Status of Batteries for Aviation Applications

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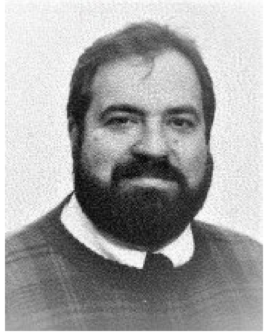
NASA-DOE Meetings on Batteries for Electric Aviation

- Bring together two different communities: aviation and battery
- Goal: access the status of electric aviation and RDD&D needs
- Learning from EVs to accelerate EA technology and adoption



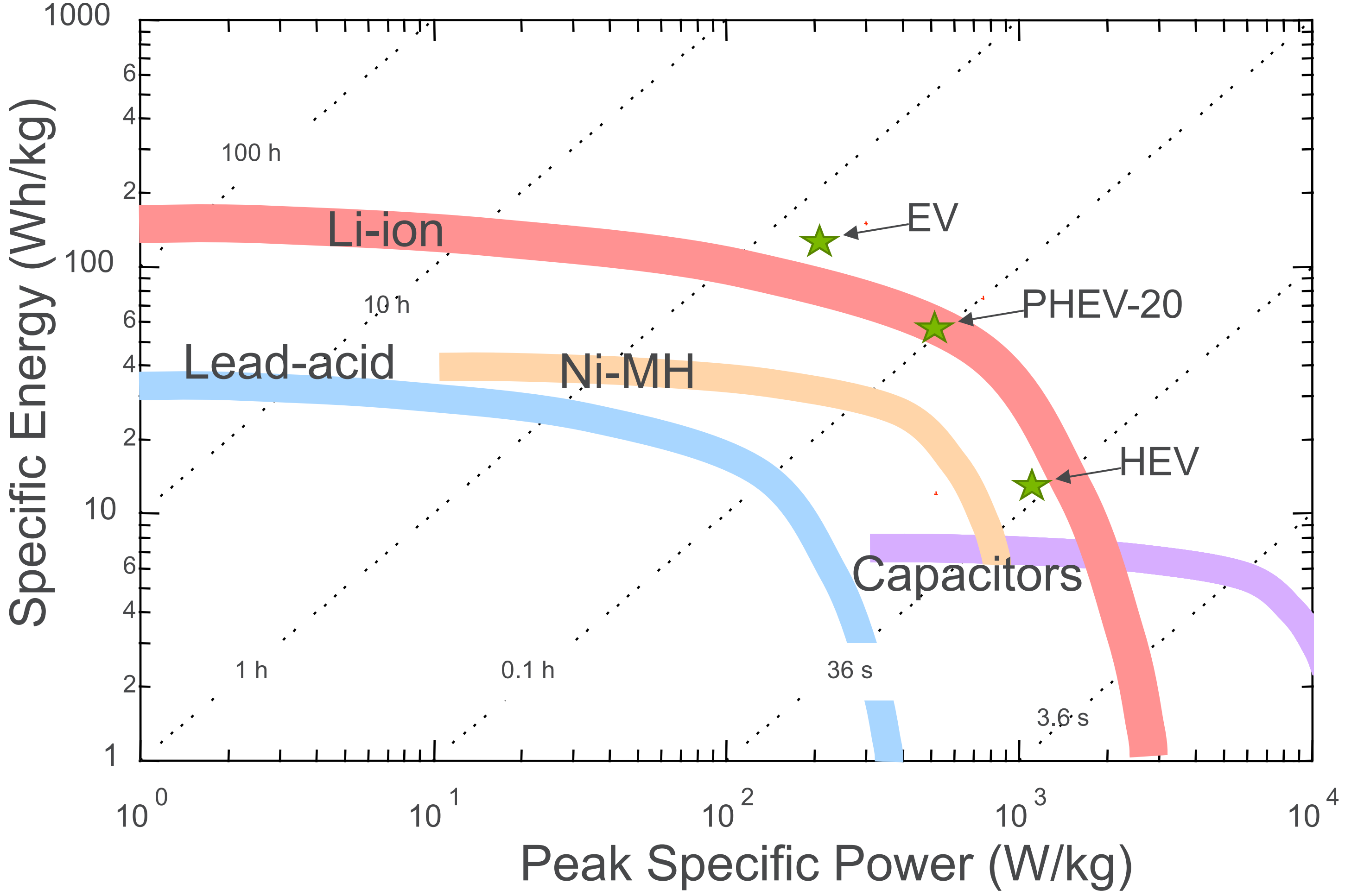
Peter Faguy

Ajay Misra

Tien Duong

Simon Thompson

Ragone Plot Comparing Battery Types and Applications



USABC
UNITED STATES ADVANCED BATTERY CONSORTIUM

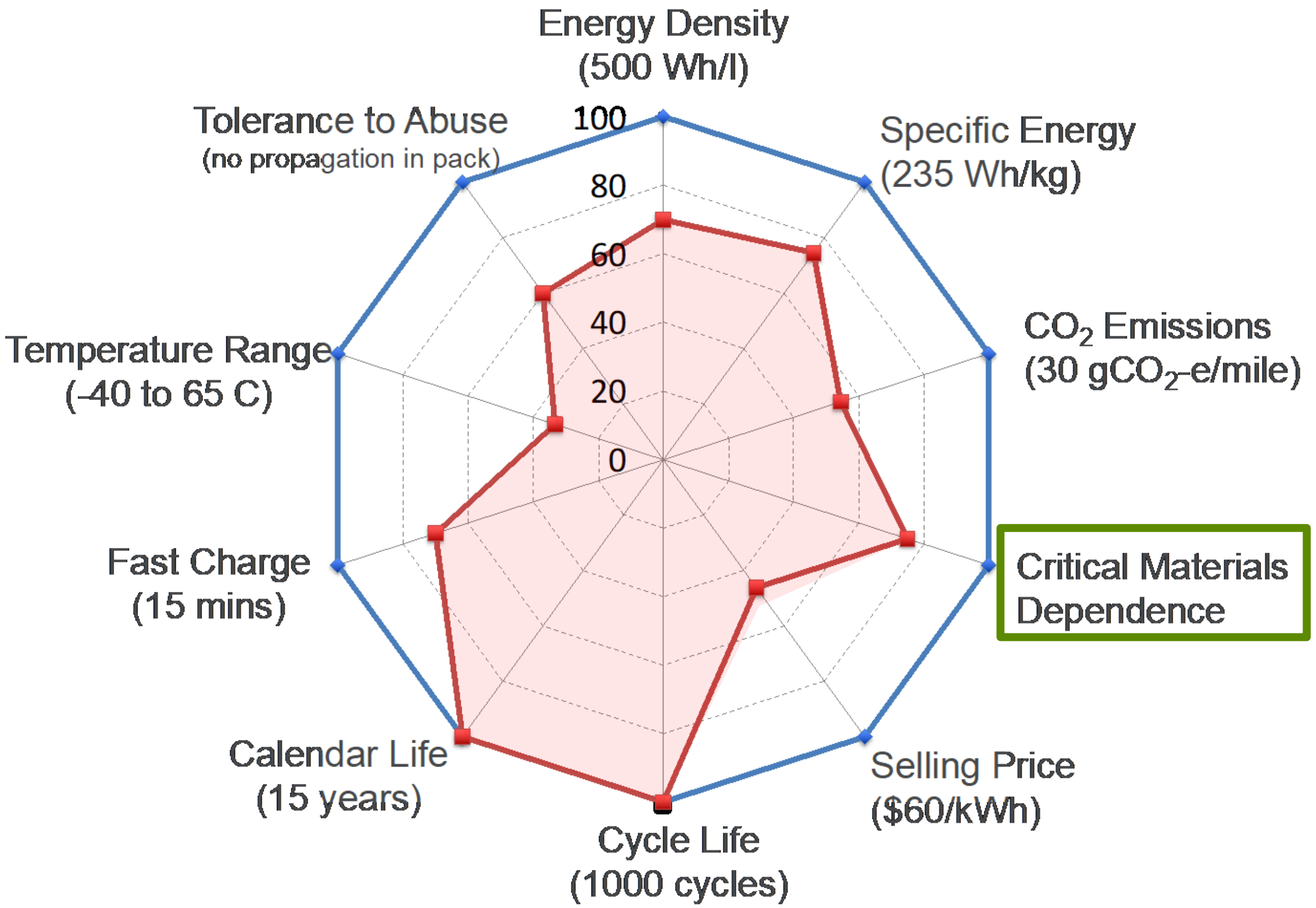
EV: Electric car
PHEV: Plug-in electric
HEV: Hybrid electric

10s pulse power for xEV.
All values at battery pack level

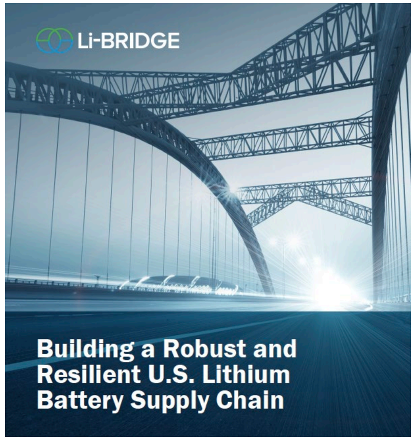
Clear targets crucial in driving battery innovation

The Challenge in EVs Have Changed.

