Q2 2019 | Pulse
Battery Energy Storage

FutureBridge

WHAT'S INSIDE!

European carmakers and governments accelerated their shift to electrification in Q2'19, as demonstrated by increasing investment in battery technology.

In Q2'19, we saw strong focus on battery recycling as well as players continuing to invest to shrink the timelines for the commercialization of solid-state batteries.

As part of our continuous product enhancement, with this version of the Pulse we introduce two new sections of analysis:

- A review of breakthrough academic research; and
- Insights on the development of our Startup Tracker in this quarter

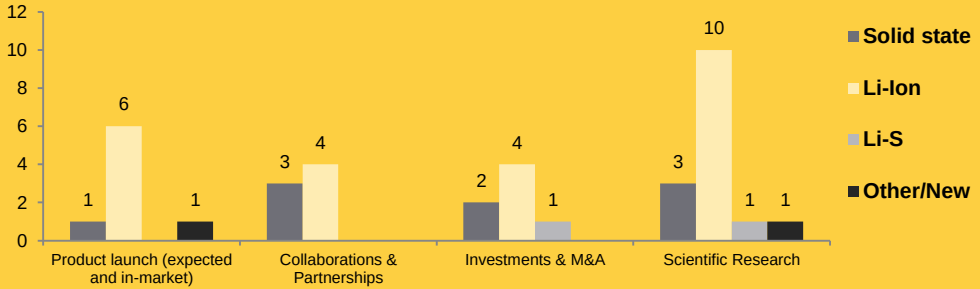
01 **Pulse themes**
a. 3 reasons why recycling of used EV batteries is gaining traction
b. Commercialization of Solid-State batteries is gaining momentum
c. Technological advancements and collaborative activities in BES in Q2'19

02 **Quarterly review of early-stage research** NEW
a. Academic review
b. IP & Patent, technology and activity of key player in battery domain

03 **Startup Tracker highlights** NEW
a. Summary statistics & commentary
b. Investment & Funding

Key developments in Battery Energy Storage in Q2'19

*(*Source: FutureBridge Development Tracker)*



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01 Emerging trends

3 reasons why recycling of used EV batteries is gaining traction

CONTEXT

As the automotive sector is shifting towards electrification at a high rate, the number of batteries to power an EV is also increasing. The batteries are being produced at an enormous rate but there has been very little effort to recycle and re-use the "used" batteries.

Keeping in view the hazardous effects of left out or used batteries, OEMs/suppliers and even startups are now putting more and more efforts to "recycle" the batteries.

We see 3 main reasons why battery recycling is gaining traction:

1. **Because of the commercialization of Li-Ion, major players are now looking at a sustainable product lifecycle**
2. **Moreover, raw materials can be re-used in the manufacturing process of new batteries**
3. **The overall process can reduce carbon footprint for the companies involved in this procedure.**

Developments

- **Volkswagen** is setting up pilot plant for Lithium-ion battery recycling at Salzgitter factory in Germany. Recycled batteries can actually serve as valuable sources of raw materials which could return to the manufacturing process chain.
- U.S. Department of Energy (**DOE**) launches its first lithium-ion battery recycling R&D center: *''ReCell will help expedite the pursuit to profitable lithium-ion battery recycling", according to Jeff Spangenberger, director of the ReCell Center.*
- **Volkswagen** and Swedish battery maker **Northvolt** partner for research on raw materials, cell technology and recycling of used batteries. The companies are accelerating their investments as part of the *European Battery Union* starting in 2020.
- **Tesla** launches battery recycling at Nevada Gigafactory.
- **Volkswagen** teams up with **Ganfeng Lithium** for battery supply and recycling.

