



# Battery Energy Storage Technologies Manufacturing and Supply Chain Overview

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# Rechargeable Battery Energy Storage Technologies



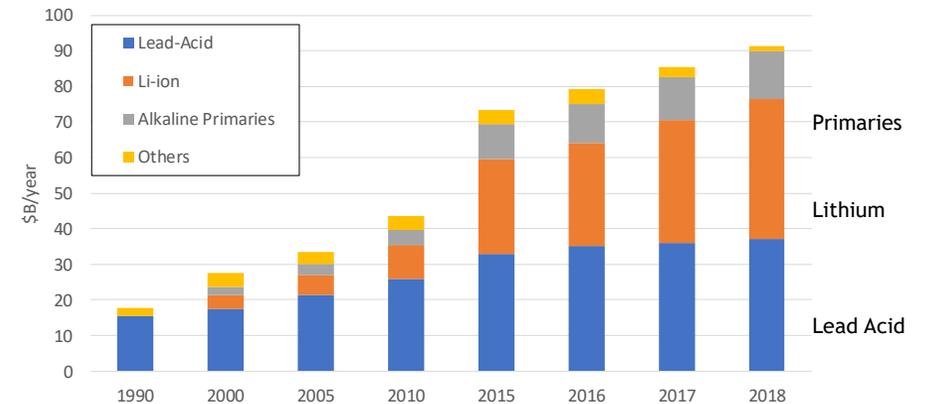
## End Markets for Battery Energy Storage

- Consumer electronics, Mobile devices, and Electric Vehicles – Lithium batteries
- Automotive batteries, fork lift, traction (mostly Lead Acid)
- Stationary energy storage – Backup Power (mostly Lead Acid), Grid Energy Storage - range of technologies

### Battery Technologies

- Traditional Batteries
  - Lead acid, Nickel Cadmium, Nickel Metal Hydride
  - Zinc-batteries
- Lithium Batteries
  - Lithium-ion, Lithium-polymer, Lithium-sulfur
- High-Temperature Batteries
  - Sodium Sulfur
- Flow Batteries
- New emerging technologies
  - Solid state batteries

## Annual Sales of Batteries



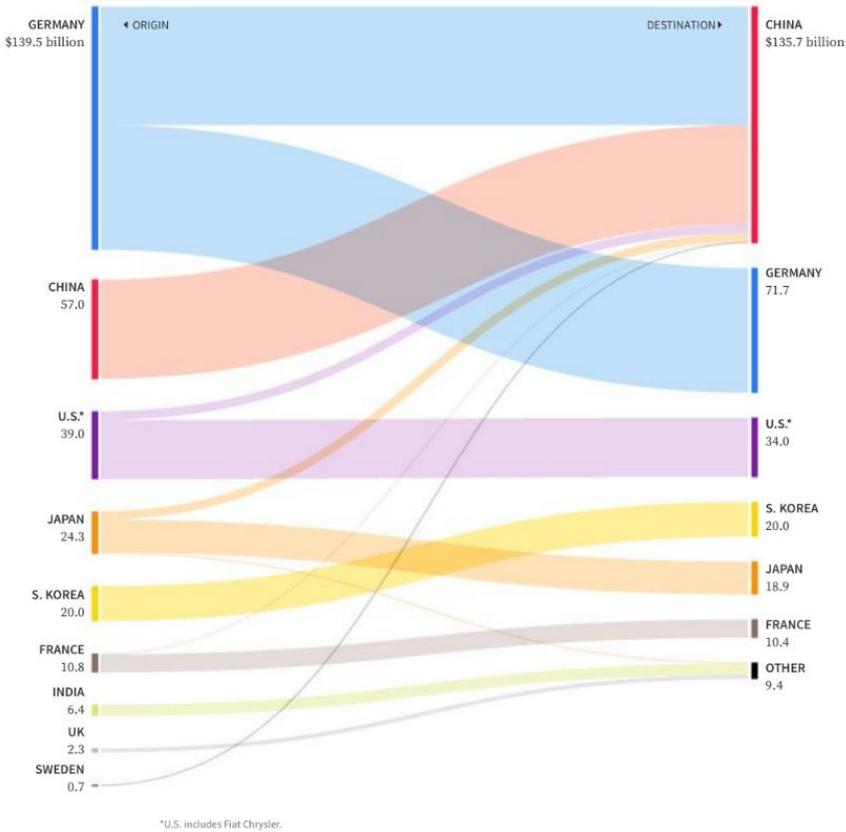
Sources: S. Banerjee, CUNY Energy Institute (2020); C. Pillot, Avicenne Energy (2020), and other industry sources