EV battery performance targets (blue)
and actual average performance (red)



Li-BRIDGE



Strategy:

- Material traceability and end-of-life
- R&D to bridge the supply gap
  - Substitutions (e.g., Na-ion- see LENS): https://www.anl.gov/lens
  - Recycling
  - Extract local resources (e.g., urban mining)
- Lab-to-fab pilot line networks

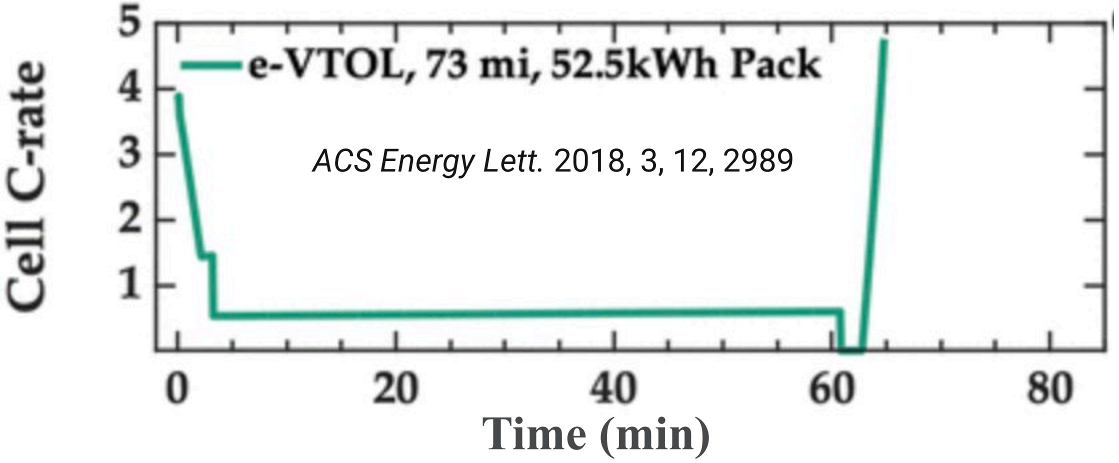
Electric aviation (EA) is like xEV from early 2000

Why Electrify Aviation? i.e., Beyond GHG

1. Enable markets that are not accessible before
   - eVTOLs (air taxis) enabled by distributed propulsion
2. Reduce maintenance/inspections
   - ~50% lower maintenance cost and longer inspection schedules (3 vs 10 years)
3. Reduced noise
   - As much as 50% reduction near take-off/landing zones
4. Reduced total cost of ownership
   - 20-30% lower. Driven by fuel savings, lower maintenance, and higher efficiency.

