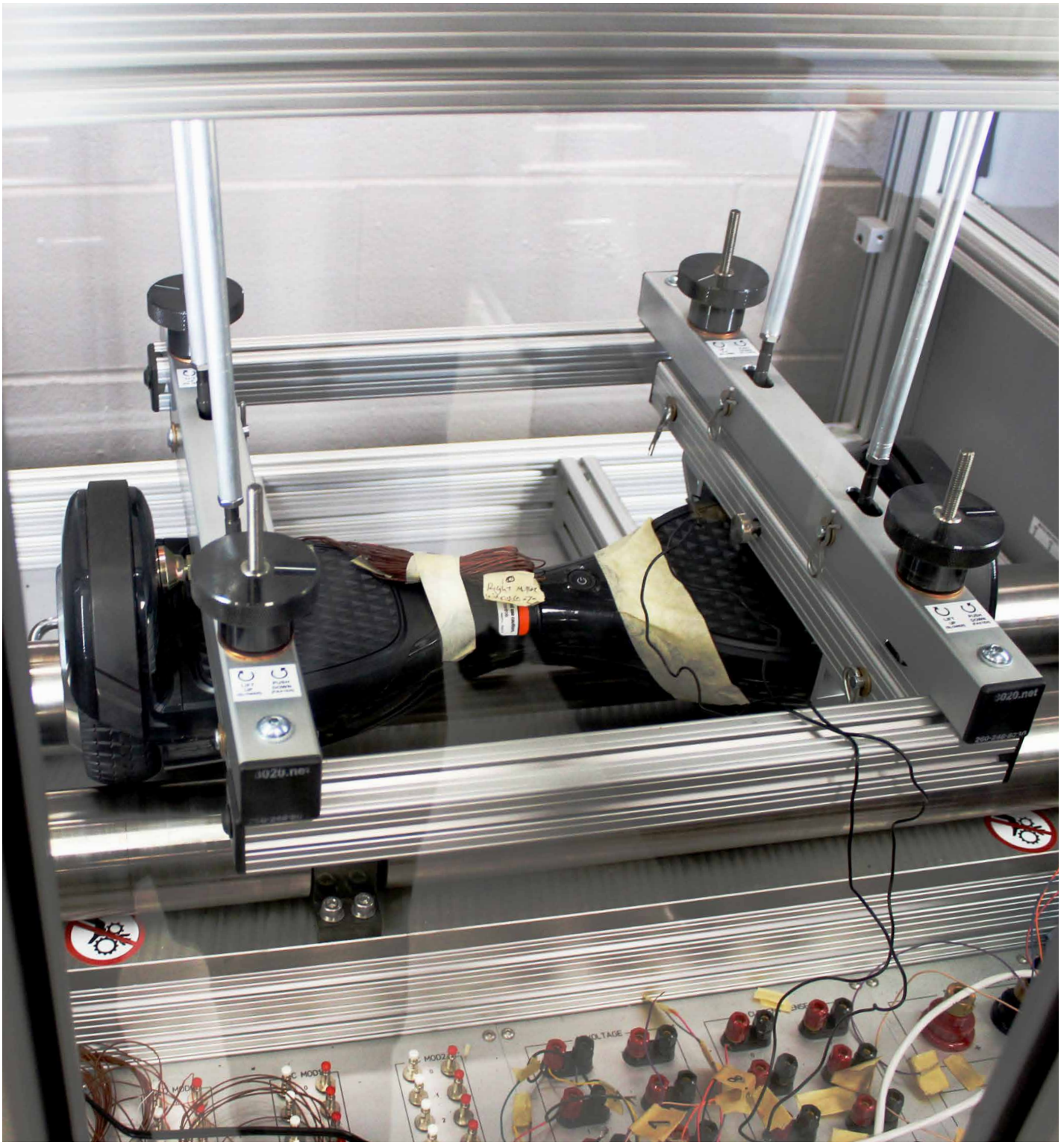
Because consumers crave higher-capacity batteries in smaller packages at lower prices, there will continue to be more chances for problems with devices and products. The energy density of lithium-ion cells has doubled since 1991 as battery manufacturers pack more active material into a device. Pressure from the surrounding hardware can cause damage to the electrodes or separator. Manufacturing methods become more critical as cells become denser.



Production flaws

The presence of microscopic metallic particles could come into contact with parts of a lithium-ion battery cell, leading to a short circuit within the cell. Cells with ultra-thin separators are more susceptible to impurities than ones with enough space between the cell's protective pouch and the electrodes inside. Complex assembly techniques make the elimination of all metallic dust almost impossible.