- Lead-Acid: 350 GWh production capacity, ~\$40B/year
- Li-ion: over 500 GWh in 2020 and growing capacity, reaching \$100B/year in revenues
- Primary cells: \$13B/year

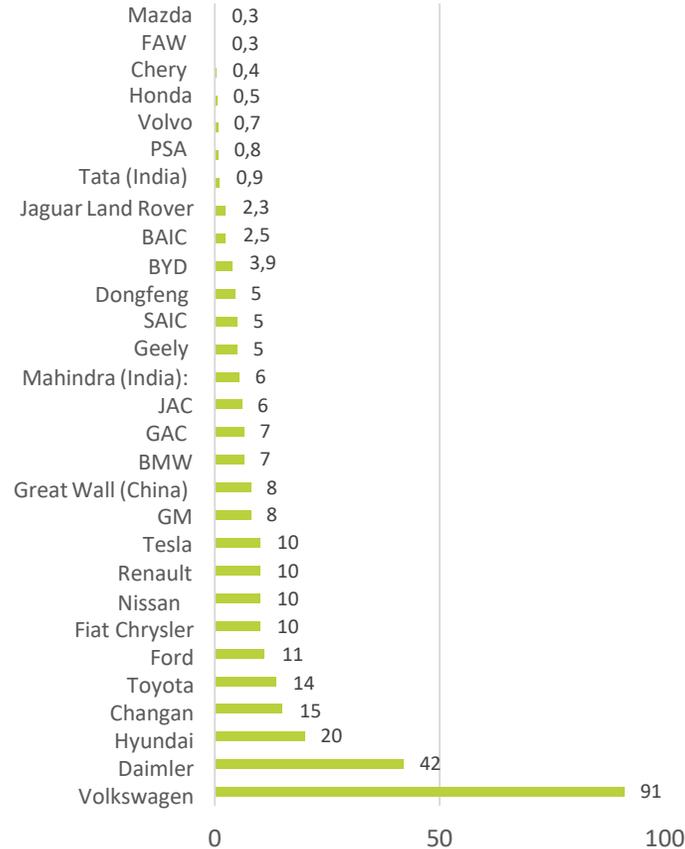
# EV Market Driving Growth in Lithium Battery Manufacturing



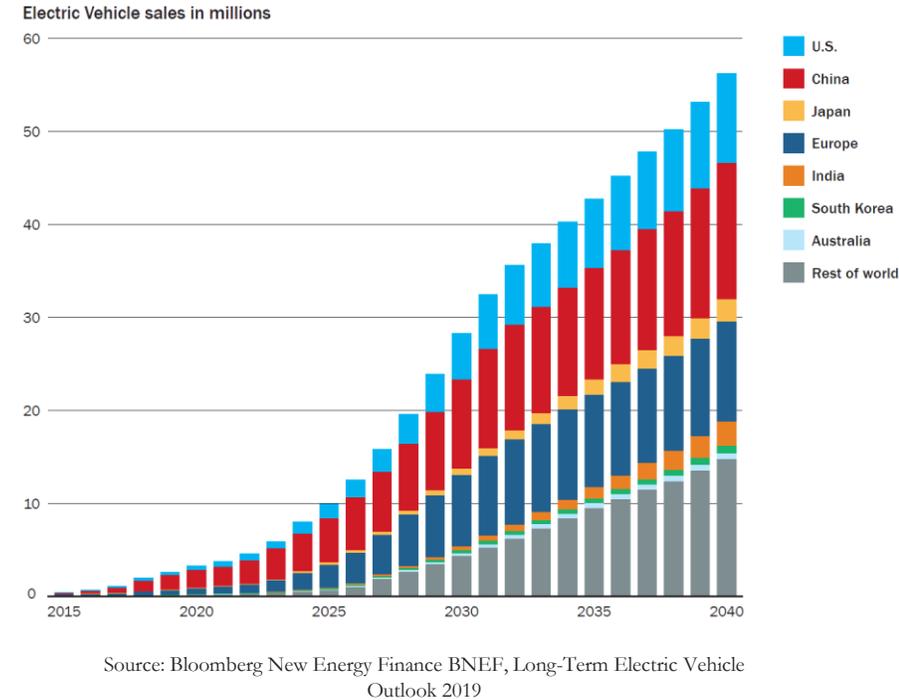
## EV Investment Flows by Country of Origin of Automaker (in billions of dollars)



## Announced EV Investments by Global Automakers



## Annual Sales of Battery Electric Vehicles and Plug-in Hybrid Electric Vehicles



Reuters analysis of 29 global automakers. \$300 billion in electric vehicles, with more than 45 percent of that earmarked for China.