Some significant differences between Aviation and EV battery needs

1. Unlike EVs, mission profiles still in the works
2. Pulses are higher power and for much longer time (2 mins)
3. Wh/kg critical. Wh/l not as much?
4. Reducing thermal management opens the door for high temperature batteries
5. Constrained landing locations could enable battery swapping and mechanical recharging
6. Back to structural batteries?



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We need to define few targets (much like in xEV)

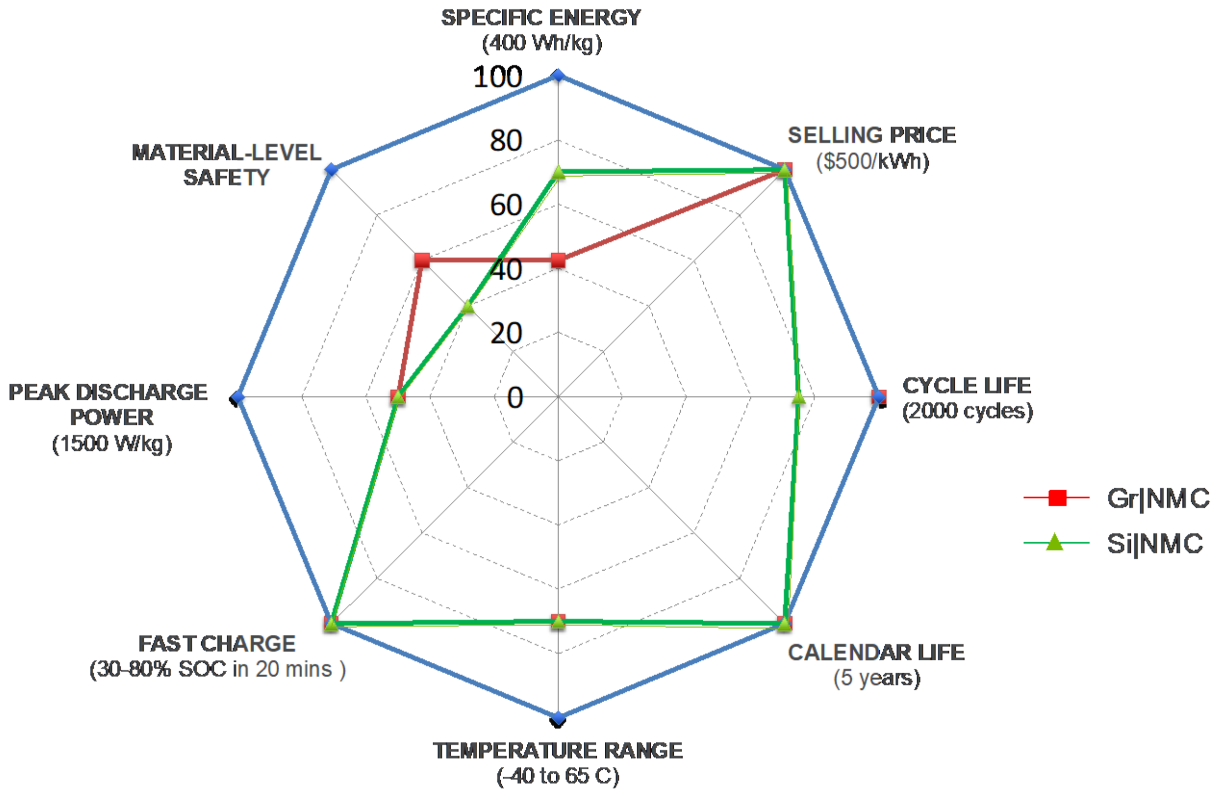
Potential Missions	Unique Characteristics	Potential Market Introduction
 737 CLASS SHORT-HAUL E-AIRCRAFT	• Specific Energy: 5-6x vs. EVs • Take off/landing power: 4x vs Evs • Cycle life: 10x vs. EVs	737-type short haul jet with 700-mile range and 100 passengers.
 737 CLASS HYBRID AIRCRAFT	• Specific Energy: 2-3x vs. EVs • Take off/landing power: 5x vs EVs • Cycle life: 10x vs. EVs	737-type hybrid short haul jet with 700-mile range and 100 passengers.
 COMMUTER E-AIRCRAFT	• Specific Energy: 2-3x vs. EVs • Take off/landing power: 2x vs EVs • Cycle life: 2x vs. EVs	Commuter flights with 300-mile range, 9-19 passenger with 3-4 trips a day.
 EVTOL	• Specific Energy: 2-3x vs. EVs • Power: 3x vs. EVs • Cycle life: 2x vs. EVs	All-electric eVTOL urban air mobility with <7 passenger and 50+ mile range with 8-10 trips/day.