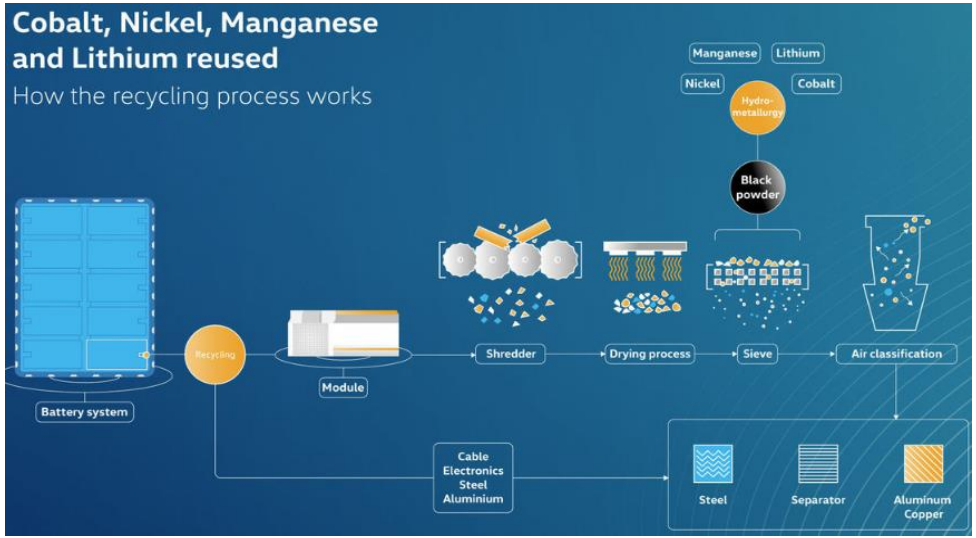
Researchers are continuously working on more novel solutions aimed at completely redesigning the battery recycling process. Fortum, University of California San Diego (UC San Diego) and Worcester Polytechnic Institute (WPI) have provided methods for improving the recycling methods.

Car makers as well as battery research firms across the globe are making investments to set up facilities for recycling. This is because the cost associated with the process and the infrastructure required for actual procurement, have not yet proved economical.

FutureBridge Insight & What should you investigate ?

FutureBridge on recycling of used EV batteries

- Various governments are framing regulations to push EV battery recycling. For instance, the UK has put in place a regulation that mandates battery makers to finance and initiate collection, treatment and recycling of electric batteries. This has kickstarted a number of partnerships between battery producers and car manufacturers. One example is Umicore's collaboration with Toyota and Tesla.
- Electric car batteries are far more complex than their conventional lead acid counterparts, containing different potential combinations of metals alongside lithium including cobalt, manganese, nickel and aluminum which means recycling plants are currently ill-equipped to handle them.
- Recycling processes for electric vehicle batteries are going to challenge the recycling industry in the years to come. Hence legislation and recycling technology will take time to catch as the number of EVs is eventually going to increase in the future with electrification reaching wider market adoption.
- To learn more about recent research publications and player activities in EV battery recycling read our upcoming H1 2019 – Deep Dive.



Source: Volkswagen

What should you investigate ?

What are the various challenges for recycling of batteries that need to be addressed?

What are the steps taken by governing bodies to ensure recycling becomes an important parameter in electric mobility?

In this process, the individual battery parts will first be shredded, then the material will be dried and sieved, allowing the employees to extract the so-called "**black powder**." This contains the valuable raw materials of **cobalt, lithium, manganese,** and **nickel**. These materials then just have to be separated individually, after which they are available again for the production of new batteries.

Commercialization of Solid-State batteries is gaining momentum

CONTEXT

Today, solid-state battery cell technology is seen as the most promising approach for future e-mobility. This battery technology has advantages over the present current lithium-ion technology:

- **higher energy density,**
- **enhanced safety,**
- **better fast charging capability,**
- **and above all they take up significantly less space.**

Hence the commercialization of solid-state batteries holds strong potential for automotive industry to replace the conventional lithium ion battery.

Launches

- **Ford** Motor Company is teaming up with **Solid Power** to develop all solid-state batteries (ASSB) for next-generation electric vehicles.
- Chinese start-up **Enovate** has formed a strategic cooperation agreement with battery maker **ProLogium** at the Auto Shanghai 2019. As a part of the deal ProLogium will help commercialise Enovate's solid state battery technology.
- **Toyota** pulls forward electrification plan, eyes solid-state battery next year (2020).
- **A123** and **Ionic Materials** have developed an innovative and industry first approach to an All Solid State Battery (ASSB) that will accelerate the commercialization of the Solid-State battery.
- **Mercedes Benz** to supply 56 electric buses to Wiesbaden with by solid-state batteries.

