

Designing Better Materials for Future Batteries

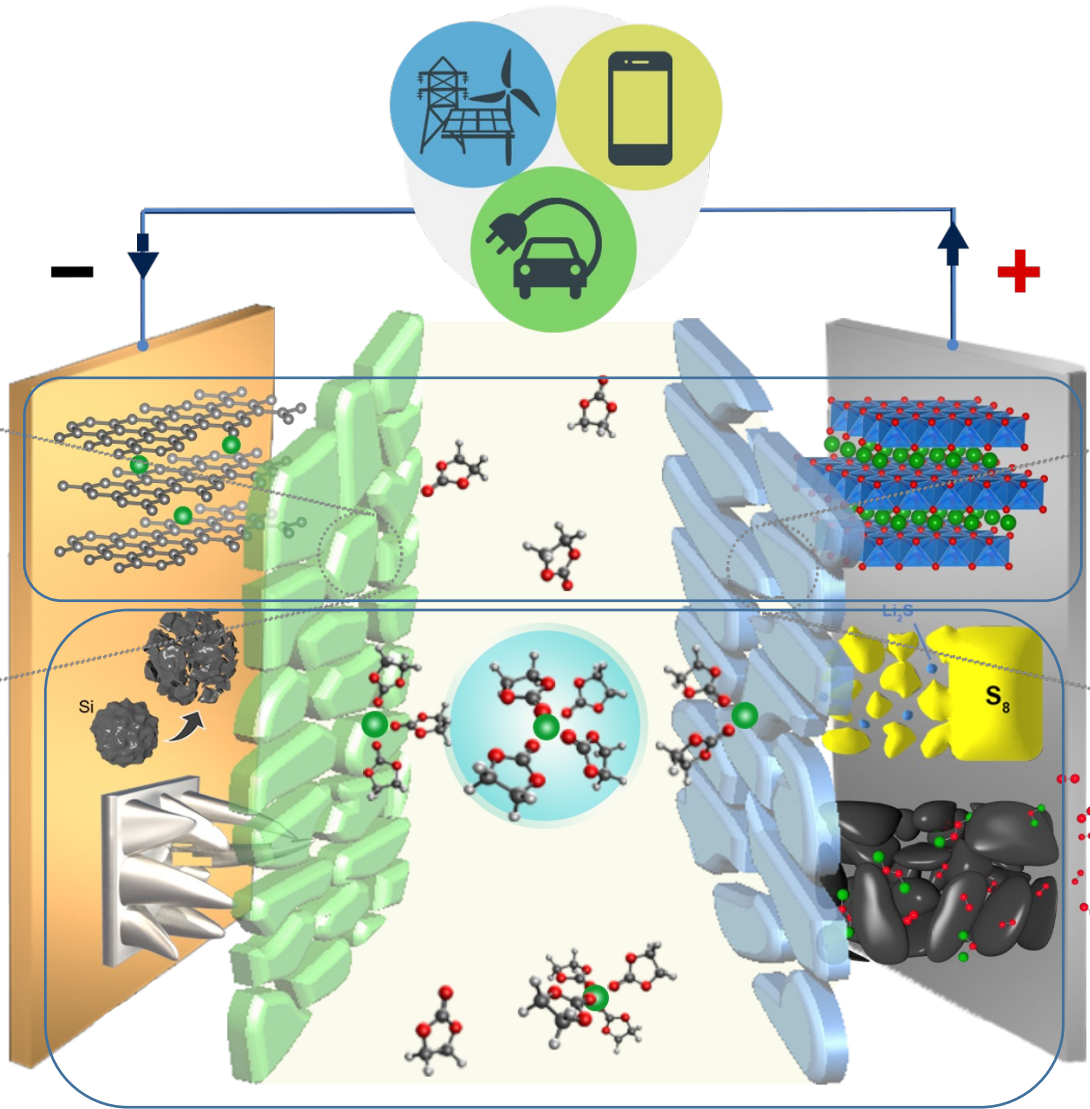
Y. Shirley Meng

Argonne Collaborative Center for Energy Storage Sciences

The University of Chicago

Lithium Ion/Metal Battery - A Complex “Living” System

Perspective – K. Xu and Y. S. Meng – 2021



Moving Ions
(Chemical Bond)

