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# How batteries will power the future

Member exclusive by



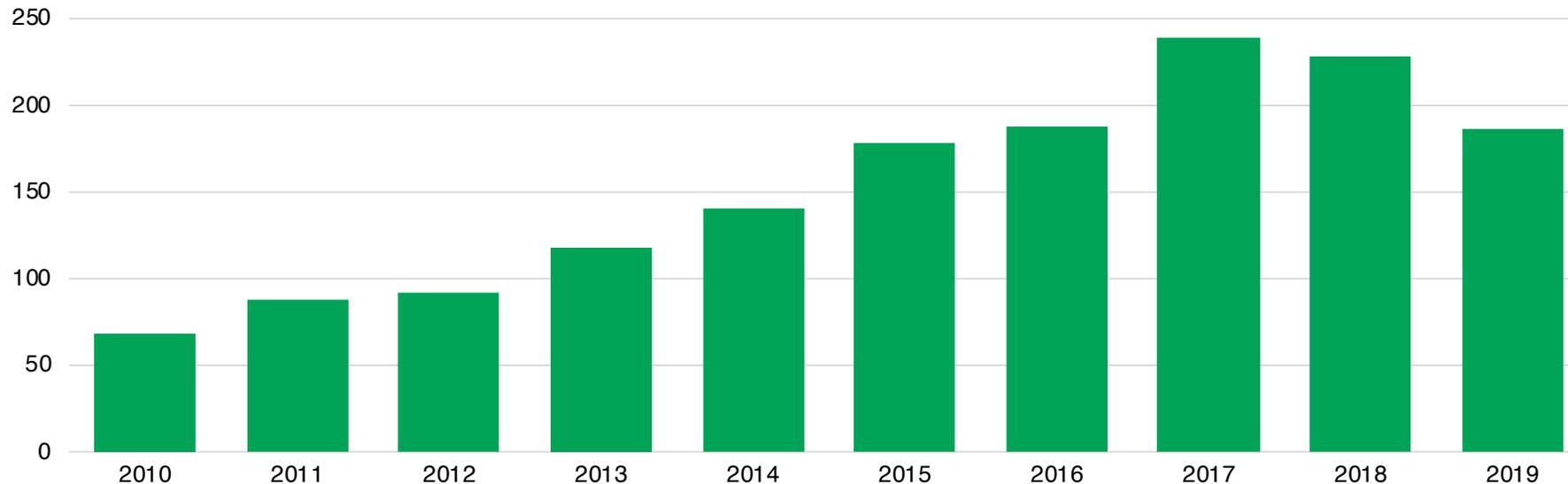
Dasia Moore

## Better batteries are key to powering a greener future

Batteries are set to overtake fossil fuels as the primary way we power the world. RMI reports that the first half of 2019 saw \$1.4 billion in battery technology investment, and Bloomberg New Energy Finance says electric cars will outnumber gasoline cars in 2038. But batteries' shortcomings—technological, economical, and environmental—mean an all-electric world isn't possible just yet. How did batteries become central to renewable energy? Who's who in the multi-billion-dollar business behind them? And will they improve fast enough to slow climate change?

### Annual deal count for battery technology investments

Includes all venture capital and private equity deals compiled by Pitchbook.



## Before we get started, your battery vocab cheat sheet

A few terms you need to know, as defined by Akshat Rathi in Quartz's guide to the battery revolution:

- **Power vs. energy:** “Power is the rate at which energy can be released. Think of power like a car’s acceleration capabilities, and energy like the car’s range on a full tank.”
- **Power capacity:** “The measure of how much energy a battery can deliver in a short time”
- **Energy density:** “The amount of energy stored in a battery per kilogram”
- **Watts (W):** “The rate at which energy is supplied. A small refrigerator requires about 100 W of power... A typical nuclear reactor can generate more than 1,000 MW, or 1 gigawatt (GW), of power.”
- **Watt-hours (Wh):** “A unit of energy, where 1 Wh is equal to consuming 1W of power for one hour. It’s the unit that appears on your utility bill. A typical household in the UK consumes about 10 kWh of energy each day.”