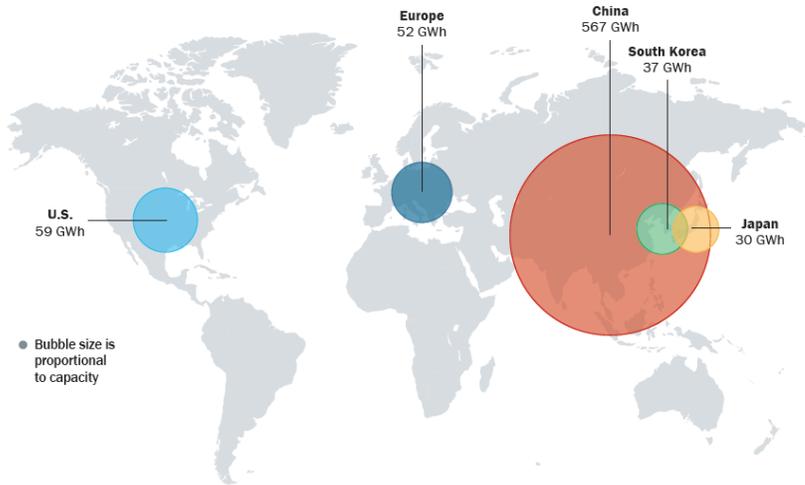
By Paul Lienert and Christine Chan, Published Jan. 10, 2019 | Updated April 4, 2019

<https://graphics.reuters.com/AUTOS-INVESTMENT-ELECTRIC/010081ZB3HD/index.html>

# 4 Lithium Batteries for EV is Driving Global Growth

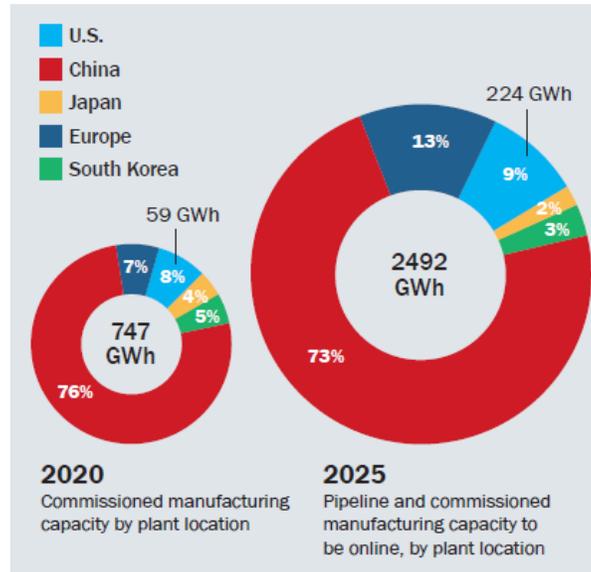


## Cell Manufacturing Capacity by Country or Region in 2021



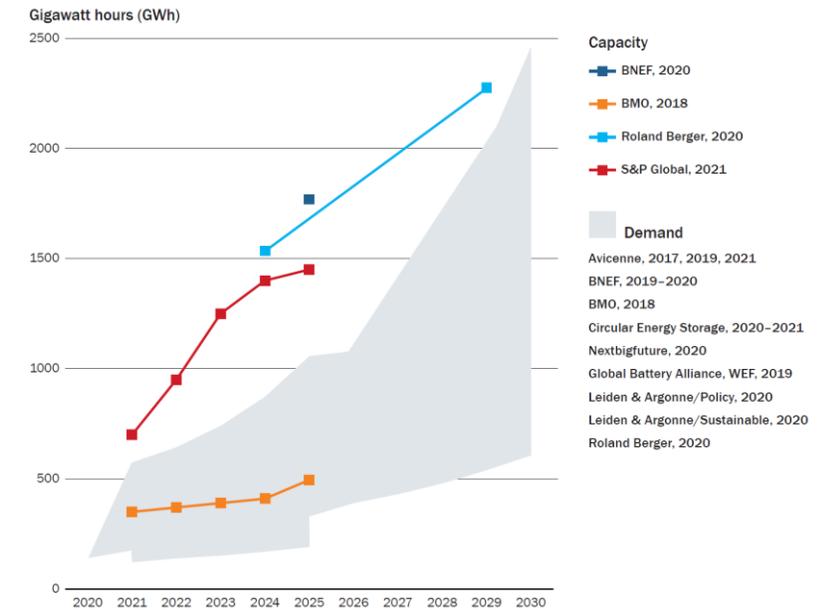
(Source: *Lithium-Ion Battery Megafactory Assessment*, Benchmark Mineral Intelligence, March 2021)