Because consumers crave higher-capacity batteries in smaller packages at lower prices, there will continue to be more chances for problems with devices and products.



The Mark of safety

UL testing lab intent on finding out where flaws lurk in batteries

By Marco Buscaglia

Jesse Rodriguez gets to blow things up for a living.

Batteries, mostly. He gets to drop batteries, crush batteries, submerge them in water and pump them full of way too much electricity.

Rodriguez is especially proud of puncturing things, which takes place when technicians drill holes into batteries.

"This is usually pretty fun for the kids," Rodriguez says, pointing to the exploded bits of battery embedded in the ceiling and assuring us that everyone stood outside of the enclosed space when the battery exploded. "We did it on Take Your Child to Work Day. The kids had a lot of fun."

The kids?

"OK, it's pretty cool for us, too," he says.

Rodriguez is one of four engineering technicians who work in UL's battery-testing lab in Northbrook, Ill., and push various batteries and cells to their breaking point to see if they comply with UL's Standards. In some cases, they'll stress a batteries component — overcharge them, overheat them — to test the batteries' casing.

The lab itself is in a space that seems smaller than its role, but it is a testament to efficiency filled with small, enclosed rooms, various-sized explosion-proof boxes, numerous exhaust fans and vents and an abundance of screens filled with charts, graphs and an ever-changing collection of numbers, all tied to the various testing mechanisms in the lab itself.

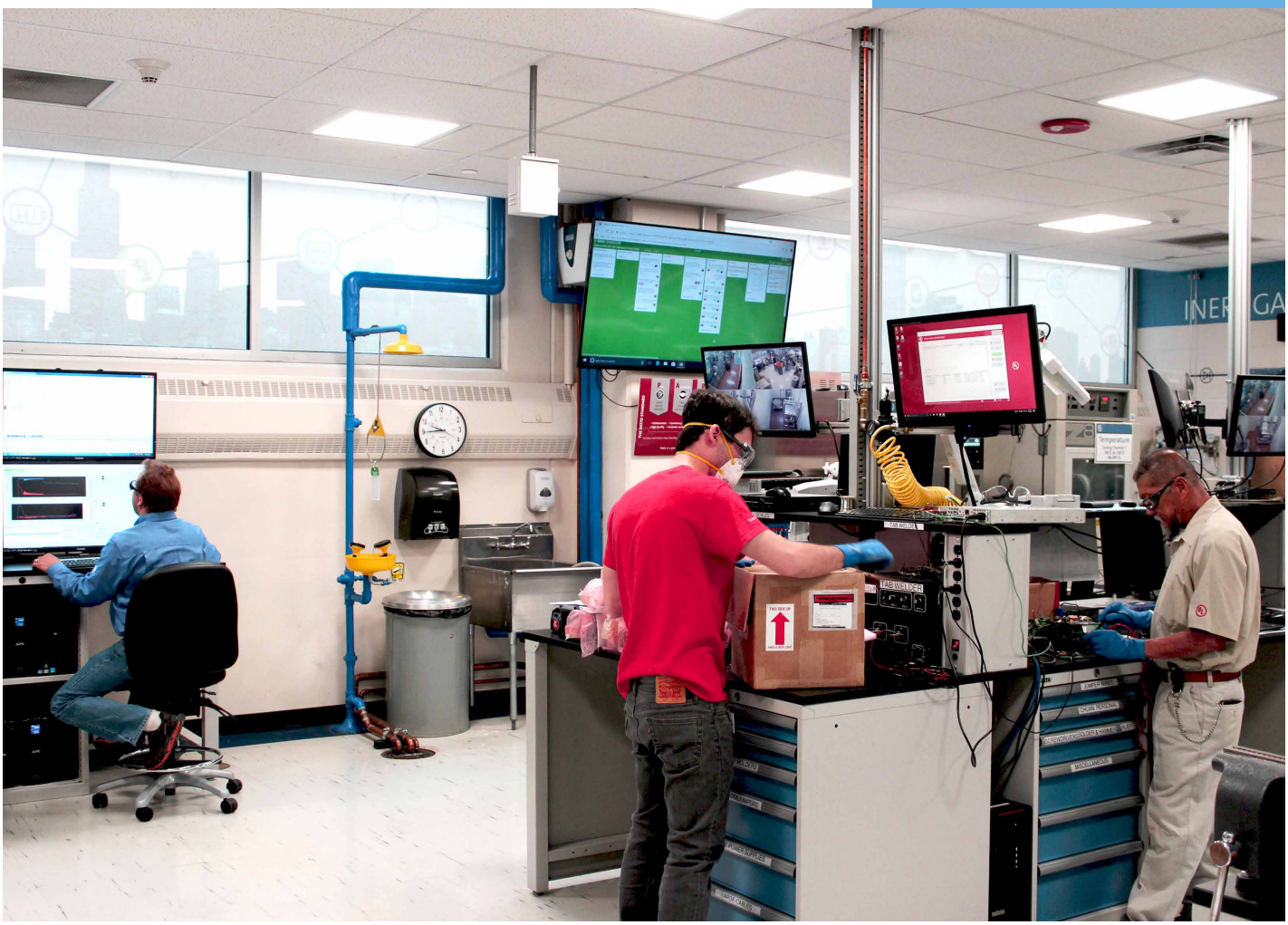
"It's a pretty elaborate setup," says Matthew Thomas, the lab's senior engineering technician. "We do a lot in a fairly small space."