## A history of reinvention

Anything that converts chemical energy to electrical energy is a battery. The first one was invented in 1799 and was made of copper and zinc. Since then, battery technology has proven remarkably adaptive, with centuries of improvements to power capacity, energy density, size, and cost making contemporary batteries possible.

1799

Alessandro Volta invented the **first battery**. It used copper, zinc, and salt water-soaked cardboard to provide electricity.

1859

Gaston Planté invented the lead-acid battery, the **first rechargeable battery**.

1888

An **early full-size electric car** was built in Germany. For a time, batteries were preferred to noisy, dirty hand-crank car engines. But affordability, driving range, and speed soon led to gasoline domination

1970s

**Oil shortages** prompted Big Oil to invest in researching fossil-fuel alternatives. ExxonMobil chemist Stanley Whittingham developed the first **lithium-ion batteries**.

1986

**Nickel metal hydride batteries** (NiMH) were invented. They offered better power capacity than lead-acid batteries but still had low energy density.

1990s

**Environmental regulations** aimed at cutting emissions from transportation began to revive electric car research.

1991

Sony and Asahi Kasei released the **first commercial lithium-ion battery**.

1996

General Motors attempted an **all-electric car revival** with their NiMH-powered EV1. The battery's low energy density limited the EV1's range to just 100 miles.

2000

Toyota released the **Prius**, the world's first mass-produced hybrid electric car. The car used a NiMH battery.

2008

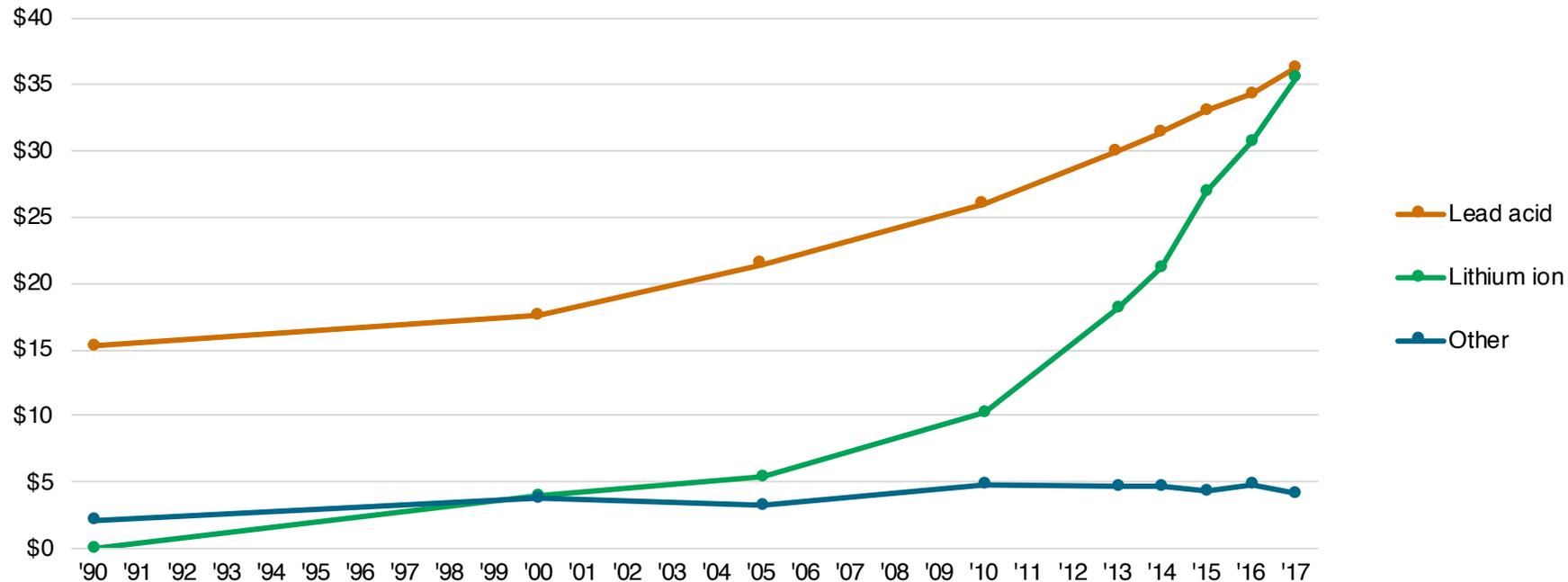
**Tesla Motors** released its Roadster, the first mass-produced all-electric car using lithium-ion batteries and the first all-electric car to have a 200-mile range.