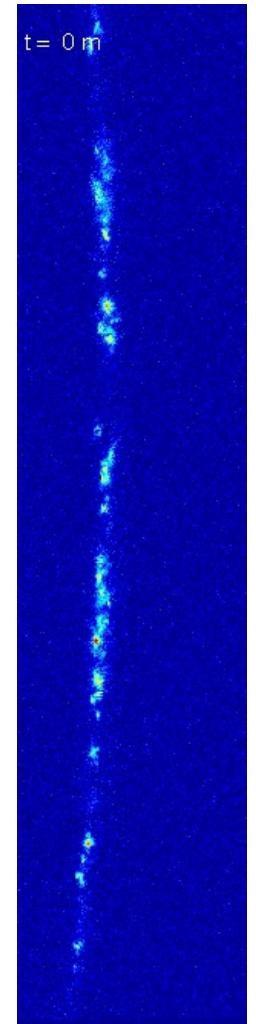
Dynamic Phenomena

Strain - Fatigue

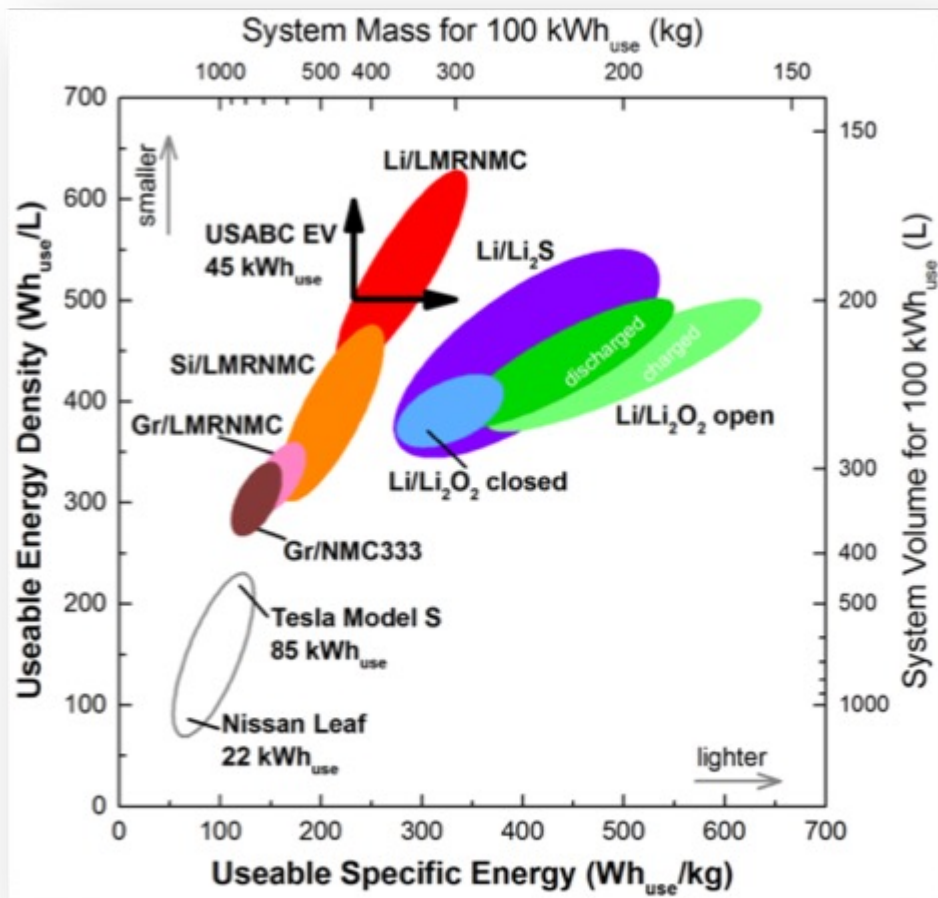
Thermodynamically Closed System 99.9% efficiency needed

SEI – Life and Safety Differentiators

Data from APS



What We have Achieved in the Last 30 Years



Courtesy of Argonne National Lab

Breakthroughs in Fundamental Materials Science and NanoEngineering

Cathode Materials: $\text{LiCoO}_2 \rightarrow \text{Li}(\text{Ni}, \text{Mn}, \text{Co})\text{O}_2 \rightarrow \text{Li Rich (Mn-Rich) Oxides}$