Spider chart for EVs vs eVTOLs

Silicon calendar life extrapolated based on 2 years of data

Light duty EVs

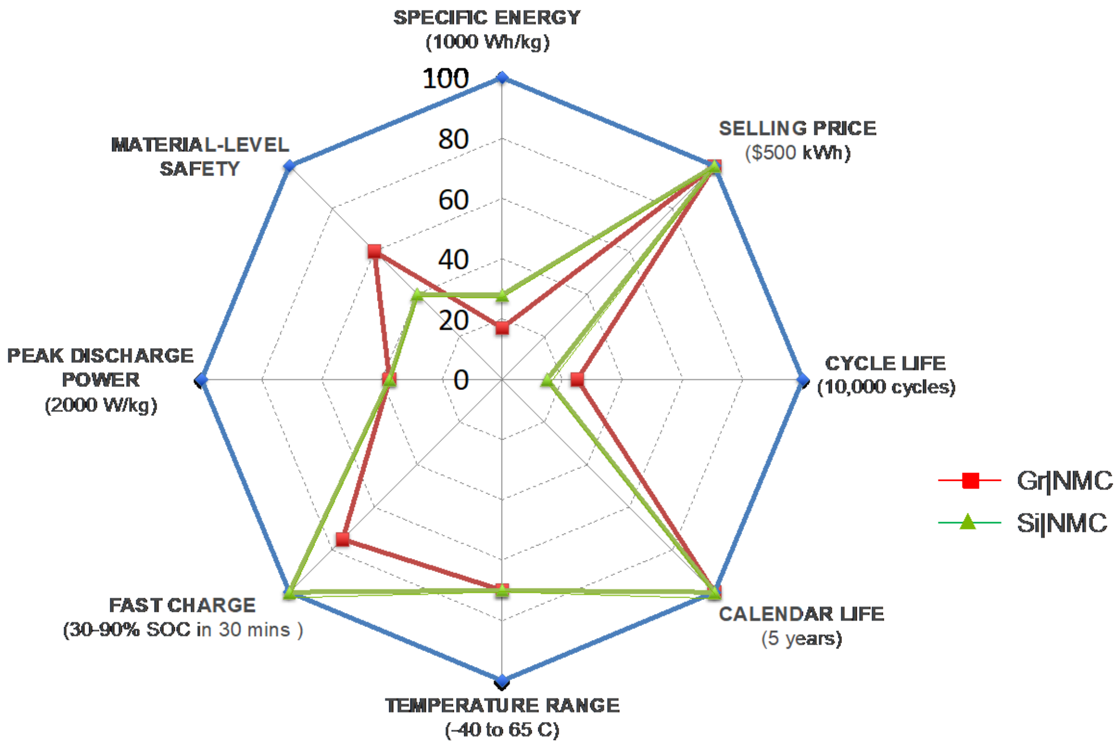
eVTOLs



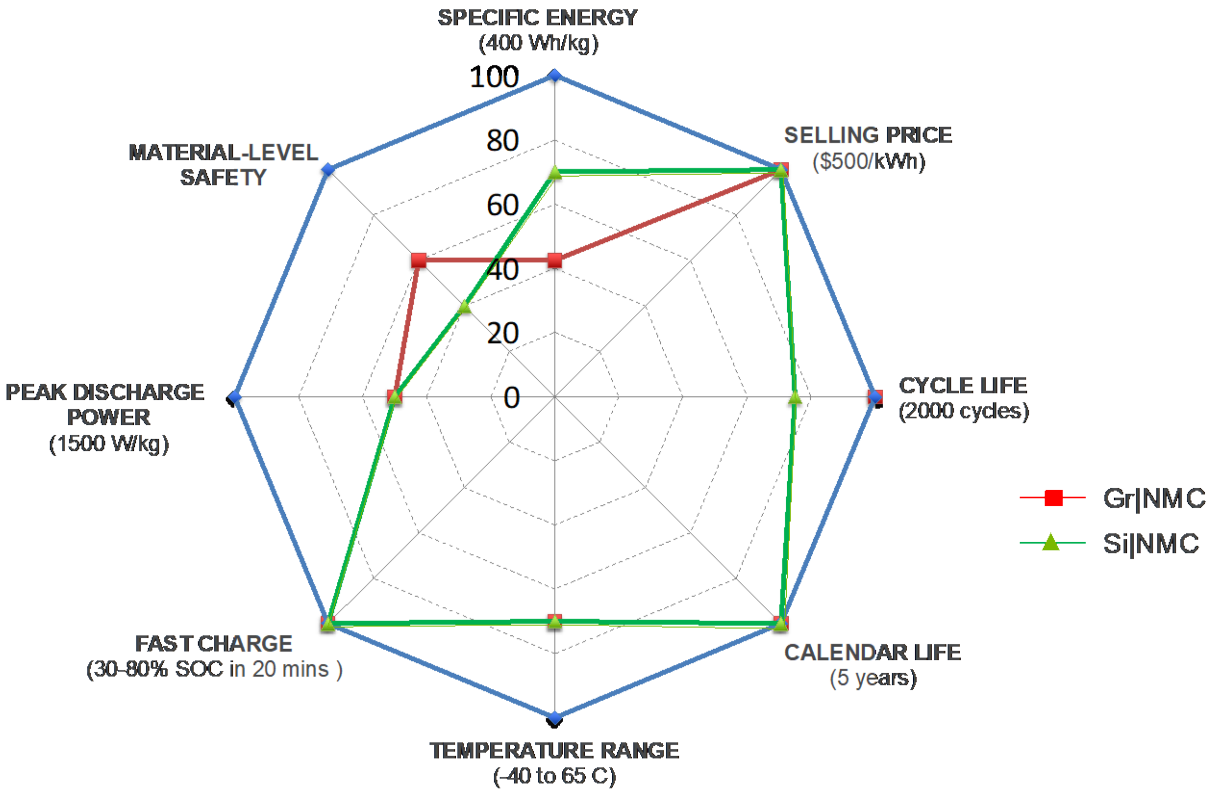
More energy, a lot more power, and lower calendar life