## The lithium-ion revolution

Of all the batteries available today, lithium-ion (Li-ion) batteries, or LIBs, are most important to the future. LIBs have higher power capacity and energy density than batteries made of other materials. Though all-electric cars had existed before, it was Li-ion technology that made mass-manufacturing electric vehicles (EVs) possible.

### The market for lithium-ion batteries has soared

Battery market by type of chemistry, for available years

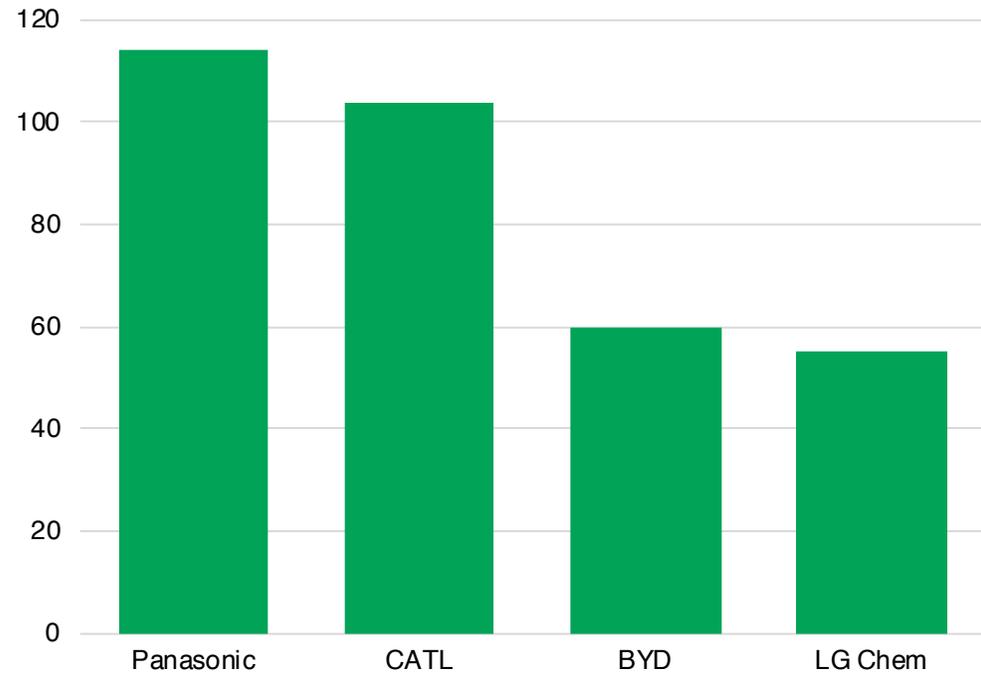


## The business of batteries

Familiar household battery brands like Duracell and Energizer account for a tiny percentage of battery sales. Most batteries are sold business-to-business, and many are totally invisible to consumers—you won't see them even if you take your gadgets apart. Built-in LIBs invisibly power innumerable technologies, including smartphones, laptops, mobility aids like powered wheelchairs and scooters, electric cars and buses, and deep-sea drilling equipment.