DEVELOPMENTS Emerging trend

- OEMs, suppliers and startups are collaborating with each other for the development of All Solid-State Batteries (ASSB).One such prime example is collaboration of VW with QuantumScape
- Researchers are working continuously to develop an efficient, safe and high energy density solid state battery which can accelerate the process of commercialization of All Solid State Batteries (ASSB) .

FutureBridge Insight & What should you investigate ?

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FutureBridge Insight on Solid-State battery

- Over the last several years, numerous players have made announcements regarding the readiness of prototype solid state batteries and expected market introduction, only to see these ultimately be cancelled or postponed. And despite decades of development, many technology challenges remain unsolved. The biggest challenge for solid-state batteries is getting their prices down to where they can compete with the incumbent technology.
- However, over the last 6-12 months, there has been significant increase in R&D activities among key OEMs such as Toyota, BMW, Volkswagen, Hyundai etc., to implement solid state batteries in vehicles .
- A difficulty impeding the rapid adoption of solid-state batteries is that they are hard to analyze because the components of a solid-state battery adhere so tightly to one another.
- The simplification of battery-pack design and its components will improve the solid-state battery's cost-competitiveness compared to conventional Li-ion batteries.

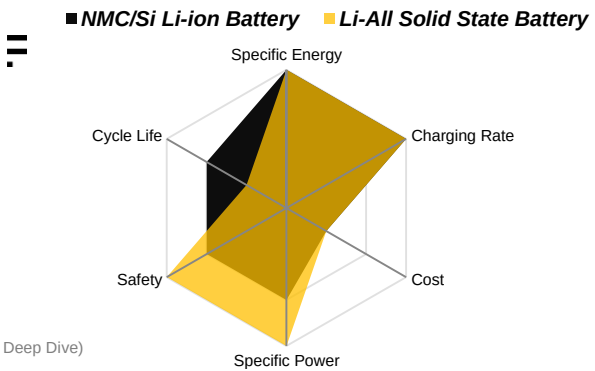
What should you investigate ?

Where is the major drive for solid-state batteries to be used in place of conventional Li-Ion battery?

What steps must be taken to accelerate the process of commercialization of solid-state batteries?

Key Developments in solid state batteries

- **Solid Power** closes $20M in Series A ; Hyundai, Samsung, A123 among investors
- **Volkswagen Group** closes $100M **QuantumScape** investment
- **Toyota** and **Panasonic** form JV to make solid state EV Batteries
- **Blackstone Resources** to build world-class solid-state battery
- **Ion Storage Systems** raises $8M for solid state battery development



*(Excerpt from H2-2018 Deep Dive)

Major developments during Q2'19 – Lithium-Ion battery featuring in almost all the new launches

NEW

Investments/Funding

- Volkswagen invests €900 million in Northvolt AB for battery activities >>
- European Investment Bank invests €350 million in Northvolt's battery gigafactory >>
- Bangchak Invests in Enevate's Fast-Charging EV Battery Technology >>
- USABC awards $4.8M to Zenlabs Energy to develop low-cost, fast-charge EV batteries >>

Launches

- EQC SUV powered by lithium ion battery >>
- Electric urban buses powered by lithium ion and solid state batteries >>
- First all-electric car with lithium-ion battery pack >>
- Hyundai Kona with lithium ion battery >>
- Launches limited edition Rapide E powered by lithium ion battery >>

Technology advancements

- New functional electrolytes expand the temperature range of lithium-ion batteries >>
- Doubles energy density of solid state battery >>
- Semi-liquid metal anode >>
- New Li-metal battery for EVs >>
- New 49.5Ah (3.61V) lithium-ion battery >>
- High performance solid-state sodium-ion battery >>

Collaborations/Partnership

- Develop solid-state batteries >>
- To add battery packs to its propulsion portfolio >>
- Make Lithium battery packs for EVs >>
- 2nd life applications for used EV batteries>>

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02 Quarterly review of early-stage research

New lithium ion battery for EV that outperforms LMBs reported in the literature till date

(May 2019, **Jang-Yeon Hwang,** Department of Energy Engineering, Hanyang University**, Seong-Jin Park,** Department of Energy Engineering, Hanyang University**, , Chong S*. Yoon*b,** Department of Materials Science and Engineering, Hanyang University **and Yang-Kook Sun*,** Department of Materials Science and Engineering, Hanyang University)

Background

As an alternative for the current commercial LIBs, rechargeable batteries using lithium metal as an anode were suggested for future high-energy-density batteries for EVs.