Thomas isn't kidding. With three or four technicians moving throughout the room, there is a calming atmosphere that stands in direct contrast to the exploding, overheating, drilled-through and crushed batteries that are being tested throughout the space.

"It's pretty calm down here," says Rodriguez. "We're all very tuned in to what we do, and we take every precaution necessary. It's not like we're running around blowing things up. There's an order to all of it."

Thomas says that calm comes from a staff who has worked together for a number of years, and a methodical approach to a job that requires precise results and measurements.

"It's a pretty elaborate setup. We do a lot in a fairly small space."



"We are testing batteries to their breaking points, so everything has to be precise—how we set up the equipment, how we set up the batteries and cells, how we measure our results—it's an exact science when it comes to testing," Thomas says. "The testing itself can be loud and messy but we track the results as precisely as we can. There's no fluctuation when it comes to testing our Standards."

Standards rule

The Standards, in fact, are king, ruling everything that happens within the lab once they've been passed down from UL engineers and the UL Standards committees.

Diana Pappas Jordan, a senior programs manager and standards technical panel chair at UL, manages the process of setting the battery standards.

Each UL Standard is governed by a Standard Technical Panel (STP), which is the consensus body and is required to have a balance of interest. The STPs are an important part of the process by which UL develops and maintains its Standards for safety.

The STP is comprised of different interests, such as, producers of products; supply chain participants, like suppliers and retailers; consumer advocate groups; government organizations; inspectors, testing and standards organizations and general interest, like consultants.

Most UL Standards are American National Standards (ANSI).

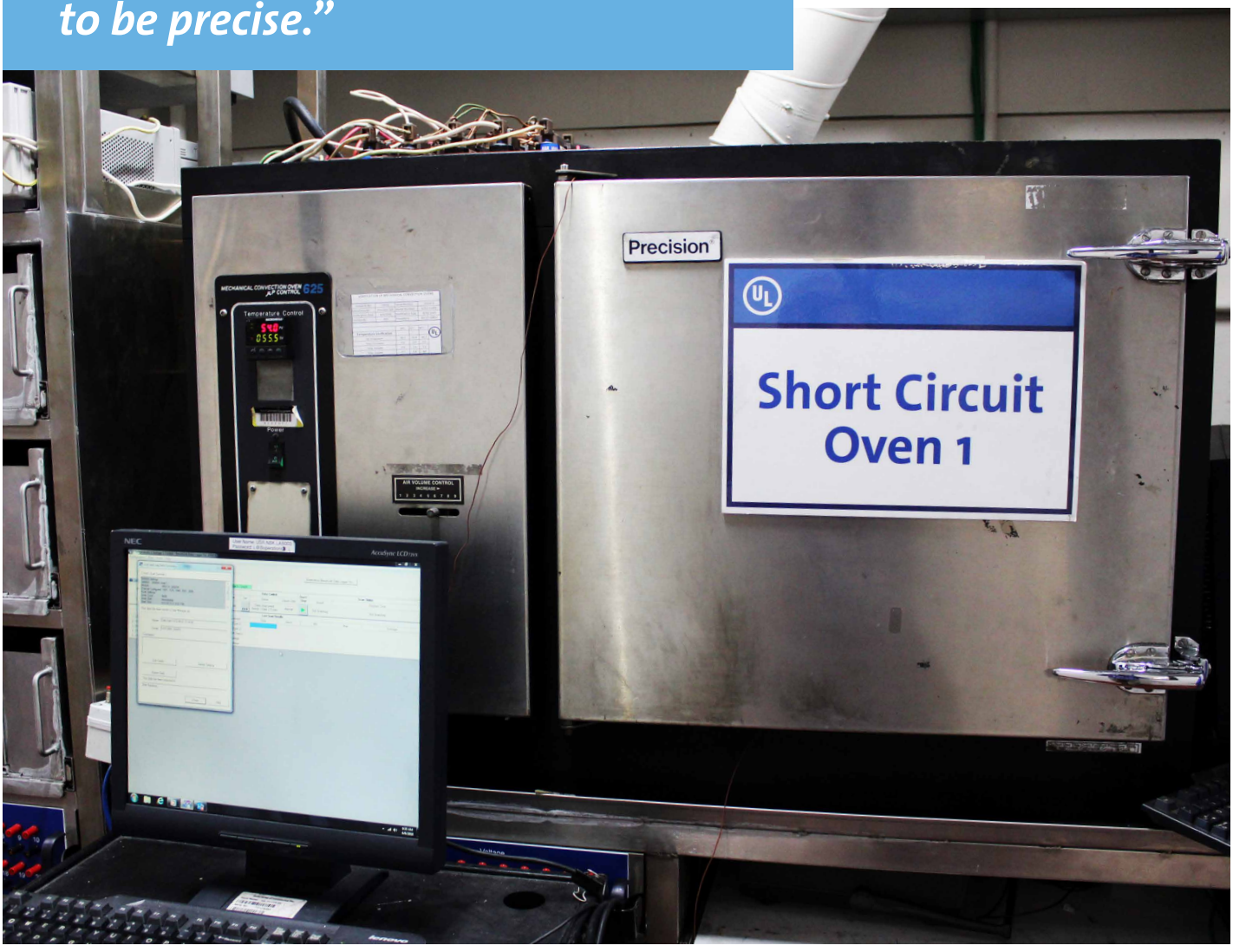
"Standards continue to evolve and change as technology changes and new products are developed," Pappas Jordan says. "Scopes and requirements of current UL Standards may need to be revised to address new technology features."