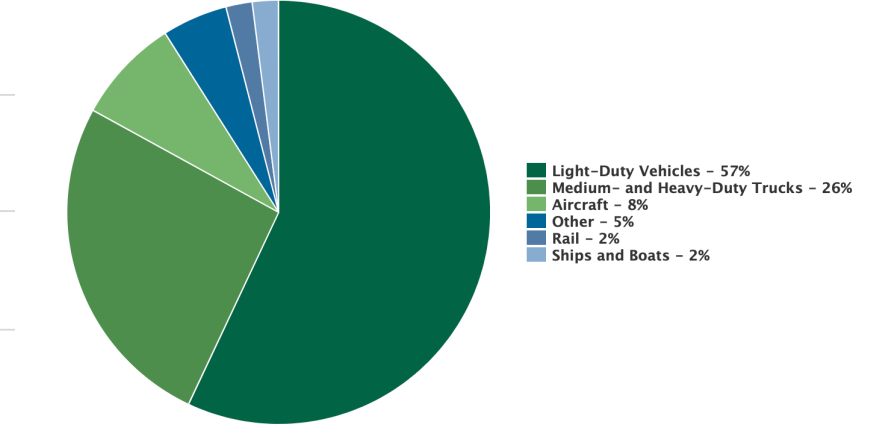
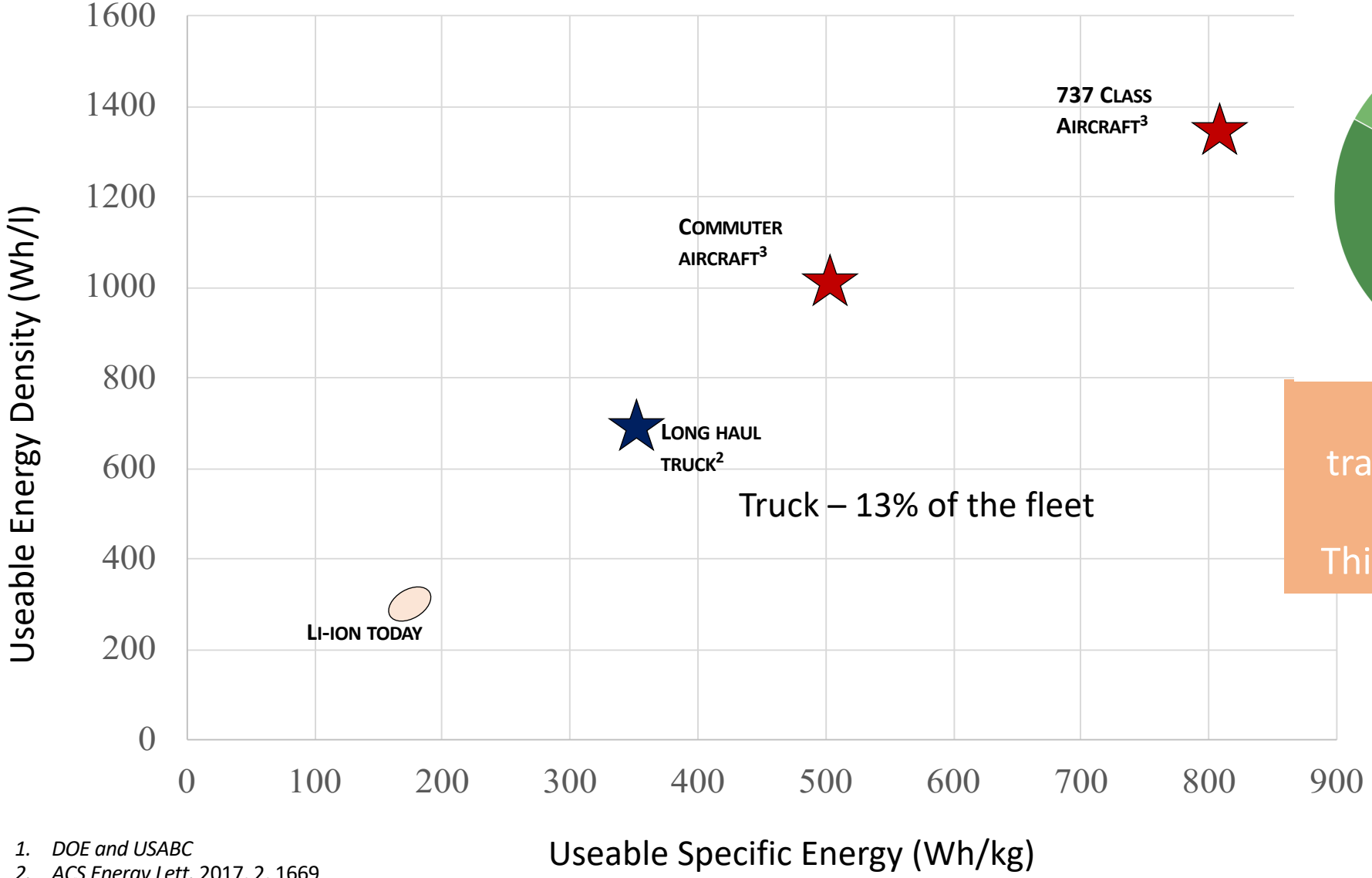
Anode Materials: Graphite \rightarrow Silicon/Carbon Composite \rightarrow Li Metal

Electrolytes Materials: Carbonates (EC, DEC, EMC) \rightarrow Highly Concentrated \rightarrow Solid State

- **Tripled the Energy Density** - 18650 Cylindrical Cell 1Ah \rightarrow 3Ah
- **Lowered the Cost 10 Times** - 2005 (2000\$/kWh) Today (<150\$/kWh)
- **Extended Cycle Life** - 300 cycles to 3000 cycles deep DOD
- **Recycling of LiB** - Happening Now!!!