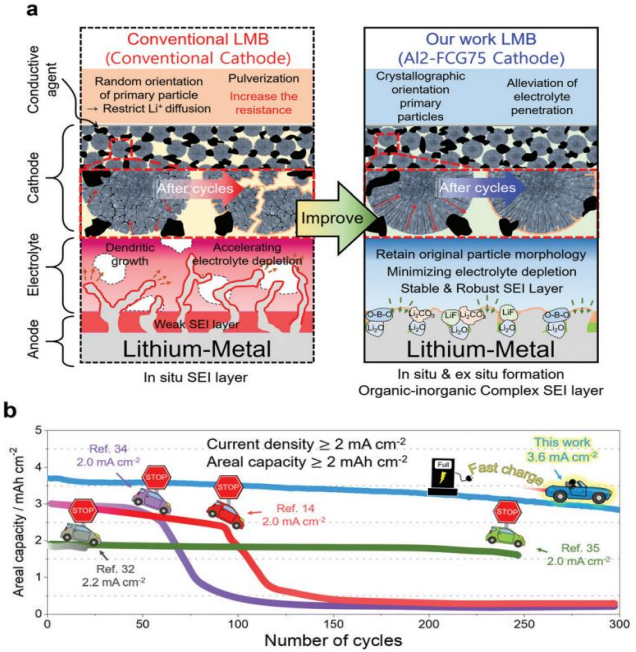
- This is largely because of the li–metal anode's exceptionally high specific capacity (**3860 mA h g1**) compared to that (**372 mA h g1**) of the conventional graphite-based LiC6 anode;
- faster reaction kinetics stemming from a low redox potential (3.004 V vs. standard hydrogen electrode) and
- high electronic conductivity of Li are also potentially favorable for reducing the charging time.

However, the practical application of LMBs has been proven difficult owing to the inferior cycling stability and safety hazard of Li Metal.

Invention

A Li/NCM battery that enables fast charging and extends the driving range of an EV is proposed. To mitigate the Li instability, formation of a robust and stable SEI layer is enabled by first pre-treating the Li metal with LiNO3 and using an electrolyte consisting of 1 M LiPF6 and 0.05 M lithium difluoro(oxalate)borate (LiDFOB) dissolved in a mixture of ethyl methyl carbonate (EMC) and fluoroethylene carbonate (FEC).

An Al-doped full-concentration-gradient Li [Ni0.75Co0.10Mn0.15] O2 cathode provides the necessary cycling stability at a high cathode loading. By integrating these components, a new LMB was formed that survives practical operating conditions for electric vehicle applications.



a) Comparison of conventional LMB with proposed LMB concept

b) Comparison of the cyclability of the proposed LMB with previously reported cyclability values under practical test conditions (current density: ≥2 mA cm2 and capacity loading: ≥ 2 mA h cm2).

Limitations of till date LMBs

- Li dendrite growth induces poor cycling efficiency at fast charging rates and at high active material loadings, hindering the application of LMBs in EVs.
- Fast charging aggravates the parasitic reactions between the Li–metal anode and electrolyte.

Advantages of invention

- The Al-doped full-concentration-gradient Li[Ni0.75Co0.10Mn0.15]O2 cathode (Al2-FCG75) provided the necessary cycling stability at a high loading level.
- LMB that allowed a high areal capacity of **4.1 mA h cm2.**
- An unprecedented cycling stability over **300** cycles at a high current density of **3.6 mA cm2** .
- The scaled-up pouch-type cell assembled by these components represents excellent practical applicability, with an outstanding cycle retention of **90%** over **500** cycles.

Key Player in Battery Energy Storage – 24M Technologies

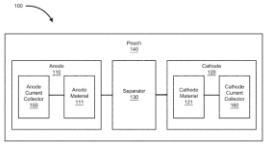
NEW

PATENTS

US10181587B2

Single pouch battery cells and methods of manufacture

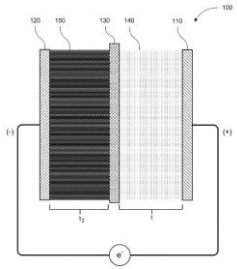
Patent relates to the preparation of battery cells and more particularly to systems and methods of preparing and using single pouch battery cells in a battery module.