Skaters and smokers

Thomas, who has been with UL for 19 years, says the UL Standards can apply to a complete battery or a single cell. In some cases, they'll test batteries in tandem with the products they power, especially if those products, by design, might put a lot of stress on the batteries.

"Hoverboards are the best example

"We are testing batteries to their breaking points, so everything has to be precise."



right now," Thomas says. "We'll run tests to see how the batteries will react under certain conditions, which are much different than the conditions for a laptop or a phone."

Thomas says he thinks testing small batteries for e-cigarettes is about to play a major part in the lab's daily activities.

"Things are happening in the news every week, it seems," he says. "The e-cigarette Standard is out there but there are some external standards, too. It's going to take some different equipment and different ways to test the normal wear and tear: how the battery charges, how the vapor impacts the battery. The batteries are really complex. I was amazed at how much they fit into that little battery, so there's a lot to test."

The Mark matters

Thomas says that UL's Standards are as relevant now — if not more so — than ever.

"Back in the day, my grandparents would say they would never buy something without a UL Mark," he says.

Because of what he knows, Thomas says his job has had a direct impact on his life as a parent, consumer and member of society in general.

"There are things I would never let my family buy," he says. "I see some of these chargers and I'm like, 'No, no, no. Not for us.'"

Thomas says he's confident UL Marks matter to those consumers who take the time to do a little research.

"It's peace of mind," Thomas says. "I know what goes into setting safety standards and testing safety standards, so I see what can go wrong if things aren't properly tested."

As can Rodriguez and the other engineering technicians in Northbrook.

"We see the news, we know what can happen," Rodriguez says. "We joke around about blowing things up, but we know what we do is important."

—Marco Buscaglia is a freelance contributor

The green scene

The environmental risks of mining, disposal

Salt mounds pile up in Bolivia as part of a lithium-extraction operation.

By Dave Wilson

Add to the list of popular Australian exports lithium, atomic number 3, the lightest metal of all on the periodic chart of the elements and the world's lightest solid element.

It's an adaptive chemical artifact, the salts of which are used as a mood-stabilizing drug to treat bipolar disorders, but lithium can also be used as an additive for iron, steel and aluminum production.

Outside of Western Australia, where it is produced by typical mining methods like crushing rock and then processing it in China, lithium is found in the "lithium triangle" of Argentina, Bolivia and Chile, where it's extracted from brine evaporation pools.

However, contrary to popular belief, lithium can be found just about anywhere on the planet.