Why do We Need Even Higher Energy Density

2020 U.S. Transportation Sector GHG Emissions by Source



Deep decarbonization of transportation will require dramatic increase in energy density. This will diversify the material needs



5-7 years if some of the critical barriers are removed – Li metal and/or Solid State

1. DOE and USABC
 2. ACS Energy Lett. 2017, 2, 1669
 3. DOE-NASA electric aviation workshop

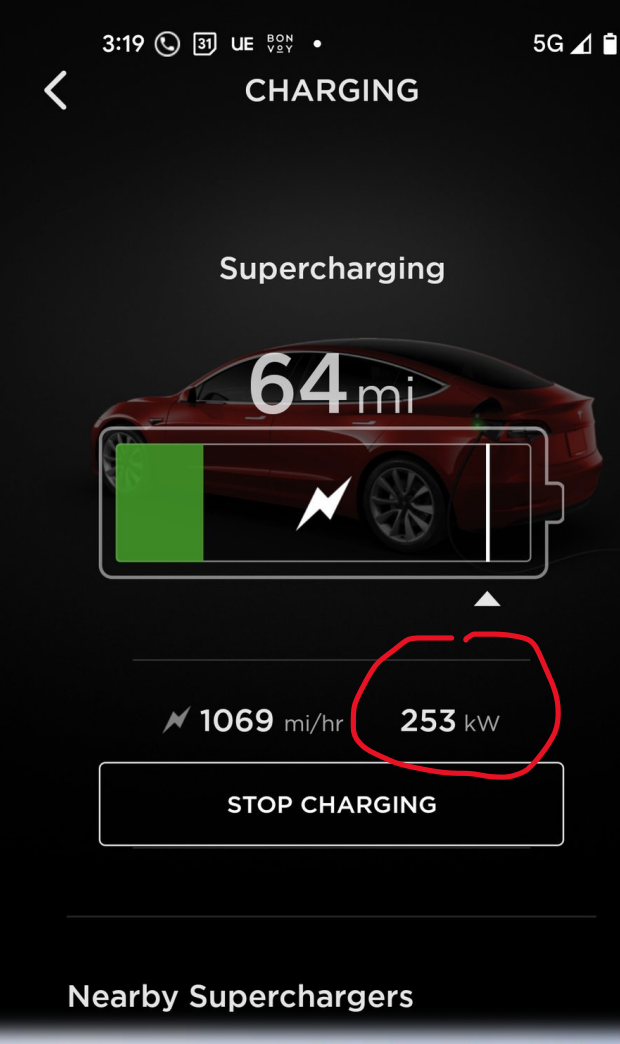
Useable Specific Energy (Wh/kg)

Why do We Need 5-min Fast Charging?



The Vivo iQOO 7 holds the title of the fastest charging phone in the world so far in 2022. The phone features **120W** fast charging speeds and its **4,000mAh** battery recharges fully from **0 to 100%** in just about **18 minutes**.

780kW is needed if we want to do 5 minutes to fully charge my 65kWh (17000Ah) Tesla Model 3 Pack



Multi-MW Charging Infrastructure Needed



“I look at decarbonization and say that’s a growth opportunity for Cummins, because now innovation is going to matter a lot.”