US10122044B2

Semi-solid electrodes with gel polymer additive

Patent discloses electrochemical cells having semi-solid electrodes that include a gel polymer additive such that the electrodes demonstrate longer cycle life while significantly retaining the electronic performance of the electrodes and the electrochemical cells formed therefrom.



US10115970B2

Semi-solid electrodes with porous current collectors and methods of manufacture

Patent discloses a semi-solid electrode includes a first porous substrate and a second porous substrate stacked together to form a current collector, and a semi-solid electrode material embedded in the current collector.

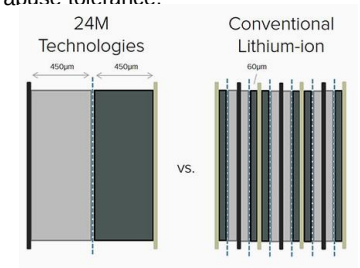
TECHNOLOGY

- **Lithium-Ion battery:**

➢ Advanced cell and manufacturing platform provides higher energy enabled by the lowest inactive materials content in the industry, outstanding cycle life and calendar life for grid or EV applications, and unprecedented safety and abuse tolerance.

➢ **More Efficient Cell Design:**

- Materials design enables up to 5x the area capacity of standard Li-ion.
- Flexible cell format (EV, Large or small Grid).
- High abuse tolerance.



➢ **Applications:**

➢ Li-ion cells tuned through chemistry and design have a wide range of applications such as Grid class and Custom designs and Electric vehicles.

ACTIVITIES

Investment/Acquisition/Funding

- Funding
  - Dec, 2018 | $21.8M / Series D | ITOCHU Corporation, Kyocera Corporation
  - Aug, 2010 | $16M / Series A | CRV, North Bridge Venture Partners & Growth Equity

Collaboration/Partnership

- 24M partner Kyocera to validate plans to validate the novel 24M SemiSolid manufacturing platform.

Competitors

ENERDEL A123 SYSTEMS XALT Energy

News

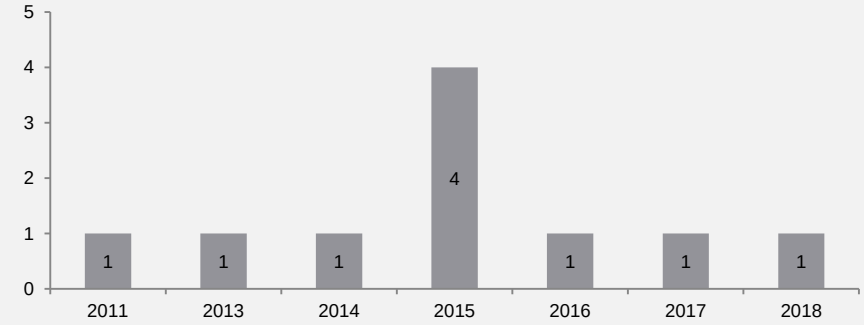
- 24M delivers first commercial scale, high energy density semi-solid lithium-ion batteries
- 24M delivers 40 grid-scale battery cells to GPSC for module build, application validation.

03 Startups Tracker highlights in Q2’19

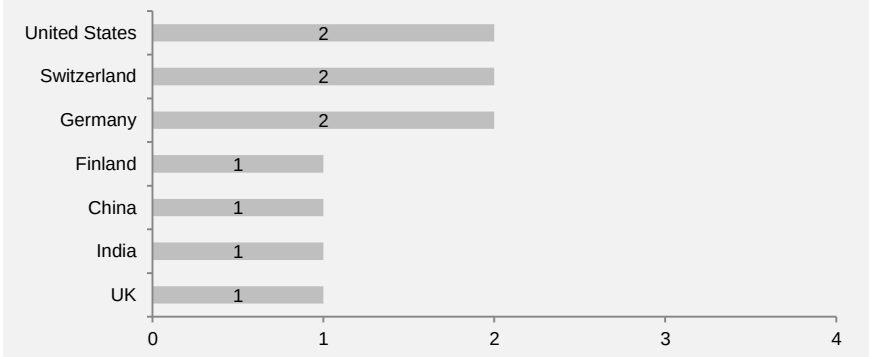
Startup Tracker summary

Segmentation of major startups active during Q2 2019 with major focus on Lithium ion battery