"One of the greatest misconceptions about lithium is that it is rare. It isn't," notes Chris Berry, a New York City-based independent analyst and consultant in the energy metals sector. "In fact, if the price of lithium ever got high enough, you could extract it from seawater."

Although lithium is often seen as a more environmentally responsible energy source than its disposable alkaline brethren or batteries found in internal combustion engines, some see the mining, transportation and destruction of lithium as being damaging to the environment.

Berry does equate the old-school Western Australian method of producing lithium from hard-rock sources to traditional mining of items like coal, platinum, copper, and tin. "I'd say that lithium mining overall has no more or less of an effect on the environment than other extractive industries, though I'm sure there is room for debate here," he says.

Berry, who has worked with investment firms, banks, corporations and academic institutions "to better understand opportunities and threats that the rapidly changing global energy mix presents us with," notes that the traditional environmental hazards with any kind of mining also apply to the finding and production of lithium.

"Once lithium is mined, it is then further processed into lithium chemicals used in lithium-ion batteries or other industries,

An open-cut gold, lithium and iron ore mine in Leonora, in Western Australia.

such as ceramics," Berry says. "The processing is well-known, and major producers and refiners continue to optimize costs to minimize any environmental issues. Lithium production is a relatively complicated process, but over time, lithium production techniques have evolved."

Many experts note that any environmental impact created by lithium mining is optimal when compared with the damage caused by widespread dependence upon other energy sources.

David Deak, the chief technical officer of Lithium Americas, told the Financial Times in 2017, "In the short term, the CO2 footprint from (lithium) hard rocks will be less than ideal.

But it is still extremely beneficial in offsetting the CO2 emissions that otherwise would come from internal combustion engines."

Within the lithium triangle, however, production relies on more organic (and less environmentally damaging) methods. "The process of producing lithium from brine pools is relatively benign in that you utilize the sun to evaporate water from lithium brine ponds and then further process the lithium crystals into lithium carbonate or other lithium chemicals," Berry says.

But, according to Friends of the Earth-Europe, a compendium of more than 30 grassroots organizations, lithium mining does cause environmental damage.

According to that group, lithium is mined through "holes (that) are drilled into the salt flats and the brine is pumped to the surface, leaving it to evaporate in ponds. This allows lithium carbonate to be extracted through a chemical process. The extraction of lithium has significant environmental and social impacts, especially due to water pollution and resource depletion. In addition, toxic chemicals are needed to process lithium. The release of such chemicals through leaching, spills or air emissions can harm communities, ecosystems and food production. Moreover, lithium extraction inevitably harms the soil and also causes air contamination."

Siena Hacker, an energy policy associate with Pick My Solar, a group that seeks to "empower communities to adopt sustainable technologies through transparency and choice," elaborates on several other lithium mining environmental side effects:

Countries that produce **the most lithium**

1. Australia
Mine production: 18,700 metric tons*

2. Chile
Mine production: 14,100 MT

3. Argentina
Mine production: 5,500 MT

4. China
Mine production: 3,000 MT

5. Zimbabwe
Mine production: 1,000 MT

6. Portugal
Mine production: 400 MT

7. Brazil
Mine production: 200 MT

8. United States
Mine production: unknown

**One metric ton equals 2,204.623 pounds*

Source: Investing News

The world's largest lithium mining companies

1. SQM

Market capitalization*: $14.89 billion

SQM has customers in 110 countries and offices in 20. The firm's efforts are mainly centered in Chile, with its largest brine operation in Salar de Atacama. Recently, the company announced plans to enter the Cauchari-Olaroz lithium project in Argentina, a joint venture with Lithium Americas that will begin production in 2020.

2. Albemarle

Market capitalization: $12.84 billion

With 5,000 employees and customers in more than 100 companies, Albemarle is one of the world's largest lithium producers, owning lithium brine operations in Chile, Australia and in Nevada's Silver Peak mine in the United States. Last year, Albemarle introduced new technology that will increase its production of lithium without further brine pumping.

3. FMC

Market capitalization: $12.06 billion

FMC's lithium operations are based in the Salar del Hombre Muerto in Argentina. Keeping its interests local, the company announced plans last year to increase its lithium production in Argentina.

4. Tianqi Lithium

Market capitalization: $9.27 billion

A subsidiary of China's Chengdu Tianqi Group, Tianqi Lithium is the world's largest hard-rock-based lithium producer. In 2016, it purchased a 2.1 percent stake in global leader SQM.