## Cell Manufacturing Capacities by Countries and Regions



(Source: "Lithium-Ion Battery Megafactory Assessment" Benchmark Mineral Intelligence, March 2021).

## Global Lithium-ion EV Battery Demand Projections



(Source: Y. Zhou Y, D. Gohlke, L. Rush, J. Kelly, Q. Dai, *Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States: 2010-2020*. Argonne National Laboratory, 2021; ANL/ESD-21/3.

# Planned New Battery Manufacturing Facilities



**Global lithium-ion battery capacity by region**  
(Gigawatt hours)

|               |                | 2018       | 2019       | 2020       | 2021       | 2022       | 2023         | 2024         | 2025         |
|---------------|----------------|------------|------------|------------|------------|------------|--------------|--------------|--------------|
| Australasia   | Australia      | 0          | 0          | 0          | 1          | 1          | 1            | 4            | 7            |
| Asia          | China          | 260        | 268        | 350        | 558        | 718        | 884          | 944          | 944          |
| Asia          | Indonesia      | 0          | 0          | 0          | 0          | 0          | 0            | 0            | 0            |
| Asia          | Japan          | 17         | 17         | 17         | 17         | 17         | 17           | 17           | 17           |
| Asia          | South Korea    | 11         | 18         | 18         | 18         | 18         | 18           | 18           | 18           |
| Asia          | Thailand       | 0          | 0          | 0          | 1          | 1          | 1            | 2            | 2            |
| Europe        | Czech Republic | 0          | 0          | 0          | 1          | 1          | 1            | 1            | 1            |
| Europe        | France         | 0          | 0          | 0          | 0          | 0          | 20           | 32           | 32           |
| Europe        | Germany        | 0          | 0          | 0          | 11         | 52         | 83           | 128          | 164          |
| Europe        | Hungary        | 3          | 14         | 20         | 28         | 37         | 47           | 47           | 47           |
| Europe        | Poland         | 6          | 6          | 6          | 22         | 54         | 70           | 70           | 70           |
| Europe        | Slovakia       | 0          | 0          | 0          | 0          | 0          | 0            | 5            | 10           |
| Europe        | Sweden         | 0          | 0          | 0          | 4          | 14         | 23           | 32           | 32           |
| Europe        | UK             | 2          | 2          | 2          | 2          | 2          | 5            | 12           | 12           |
| North America | US             | 27         | 37         | 42         | 44         | 51         | 76           | 91           | 91           |
| <b>Total</b>  |                | <b>325</b> | <b>362</b> | <b>455</b> | <b>706</b> | <b>966</b> | <b>1,246</b> | <b>1,403</b> | <b>1,447</b> |

Data as of Feb. 1, 2021.

Sources: S&P Global Market Intelligence; Company announcements

**US lithium-ion battery capacity**  
(Gigawatt hours)

|                 | 2018      | 2019      | 2020      | 2021      | 2022      | 2023      | 2024      | 2025      |
|-----------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Tesla           | 20        | 30        | 35        | 37        | 39        | 39        | 39        | 39        |
| LG Chem         | 5         | 5         | 5         | 5         | 5         | 20        | 35        | 35        |
| SK Innovation   | 0         | 0         | 0         | 0         | 5         | 15        | 15        | 15        |
| Envision AESC   | 1         | 1         | 1         | 1         | 1         | 1         | 1         | 1         |
| IM3             | 0         | 0         | 0         | 0         | 1         | 1         | 1         | 1         |
| A123 Systems    | 1         | 1         | 1         | 1         | 1         | 1         | 1         | 1         |
| <b>Total US</b> | <b>27</b> | <b>37</b> | <b>42</b> | <b>44</b> | <b>51</b> | <b>76</b> | <b>91</b> | <b>91</b> |