Most of these batteries are manufactured and sold by the industry's four giants: Panasonic (Japan), Contemporary Amperex Technology (CATL, China), BYD (China), and LG Chem (South Korea).

**Projected battery manufacturing capacity in 2022**  
Measured in GWh

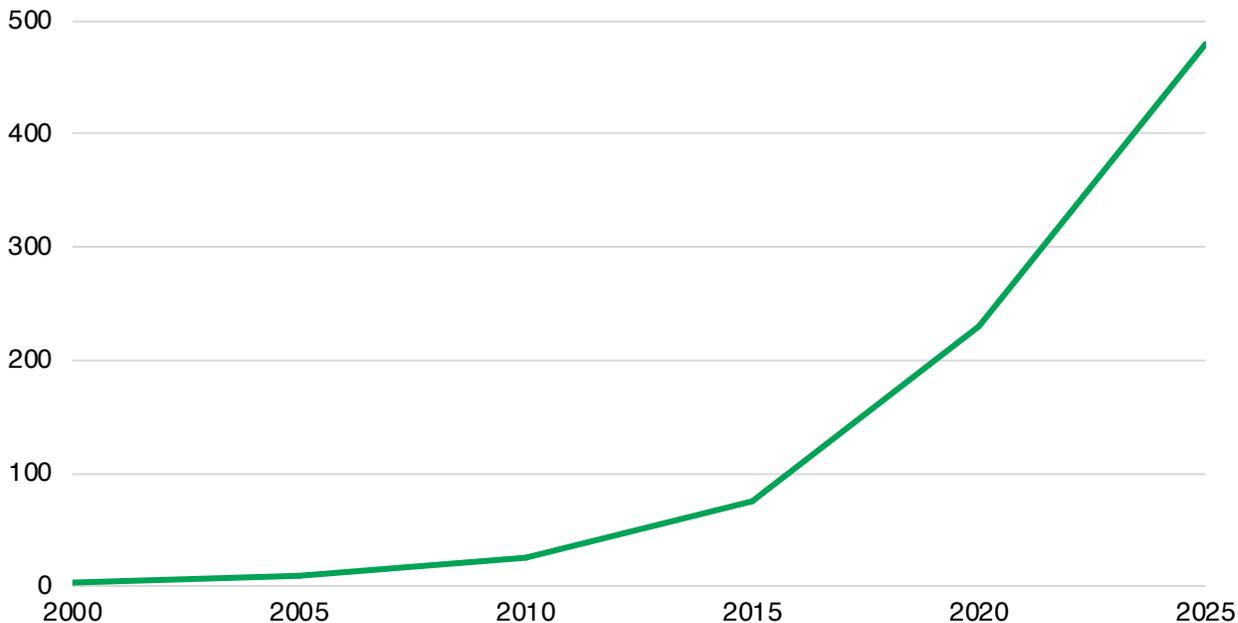


## The world has gotten good at making batteries

Li-ion battery production capacity has soared, and rapid growth is likely to continue. In 2015, the world produced 75 GWh worth of LIBs. By 2025, that figure is expected to reach 480 GWh. This has huge cost implications. According to BloombergNEF, each time battery sales have doubled, production cost has dropped by about 18%.

### Global production capacity of Li-ion batteries, in GWh

Actual values for 2000, 2005, 2010, and 2015. Projected values for 2020 and 2025.



## China leads the world

China accounts for 73% of the world's lithium cell production capacity. One reason for China's dominance is the symbiotic relationship between LIB production and the automotive industry: The country is home to more than 100 battery and electric car makers, several of which are unicorns. It is both the world's fastest-growing car market and the number-one seller of electric cars.

**1.02 million**

The number of new energy passenger vehicles (i.e. electric cars or fuel-cell cars) sold in China in 2017

**99%**

China's share of the world's electric buses. 99% of electric two-wheel vehicles are also in China.