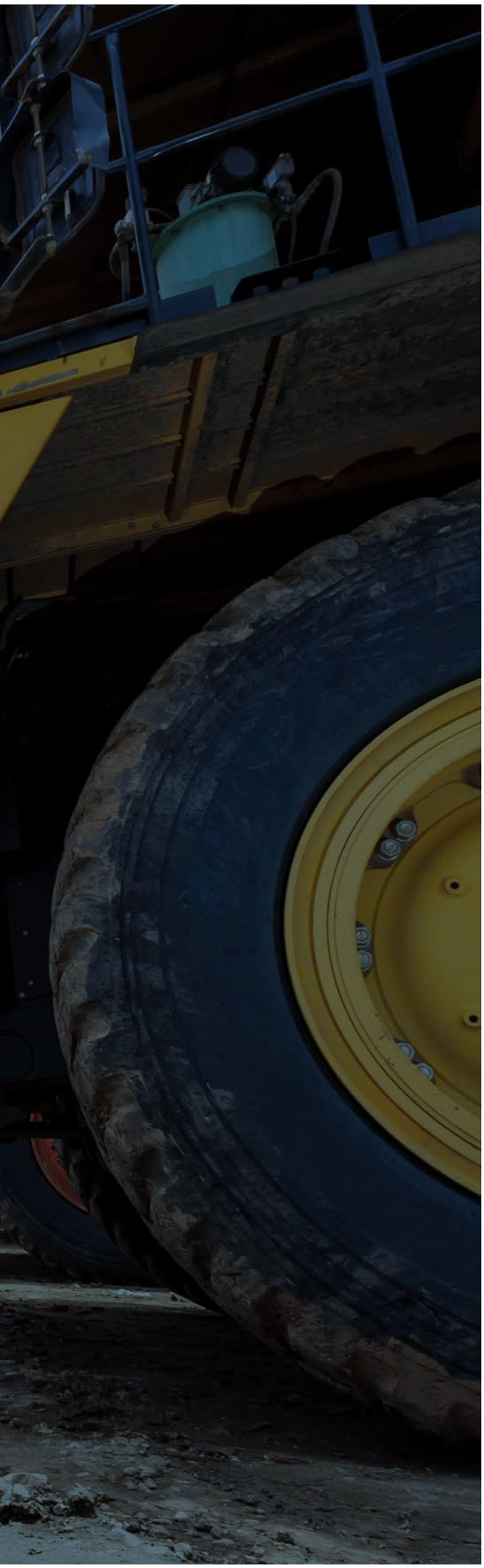
5. Jiangxi Ganfeng Lithium

Market capitalization: $7.04 billion

Jiangxi Ganfeng Lithium is the second-largest lithium producer in China. The company also owns smaller stakes in other international mining companies, including International Lithium. Jiangxi Ganfeng Lithium is looking to expand beyond mining, having recently invested nearly $300 million in lithium-ion battery technology.

Source: Investing News

**Market capitalization: Value of a company that is traded on the stock market, calculated by multiplying the total number of shares by the share price.*



"As with many other minerals, mining lithium often releases dust containing toxins into the air. For local communities, overexposure to these toxins while lithium is mined and transported can become an environmental hazard resulting in birth defects and breathing problems."

Post-mining, getting lithium through traditional supply chains (which Berry characterizes as "fragmented") from its mines and brine pools to refinery production facilities, including destinations in China, involves a journey through oil-consuming methods like trucking and shipping.

"Lithium molecules do indeed travel thousands of miles during their journey from mine to end product," Berry says. "After this step, the major battery producers are in Japan and Korea and the OEMs (original equipment manufacturers) are spread further afield still."

Specifically, Hacker notes, "The additional transportation required for Australian-mined and Chinese-refined lithium certainly increases emissions."

Berry says that plans are afoot for lithium producers to streamline both the cost and impact of production and transportation of the element. "In the future, lithium producers will look to vertically integrate their operations to minimize environmental issues and reduce costs," Berry notes.

After a lithium battery's typical 10-year lifespan of automobile, scooter and cellphone powering, disposal is still a murky unknown in terms of environmental impact. Currently, less than 5 percent of the lithium-ion batteries found in cars are recycled, as opposed to 90 percent of the lead-acid batteries used in typical gas-driven vehicles, according to the Financial Times.

The ultimate resting place of lithium-ion batteries is poised to be a large emerging industry.

"Lithium battery disposal and recycling is going to become a much bigger business in the near future should (electron-volt) adoption continue on its current torrid pace," Berry notes. "This will, of course, be led by China, and you're already starting to see startups and existing companies incorporate lithium recycling into their long-term business plans. Storing lithium-ion batteries in landfills, with their risk of explosion, is not a viable long-term strategy, and so governments and the private sector are joining forces to get ahead of the curve here."