Tom Linebarger,
Cummins CEO and Chairman

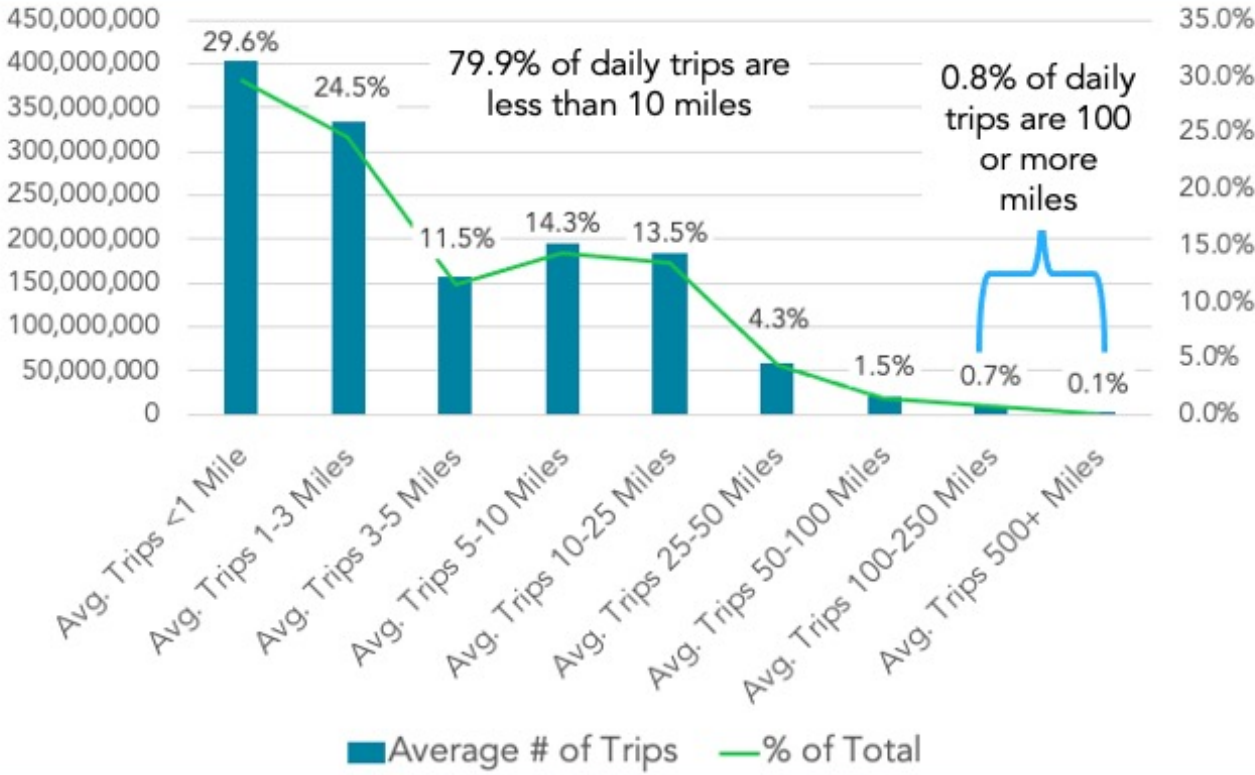


Ready now but needs actions!!!

Sodium Batteries for EV, for Stationary and More...

99.2% of US Daily Trips Are Less Than 100 Miles

Average Distance Bands of Daily Travel in the US



< 150 Miles range desired

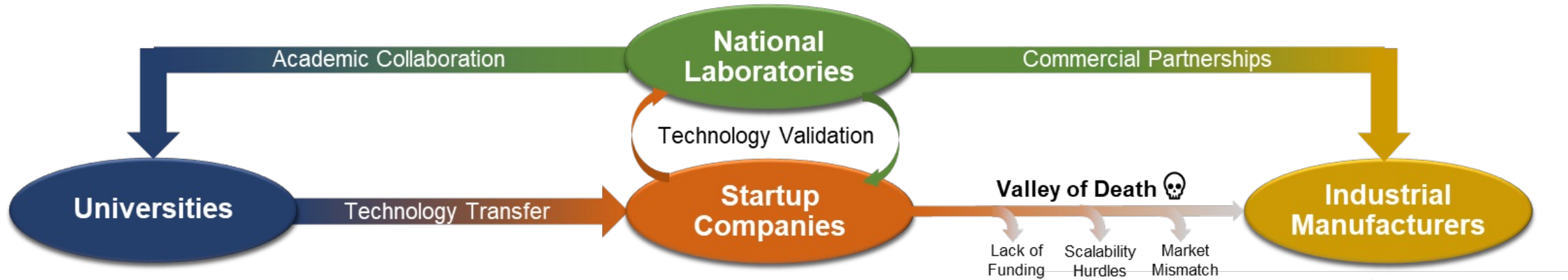
- In Countries like India
- In Cities like Paris



Ready in 2-3 years if scaling is successful

Source: U.S. Department of Transportation, Bureau of Transportation Statistics
November 2021 | Chart: Loren McDonald / EVAdoption

Academy to Industry to Society



- Energy/oil-petro companies, Mining companies, Car OEMs – infrastructure (supercharging, integration of renewables, battery passport)
- Batteries should be built with green electrons, closer to the customers, with recycling mandated.