**\$1.4 billion**

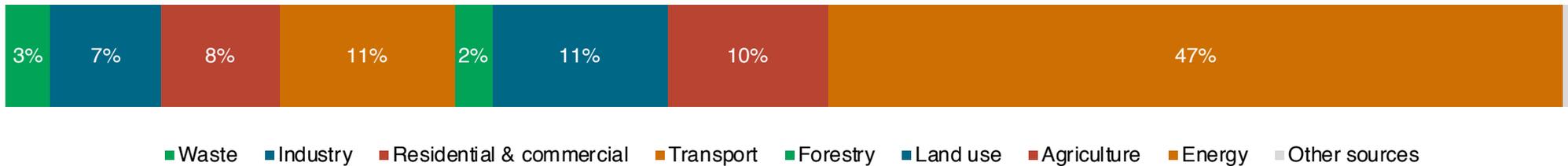
CATL's planned investment its newest battery cell plant, located in Yibin, in the Sichuan province.

## The battery-powered future

Battery development and car electrification have long gone hand in hand, but EVs are far from the only use for better batteries. Breakthroughs in battery technology could transform all transportation, with electrification extending to ships and planes. Some startups are hoping to release small, all-electric passenger planes as soon as 2022. The world’s first zero-emission cargo ship, the Yara Birkeland, is already under commission and could launch this year.

More importantly, batteries have the potential to supercharge renewable energy adoption. A major drawback to depending on solar panels and wind turbines at a global scale is that they generate electricity intermittently. But advanced batteries—with enough energy density and a long enough shelf life—could act as energy storage for the power grid.

Global greenhouse emissions by economic sector, 2010



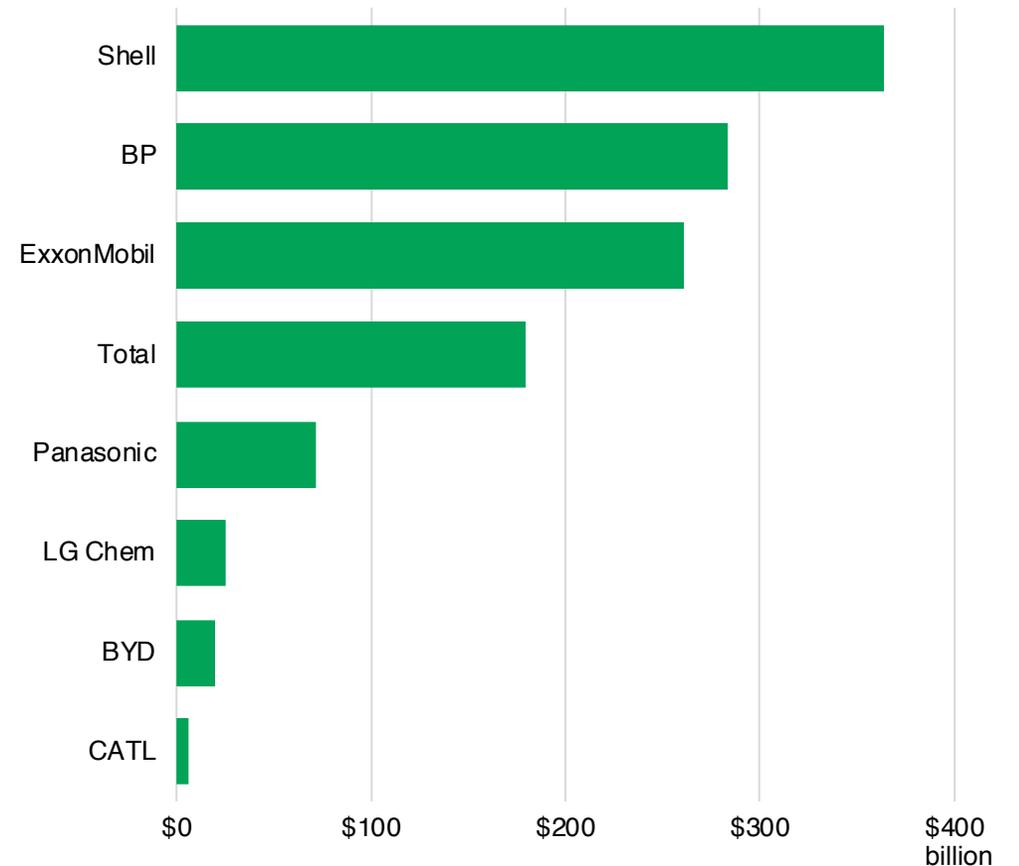
## Who wants to be a hundred-billionaire?