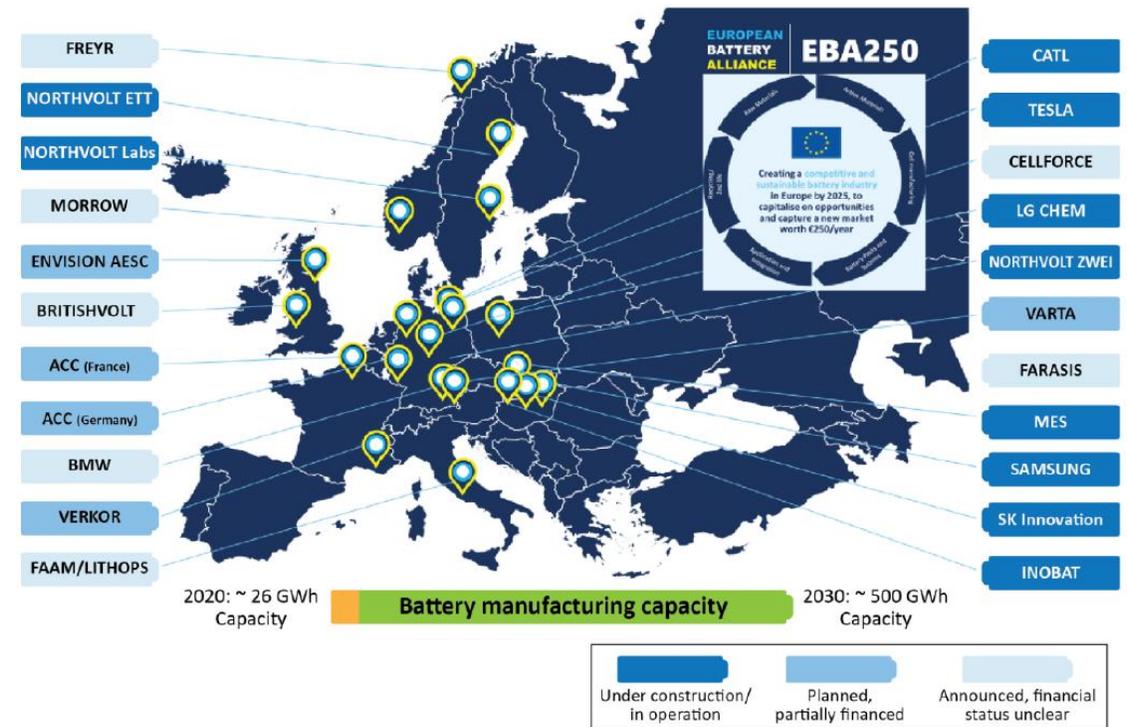
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Sources: S&P Global Market Intelligence; Company announcements

Source: S&P Global Market Intelligence blog: Top electric vehicle markets dominate lithium-ion battery capacity growth, <https://www.spglobal.com/marketintelligence/en/news-insights/> (accessed, Sept 12, 2021)

## EBA250 Project

### \$7B funding for supply chain development



Source: European Battery Alliance <https://www.eba250.com/>

# Lithium Battery Supply Chain



## Lithium-Based Battery Supply Chain

### UPSTREAM

- Mining and extraction of materials including lithium, cobalt, nickel, and graphite



### MIDSTREAM

- Additional processing for battery-grade materials
- Cathode/anode powder production
- Separator production
- Electrolyte production
- Electrode and cell manufacturing