—Dave Wilson is a freelance contributor

Workers mix cement in Rio Grande, Bolivia, as they work to extract salt brine to collect lithium. Brines in South America supply a good chunk of the world's lithium, and harvesting it in evaporation ponds leaves behind salt waste.

Living an undercharged life

Kids draining mom's batteries

By Marla Caceres

I can't escape batteries.

I'm a mom to a son, Wyatt, who's almost 4, and his little sister, Juniper, who's 1 1/2.

The thing about little kids this age is that they destroy everything — piles of carefully folded laundry; the contents of a dishwasher, so they can push the empty rack around; sleep.

Sometimes you do a little risk/benefit analysis and let them destroy one thing so you can be free to do another. I once looked the other way while my son emptied a bag of ground coffee onto the kitchen floor so he could skate through it. I really needed to catch up on emails.

They love destroying things that take batteries. Not kids' toys — most of those protect their batteries with screwed-on covers — but grown-up things, like bike lights, flashlights and remote controls.

They pop the covers off and remove the batteries, sending the double-As and triple-As scattering like marbles on a sidewalk. Some of them end up under furniture, shrouded in dog hair and ancient granola. A select few have the privilege of meeting my bare feet at 2 a.m.

Most of them end up mixed in with dead and brand-new batteries, dropped in bundles into vases or placed on shelves during rushed efforts to pick up.

I find them later and can never tell which batteries are still good, which are dead. I could test them by placing them into a remote and seeing if they work. But the remotes are lost, because the kids took them. I'll just deal with it later.

My batteries are drained.

Parents' batteries are like lithium-ions. They can sustain a charge for a long time, and sometimes all they need is a quick boost — a cup of coffee, a visit to the bathroom even if you don't have to go — to do their job for just a little while longer. Most of us operated on regular old alkaline batteries our entire lives and didn't think we had the staying power of lithium-ions.

But the market suddenly changed and we had to innovate.

My overall battery compartmentalizes its power. After a full day at the office, my

work battery is at zero, while my kid battery is at 100 percent. I greet my husband, the stay-at-home parent in our family, and he's drained, an almost-dead C shrouded in dog hair and ancient granola among our just-out-of-the-package, triple-A children.

I can take bedtime. My charge is full. I read three books to my son after I let him jump on the bed and body-slam me for 20 minutes. He has the energy of a thousand lithium-ions.

One night, I asked my husband if his kid battery is ever at 100 percent.

"Never. It's always at 60. I've never come back from anything and seen it in the green," he said.

Is it ever at zero? Do you still have to take care of them when you have nothing left?

"That's when I'm feeding them candy for dinner. Just old Halloween candy from a drawer."

He pauses.

"Even if I take a break or a vacation from them, there's still some level of my brain that is concerned for their safety. Are they safe? If something were to happen to them, how long will it take me to get to them?"

I realize that I do this; all parents do this. When we become parents, we compartmentalize our batteries so that a portion is always running, powering our concern for our kids. This portion never runs out, but it never rests. It's why my mom still calls me to remind me to take my vitamins. And now I have to worry that my kids might swallow button batteries.

You can say kids destroy this part of us, like they destroy most everything. Gleefully and obliviously. But that's their job. They're supposed to blissfully enjoy it because, one day, the crushing love they have for their kids will destroy them, too.

My son likes to pick up objects he knows are battery-powered and ask if they need batteries or a charge. But he also likes to purposely ask "wrong" questions, because it's funny.

One day he looks at me, pre-bedtime body-slam, and asks, "Mommy, are you a battery? Do you need a charge?"

Not right now, buddy. I'm at 100 percent.

—Marla Caceres is a comedy writer living in Chicago.

On alert

Button batteries can pose danger to children

IF YOU THINK YOUR CHILD HAS swallowed a battery, look for the following signs:

- **Crying**
- **Drooling**
- **A hoarse voice**
- **Lack of interest in eating and drinking**
- **Difficulty swallowing**
- **Abdominal and/or chest pain**
- **Vomiting**
- **Blood in saliva and/or stool**