When batteries replace fossil fuel as the world's engine, Big Battery will replace Big Oil. Here's a closer look at who's in the running to dominate energy in the 21<sup>st</sup> century.

- **Panasonic** is a 101-year-old tech giant. Partnerships with Tesla and Toyota make it a powerful force.
- **CATL** was founded in 2011. The young upstart has quickly gained ground by focusing on EV batteries specifically.
- **BYD** had early success with cellphone batteries and is now the world's leading EV producer. BYD plans to spin off its battery business as a standalone firm by 2022.
- **LG Chem** claims its chemistry-based approach gives it an edge over competitors. It has developed and patented several new battery designs and shapes.

### Big Battery still doesn't compare to Big Oil

Revenue for Sep. 2018-Sep. 2019

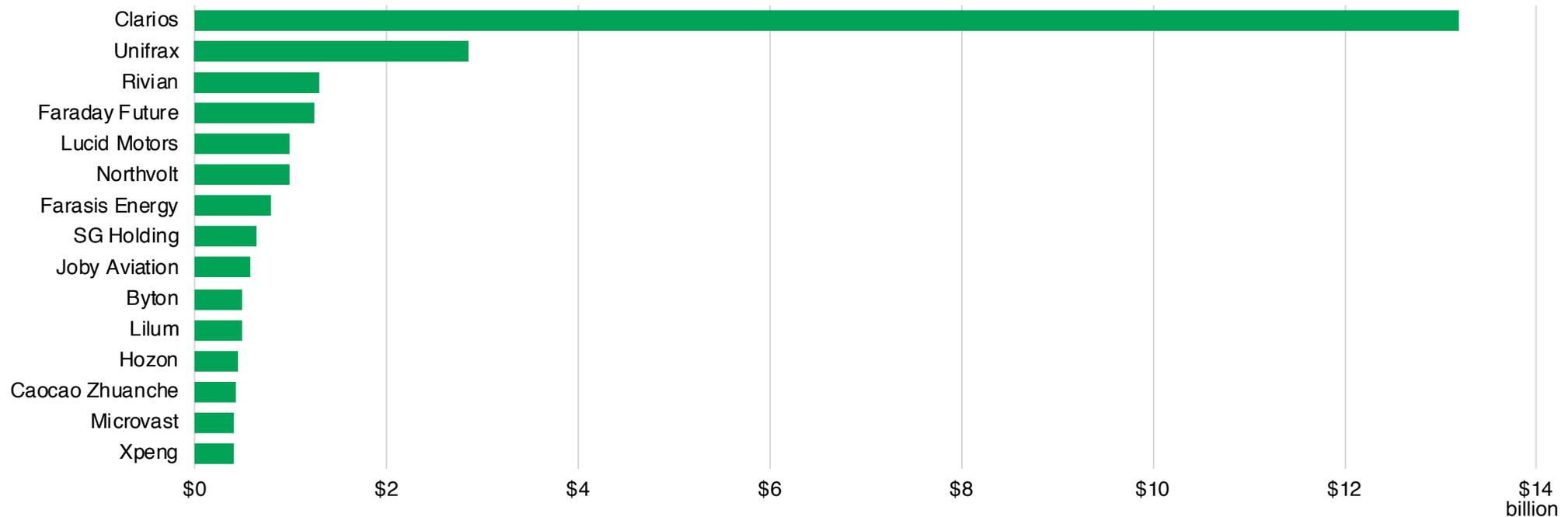


## Batteries are powering startups, too

Since 2017, 574 battery technology and electric vehicle startups have secured financing deals, according to Pitchbook. Nearly all of these startups aim to develop better batteries—with higher energy density, more compact designs, and faster charging. Many develop batteries in application-specific contexts, with 23% exploring automotive uses.