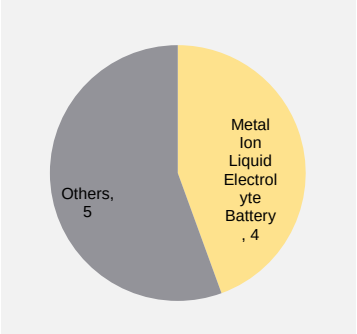
Startups by founding year



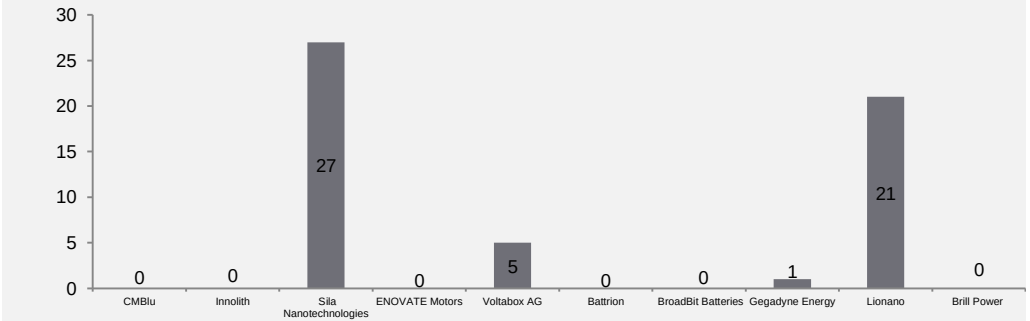
Startups by geography for the 10 new startups we've included in Q2'19



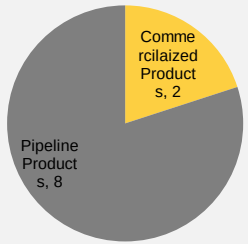
Startups by technology



Total Patents filled by the 10 new startups we've included in Q2'19



Startups with Commercialized and Pipeline products



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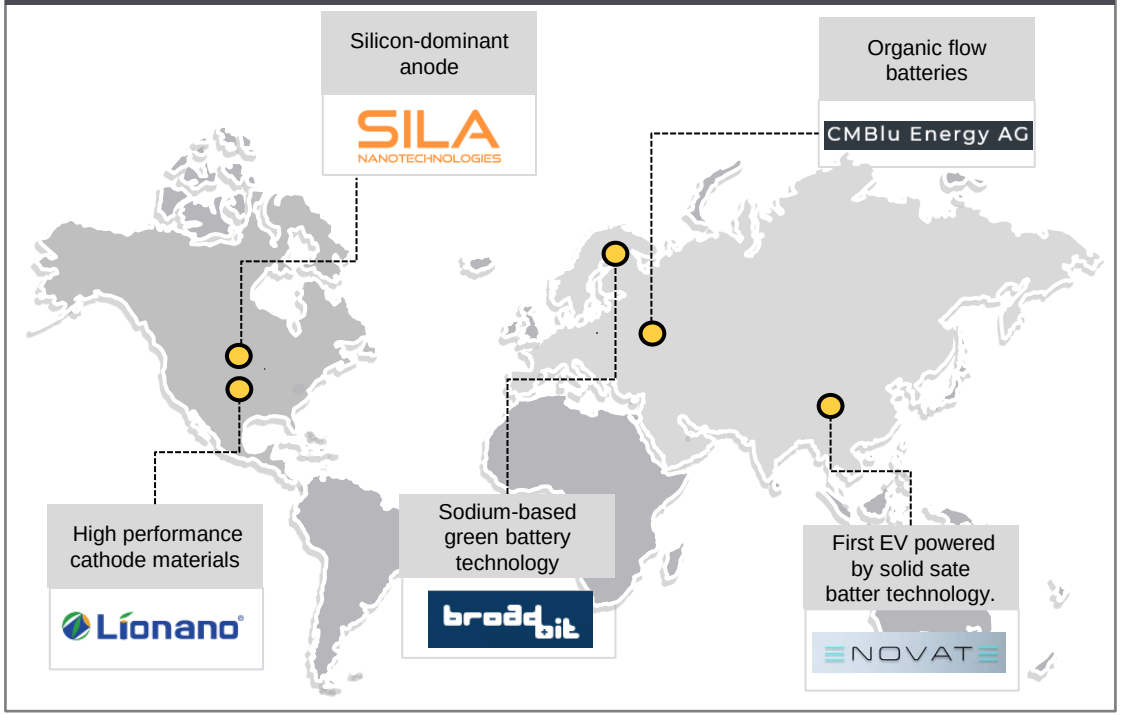
What are the hubs of startup innovation for Battery Energy Storage