Spider chart for eVTOL vs All Electric 737

737 class AEA



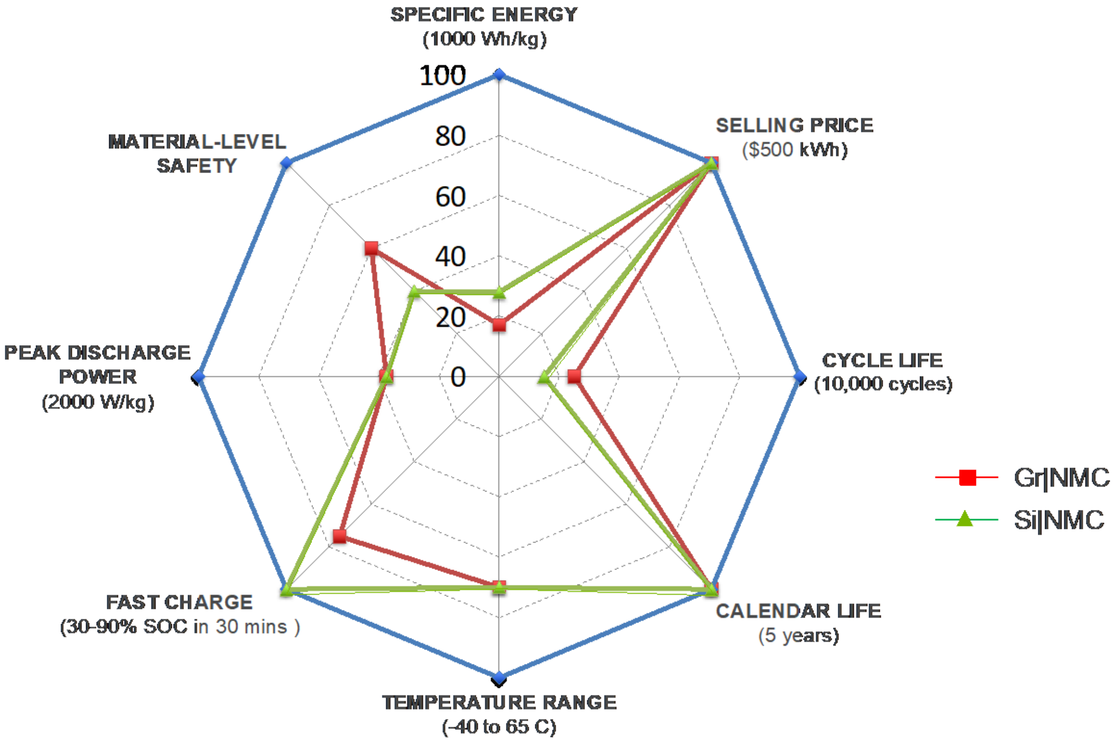
eVTOLs



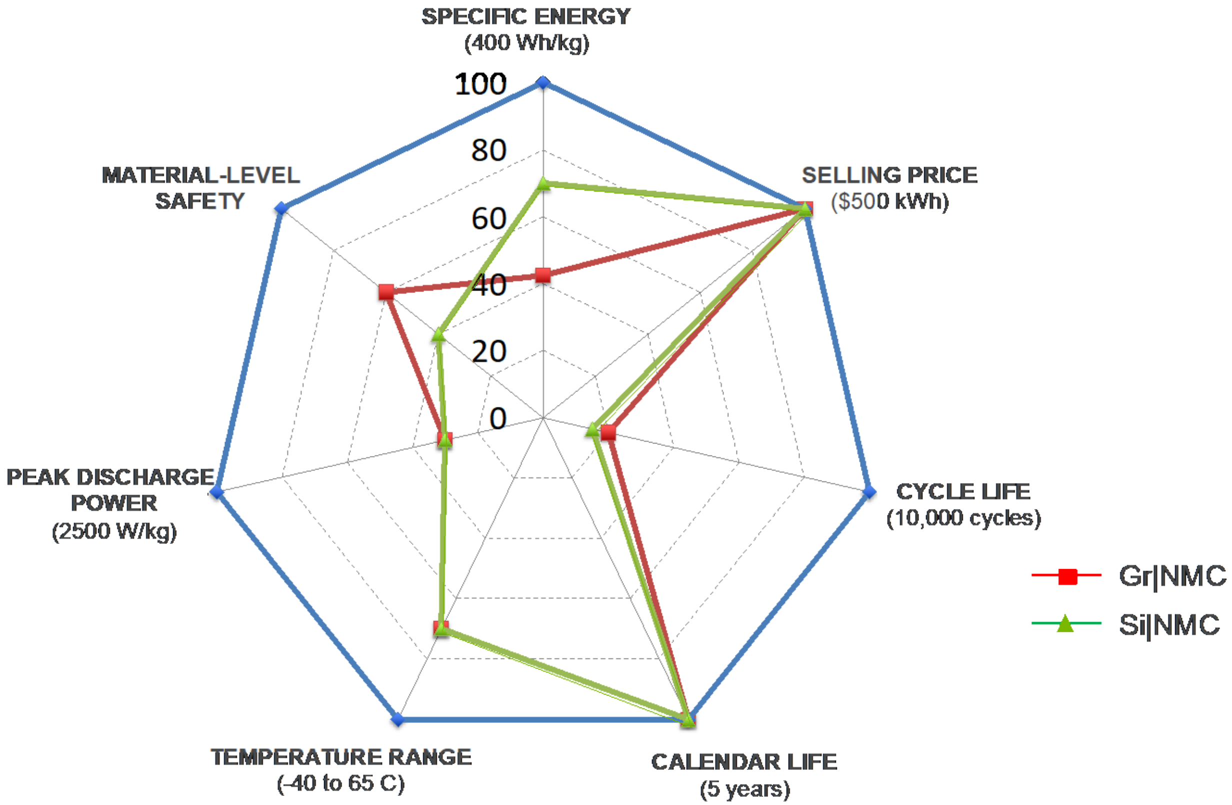
An all-electric 737 powered by batteries is not happening anytime soon