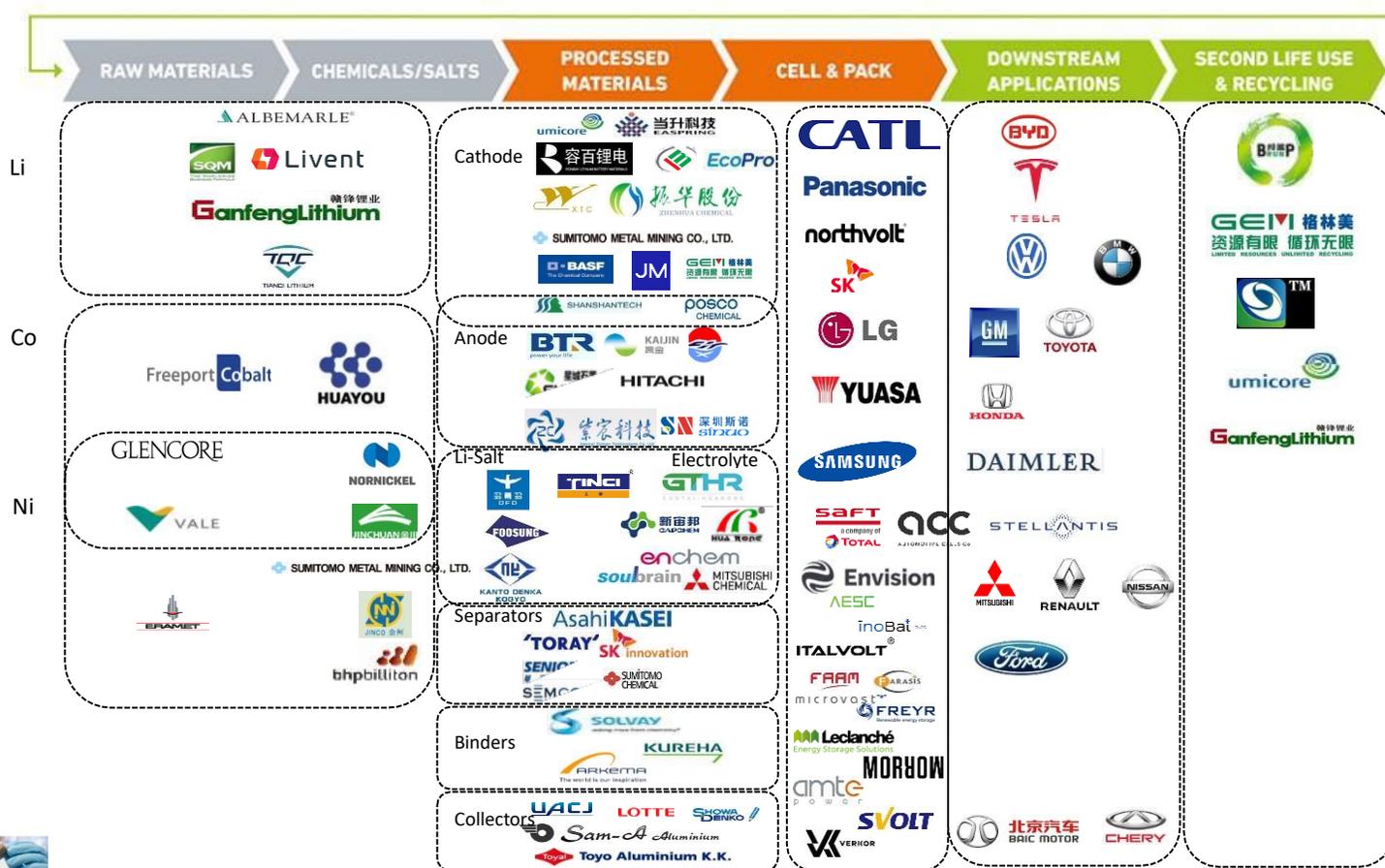
### DOWNSTREAM

- Pack manufacturing
- End-of-life recycling and reuse



Source: **National Blueprint for Lithium Batteries**, Federal Consortium for Advanced Batteries (FCAB), June 2021. DOE: [www.energy.gov/cere/vehicles/](http://www.energy.gov/cere/vehicles/) DOE/EE 2348

## Global Supply for Lithium Battery Manufacturing



Source: C. Pillot, Avicenne Energy, 2020; NAATBatt



**BATTERY MATERIALS**

Large portfolio of R&D projects related to advanced materials, new battery chemistries, electrolyte materials, and membranes.



**DEMONSTRATION PROJECTS**

Work with industry to develop, install, commission, and operate electrical energy storage systems.



**CELL & MODULE LEVEL SAFETY**

Evaluate safety and performance of electrical energy storage systems down to the module and cell level.



**STRATEGIC OUTREACH**

Maintain the ESS website and DOE Global Energy Storage Database, organize the annual Peer Review meeting, and host webinars and conferences.



**POWER CONVERSION SYSTEMS**

Research and development regarding reliability and performance of power electronics and power conversion systems.



**GRID ANALYTICS**

Analytical tools model electric grids and microgrids, perform system optimization, plan efficient utilization and optimization of DER on the grid, and understand ROI of energy storage.



**SYSTEMS ANALYSIS**

Test laboratories evaluate and optimize performance of megawatt-hour class energy storage systems in grid-tied applications.

Wide ranging R&D covering energy storage technologies with applications in the grid, transportation, and stationary storage