Europe leads among regional hubs while Other battery technologies and components are key areas of research focus

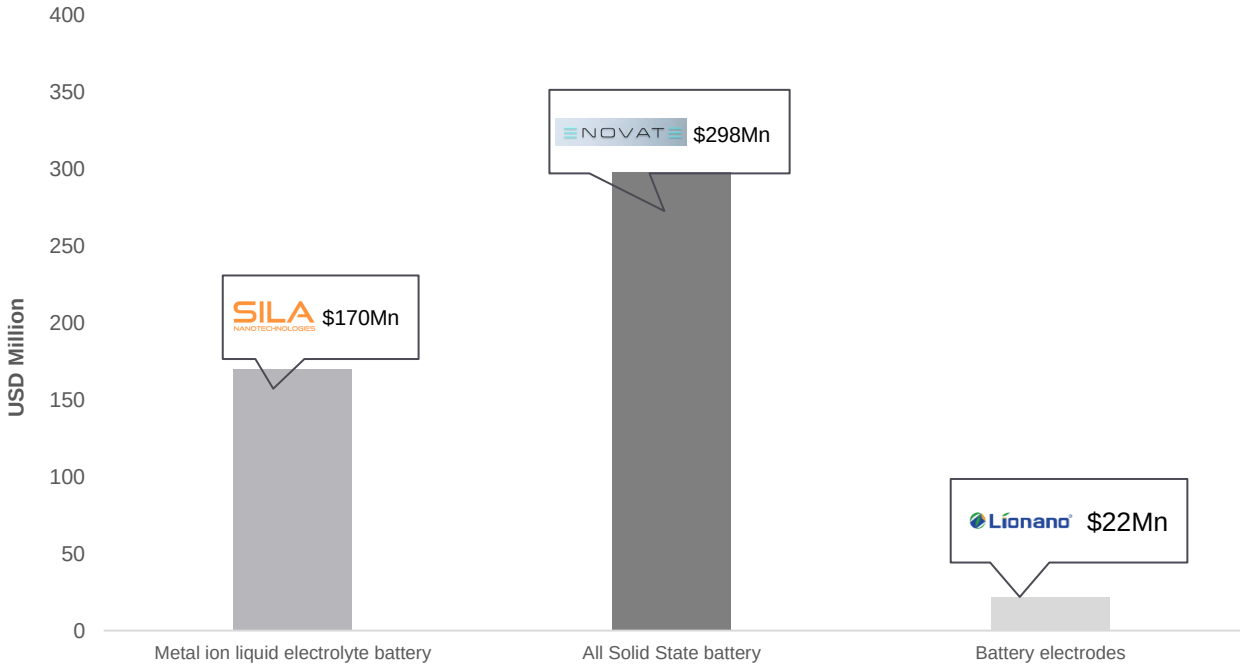
- Out of the **10** new startups we have included in our Tracker in **Q2 2019**, almost 44% focus on Metal-ion batteries
- Almost 56% are working on Other battery technologies and components such as(Organic flow batteries, inorganic electrolyte, innovative cathodes etc.)
- 60% of them are based in **Europe**(Germany, Finland, UK and Switzerland) whereas 20% are based in **Asia**(India and China) and USA
- Sila Nano raises $170M from Daimler partnership for developing next generation lithium-ion battery materials
- Enovate teams with ProLogium to work together on the commercialization of solid-state batteries

Key startups from major hubs in automotive Battery Energy Storage



Funding distribution & activities

Lithium-Ion battery and Solid State battery remain prime area of funding



- 3 out of the 10 new startups we have included in our Tracker in **Q2 2019** received funding
- OEMs are investing in traditional Metal –ion battery for advancements and Suppliers are working with startups towards alternates for Li-Ion battery
- Battery electrode(cathode and anodes) also have caught the attention of investors attracting a good amount of funding

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