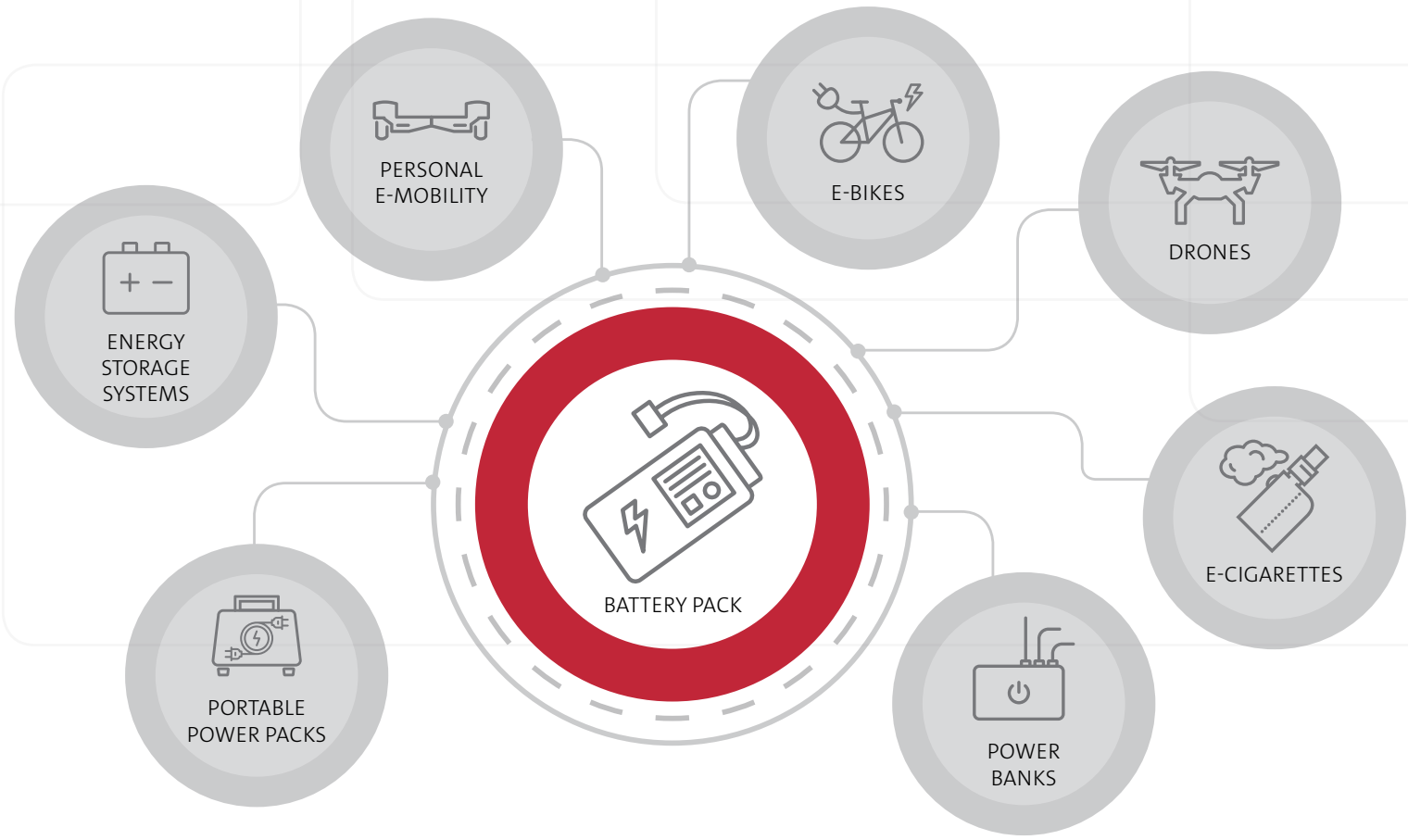
While it's important to react immediately, it's equally important not to put your child in more danger. According to the Children's Hospital of Philadelphia, adhere to the following list:

- Do not give medications to make your child move his or her bowels or vomit.
- Do not give your child anything to eat or drink.
- Do not give him or her milk; this will not prevent further injury.
- Do not attempt the Heimlich maneuver, even if you saw your child swallow the battery. The battery could change location and increase the risk of injury.

If you're unsure whether a battery was swallowed, take your child to the nearest emergency room, says Diana Brice, a physician's assistant at Highland Hospital in Oakland, Calif.

Leading the charge

Lithium-ion battery and system safety



As our world evolves, new energy-based products powered by lithium-ion batteries will continue to be developed. That's why more than ever, companies around the world are turning to UL for assistance, including: identifying hazards, mitigating risks, testing, certification and measuring performance. We are dedicated to helping drive the global battery industry forward with our continued pursuit of holistic system safety.

Trust UL to help ensure system safety is always in step with innovation.

Portable/wearable batteries: UL.com/Batt
Stationary/motive batteries: UL.com/Batteries

Empowering Trust™