Tech Scouting Report

Battery Innovation

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A Brief History

Lithium Ion to Lithium Iron – the road to batteries good enough to drive

A lithium-ion battery or Li-ion battery is a type of rechargeable battery in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. Li-ion batteries use an intercalated lithium compound (lithium cobalt oxide or $LiCoO_2$) as the material at the positive electrode (hence their name) and typically graphite at the negative electrode.

Lithium iron batteries work the same way, but use lithium bound with iron as the cathode. The energy density of $LiFePO_4$ is lower than that of lithium cobalt oxide ($LiCoO_2$), and it also has a lower operating voltage, but because of its low cost, low toxicity and long-term stability, $LiFePO_4$ is finding a number of roles in vehicle use, utility scale stationary applications, and backup power.

Early 70s

Early in the 1970s, the lithium battery was proposed by British chemist M. Stanley Whittingham. Conducting the research that led to his breakthrough at Stanford University, he discovered how to store lithium ions within the layers of a disulfide material. Later hired by Exxon, he continued to improve on his original innovation.

1979

Working in separate groups, Ned A. Godshall (Stanford), John B. Goodenough (Oxford University) and Koichi Mizushima (Tokyo University), demonstrated a rechargeable cell using lithium cobalt dioxide ($LiCoO_2$) as the positive electrode and lithium metal as the negative electrode. This innovation enabled early commercial, rechargeable, lithium batteries

1990

Jeff Dahn and two colleagues at Dalhousie University reported reversible intercalation of lithium ions into graphite in the presence of ethylene carbonate solvent, thus finding the final piece of the puzzle leading to the modern lithium-ion battery.

1991

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

2002

Yet-Ming Chiang and his group at MIT showed a substantial improvement in the performance of lithium batteries, boosting the material's conductivity by doping it with aluminium, niobium and zirconium. The exact mechanism causing the increase became the subject of widespread debate.

2011

Lithium nickel manganese cobalt oxide (NMC) cathodes, developed at Argonne National Laboratory (U.S Department of Energy), manufactured commercially by BASF in Ohio. Lithium-ion batteries have become mainstream - for example they account for 66% of all rechargeable battery sales in Japan.

2020

Musk announces that his company Tesla will be producing Lithium Iron (lithium iron phosphate or LFP) batteries, that will last longer, deliver more power and, crucially, need no Cobalt. This is a crucial step, as Cobalt costs $50,000 a ton and is in short supply. Tesla open a factory in China and manufacture the new batteries there.

At the time of writing (2021) the market is really hotting up, with battery prices (measured $ per kWh) at, or already below, internal combustion engine (ICE) parity (that is to say, in theory, a car maker can make an electric car at the same price as an ICE car). Batteries in this class, manufactured at volume, now come from Panasonic, LG Chem NCM, CATL LFP, and BYD Blade. Also Bill Gates' start-up, QuantumScape, formed a joint venture with VW last year and expect to be challenging within 4 years.

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Leading Institutions

As already mentioned, thist is now a very hot area for research, as vehicles the world over switch from ICE to EV formats. Our database lists well over 3,000 technologies from more than 400 universities and research institutions. In such a situation, picking 'top institutions' is very tricky so we had to use our judgement in order to be fair.

1 Tsinghua University

The top ranked research institute in China, Tsinghua is consistently rated in the top 50 worldwide, or higher, and collaborates extensively with industry and with universities across the globe

2 Central South University

Formed from the merger of 3 universities, including the long-established Xiangya Medical College. Teaching and researching in a very broad range of subjects.

3 Stanford University

Scientists at Stanford are designing new technologies to improve the cycle life and reliability of batteries, fuel cells and other grid-scale storage technologies. Researchers and engineers are testing a wide variety of promising low cost materials such as Prussian blue dye, nickel iron and aluminum.

4 University of California

In effect 10 universities, including Berkeley and UCLA plus 3 national labs, all working under one banner, the University of California is a global powerhouse of innovation. The 3 labs are all associated with the US Department of Energy and have produced 13 Nobel laureates.

Summary of Leading institutions

In order to pick the winners, we look at technology offers (research that is being promoted to industry) as well as recent patents. Patents are sometimes churned out by institutions, encouraged by government research grants linked to patent numbers, whereas an offer is usually made only when the institution believes somebody will be likely to want to commercialise its technology. However, in this case, looking at offers produces a top 4 list that is entirely US-based, whereas including recent patents produces a top 4 that is entirely Chinese. So, in an effort to be even-handed, we have taken the top 2 from each country.

2021

Continuing in this effort to be representative, these are other significant players in this area of research:

Rank	Instituion
05	Jiangsu Huadong institute of Li-ion Battery
06	MIT
07	Purdue University
09	Harbin Institute of Technology
10	The French National Centre for Scientific Research (CNRS)
11	Arizona State University
12	City University of Hong Kong
13	U.S Department of Energy
14	University of Oxford
15	University of Toledo

*Data sourced from Innovation DB. Visit try.innovationdb.com to learn more.