### The largest battery and electric vehicle financing rounds for 2017-Jan. 2020

Venture capital and private equity deals, including buyouts.



## Is the next Royal Dutch Shell... Royal Dutch Shell?

Big Oil isn't eager to cede its throne. The rise of new energy competitors and increasing climate change awareness and legislation have proven to be powerful motivators. Faced with slowing growth and shifting public opinion, the major fossil fuel companies are investing heavily in batteries. Notably missing from recent battery investments is ExxonMobil, even though the first rechargeable li-ion battery was created in their research lab.

**\$70 million**

Shell's investment in Sonnen, an energy-storage startup that Shell later acquired for an undisclosed amount

**40%**

Total's stake in a joint venture with battery-maker Tianneng, set to produce up to 5.5 GWh at Chanxing Gigafactory

**\$20 million**

BP's 2018 investment in StoreDot, a startup that makes faster-charging batteries for EVs

## The future isn't now

Batteries might be the solution to the world's fossil fuel dependency, but they're an incomplete answer for now.

- **Technology.** Oil has a trump card: Fossil fuels are still the best way to store energy. Even our most powerful batteries store too little energy for too short a time to be viable alternatives for global grid energy storage.
- **Cost.** The cost of li-ion batteries has dropped significantly in recent years, but they're still not cheap enough. Yet-Ming Chiang, an engineer and battery expert at the Massachusetts Institute of Technology, told Quartz in 2019 that prices would likely bottom out at \$80 per kWh, given the raw materials needed to make them. For affordable energy storage at a global scale, batteries would need to cost less than \$10 per kWh.
- **Environment and human rights.** Mining for the metals used in batteries—lithium, nickel, cobalt, and manganese—usually involves unsustainable methods and toxic labor conditions. Cobalt mines, mostly located in the Democratic Republic of the Congo, often employ children. Extracting one tonne of lithium requires about 500,000 gallons of water and chemicals that can threaten aquatic wildlife.

## What's next for batteries

With billions of dollars invested in battery research each year, it is only a matter of time before the world enters a new era of renewable energy. Besides efforts to improve power capacity and energy density, the battery industry is also interested in making batteries more environmentally friendly. Efforts are underway to build recyclable batteries, find new battery metal reserves, and design cleaner extraction methods. Ultimately, the future could belong to battery-adjacent technologies, with several startups already trying to develop cheaper energy storage alternatives.

**\$13 per kWh**

The energy-storage cost the startup Malta hopes it can reach for its reversible refrigerator, which converts excess electricity into heat

**1.9 million**

The square-footage of Tesla's Gigafactory, a largest-of-its-kind battery production and research facility that employs 7,000 people

**10,000 W/L**

The power density IBM claims its new, heavy metal-free battery has. Announced in December, this battery would outperform li-ion

## Want to know more? Read Quartz coverage of batteries.

- [Answers to burning questions on battery science and business](#) – If you're still getting acquainted with batteries.
- [Oil giants are competing to buy battery companies](#) – For more on how Big Oil plans to survive the transition away from fossil fuels.
- [Bye-bye Panasonic? Tesla is working on making its own batteries](#) – If you're curious about the Panasonic-Tesla partnership or Tesla's plan to follow Chinese automakers' lead.
- [Winners of the 2019 Nobel Prize in chemistry developed lithium-ion batteries](#) – For context on the impact of LIBs.
- [Europe is beating the US in the battery race—with China's help](#) – For more on the geopolitics of the battery industry.

You'll also enjoy our Obsession on [climate consciousness](#) and our member-exclusive field guide, [Batteries: Big Oil's big challenge](#).

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