Even Hybrid 737s Will be Hard

737 class AEA

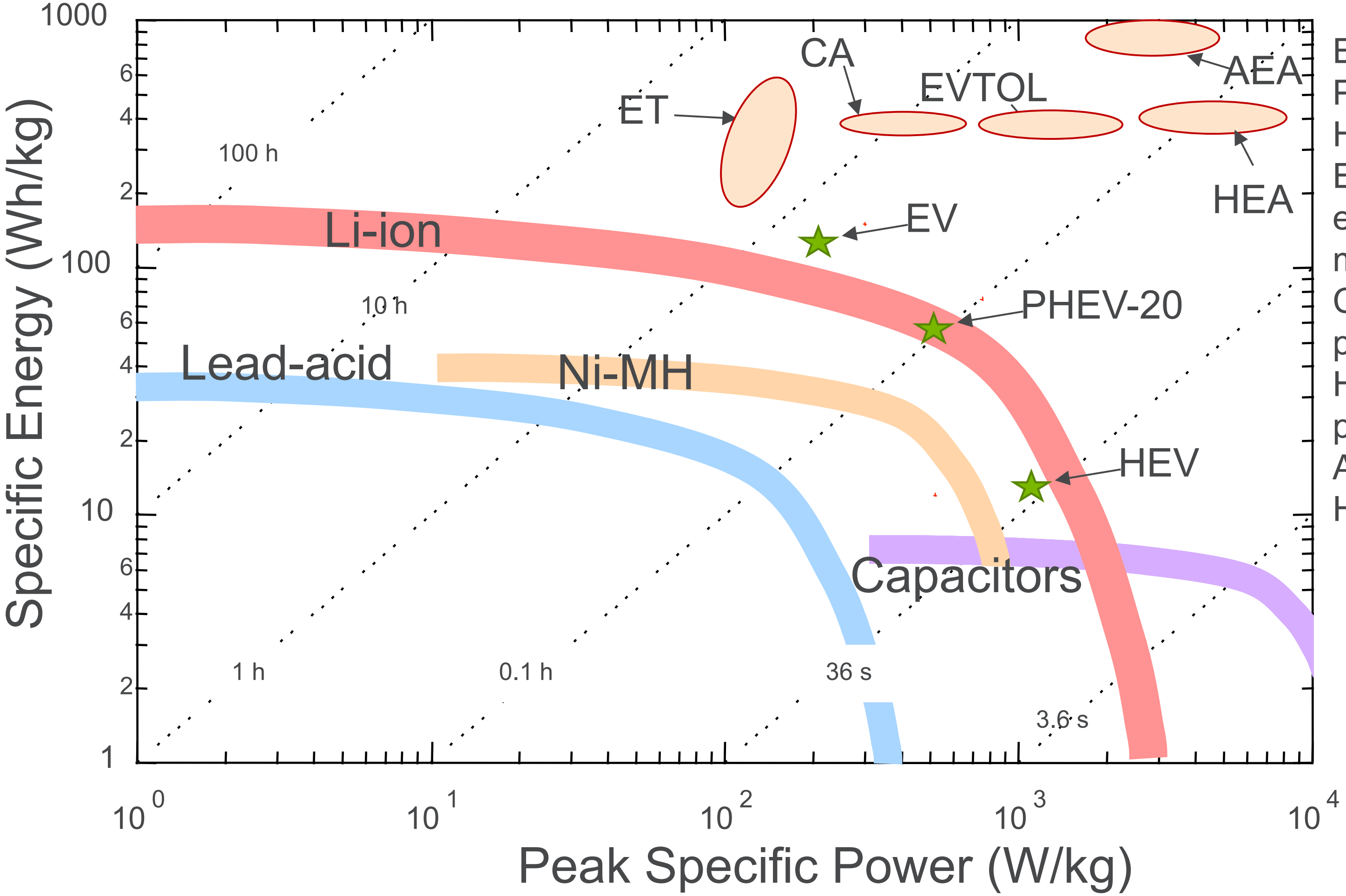


737 Class HEA



Reality is that we need more energy for all xEA applications

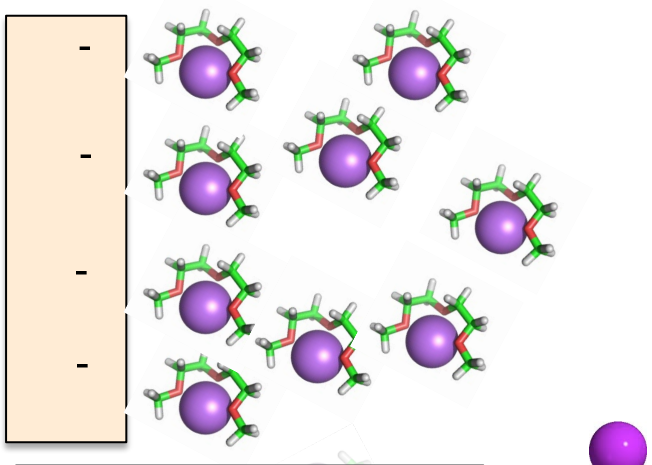
We Will Need High Energy AND High Power



EV: Electric car
PHEV: Plug-in electric
HEV: Hybrid electric
ET: Electric truck
eVTOL: <7 passenger, 50 n-miles
CA: Commuter aircraft (9-19 passenger, 300 n-miles)
HEA: Hybrid electric aircraft (100 pass., 700 n-miles)
AEA: all electric 737 class
HEA: Hybrid electric aircraft