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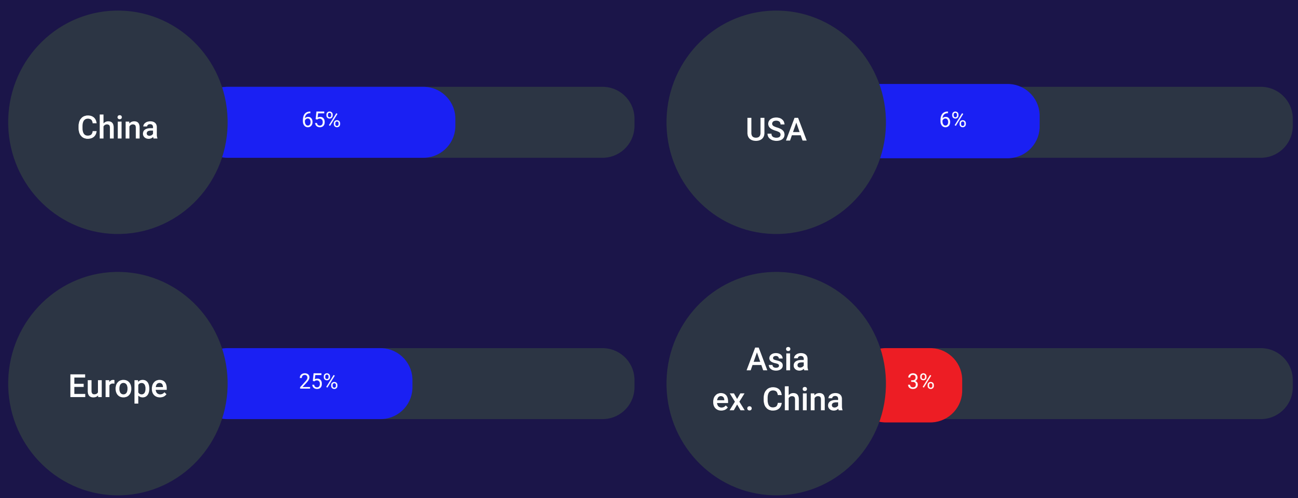
Leading Countries

Unsurprisingly, research is mostly concentrated in areas effected by legislation, especially the EU and the USA. However, China is also extremely proactive in this area, supplying about one third of global plastic production, much for export to those regions where legislation is forcing a change.

Share of the global lithium-ion battery production capacity in 2020



Leading Countries in new research

01. China	225
02. USA	74
03. Japan	50
04. France-Germany-UK	18

*Data is sourced from Innovation DB. Countries are ranked by the number of institutions with new battery technologies. Visit try.innovationdb.com to learn more.

Summary

It took close to 40 years for Lithium-ion batteries to get from the lab to widescale adoption in the market place. Given the unprecedented demand for long-lasting and highly stable batteries due to the upsurge in electric vehicle usage, we can expect the reformulated Lithium Iron batteries to get to market much, much more quickly.

All commercially applicable technology has to serve a real market need and sometimes that means the most impressive technology, viewed in its own terms, loses out to other less compelling but more immediately applicable technology. Sometimes this is a matter of cost (why have something twice the price that is only 10% better?), sometimes the way it the tech combines with other tech (there is no point having a worlds best digital tuner, if the speakers are not able to reproduce the sound), sometimes it is the state of the infrastructure within which the technology will need to operate A world-beating hydrogen engine is not good to a consumer who cannot easily buy the gas in the form).

In the case of lithium-iron batteries, all these scenarios are true. Lacking the high-cost cobalt element, they are cheaper than their predecessors. In the case of power units for cars, the vehicle does not perform in a better way, when driven in standard road conditions, using lithium-ion batteries than it does with lithium-iron. The infrastructure is in (mostly) place for charging batteries of either type but the greater range of cars using li-iron batteries means that the infrastructure can serve more vehicles more easily.

The next generations of EVs will see the beginning of the end for ICE – the roar of a Ferrari will in time seem as strange as the hiss and crackle spoiling the music on a long-wave radio.

Key Points

1. The widespread adoption of Lithium-ion batteries has caused its own demise as the preferred rechargeable power source, as its key supplemental metal, Cobalt, is not found in sufficient quantities for these batteries to be produced at a sensible price, given the high present and likely future demand.

2. The Lithium Iron alternative is cheaper and, in the specific setting of vehicle applications, can be more effective than its higher charge bearer rival.

3. The market for Lithium Iron batteries is becoming much more competitive and the future for consumers of the technology looks good.

4. Widespread adoption of the improved Li-Iron batteries will significantly support the growth of electric vehicles worldwide

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