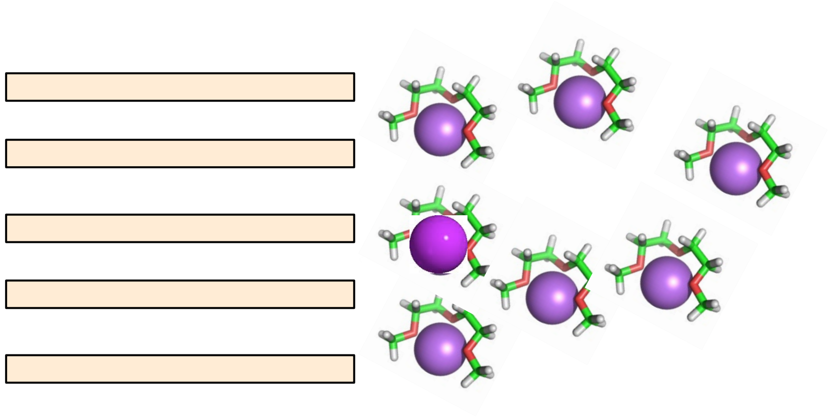
10s pulse power for xEV. 120-180 s for xEA
All values at battery pack level

How do we store energy in an electrochemical device?

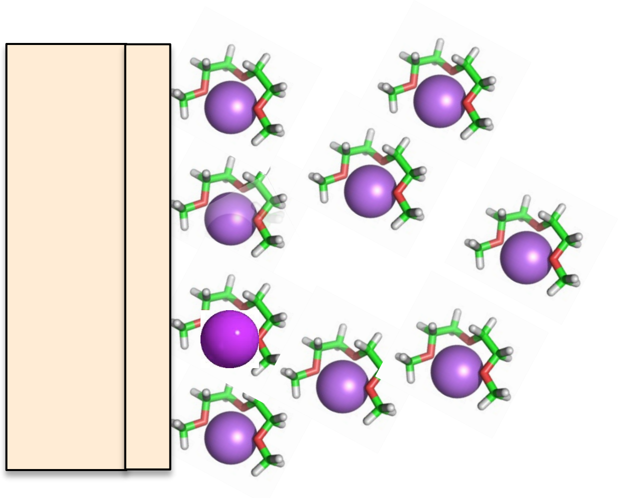


● -Lithium

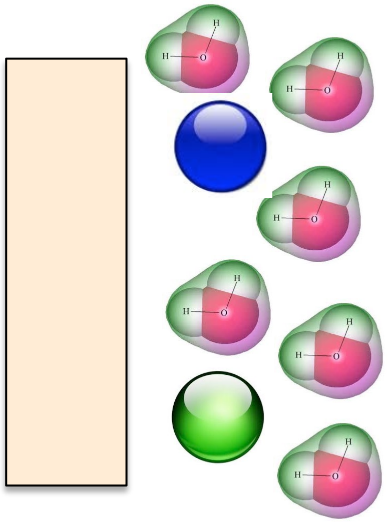
Double layer capacitor



Intercalation/alloying



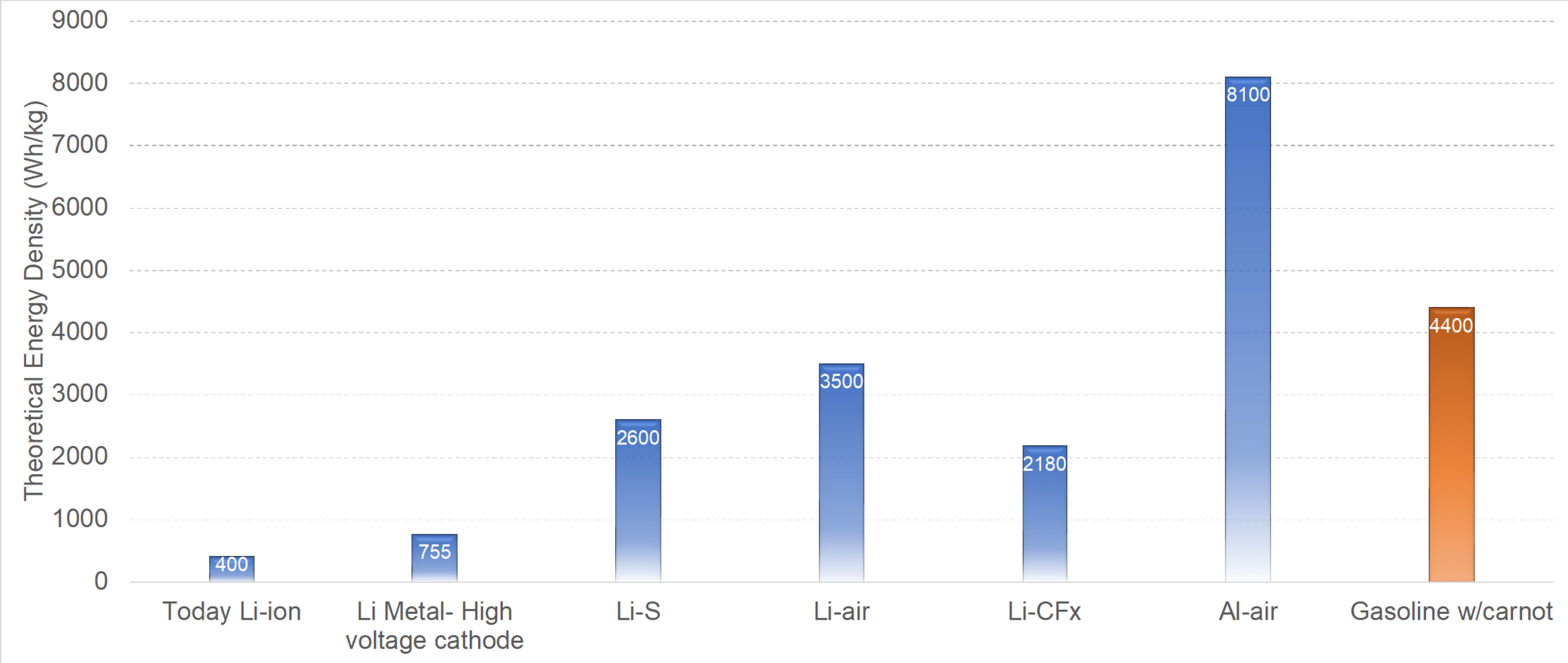
Dissolution/Deposition/
Precipitation/Conversion



● -Vanadium

Redox Flow

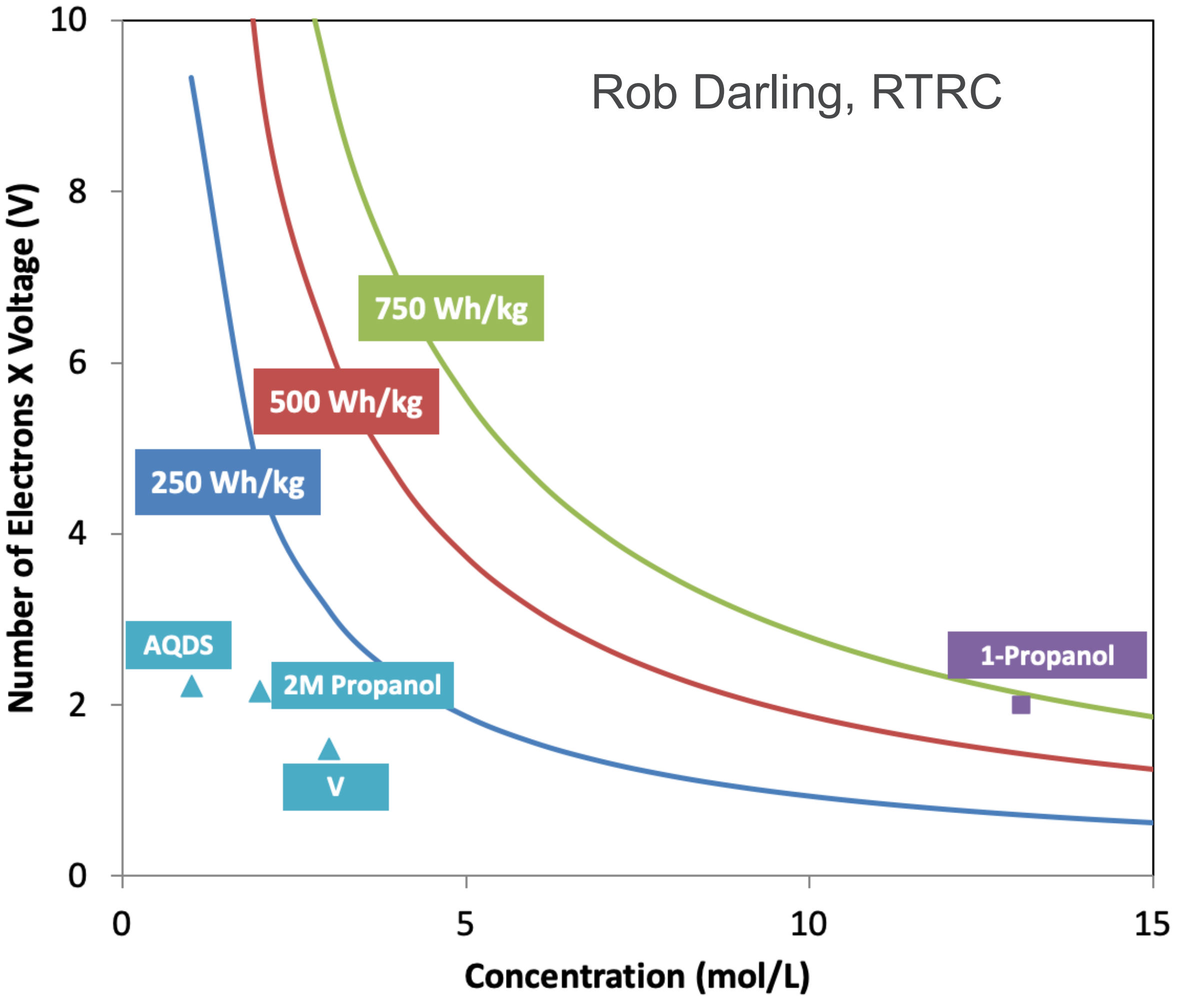
There are battery chemistries that promise gasoline-like energy density…. In theory!

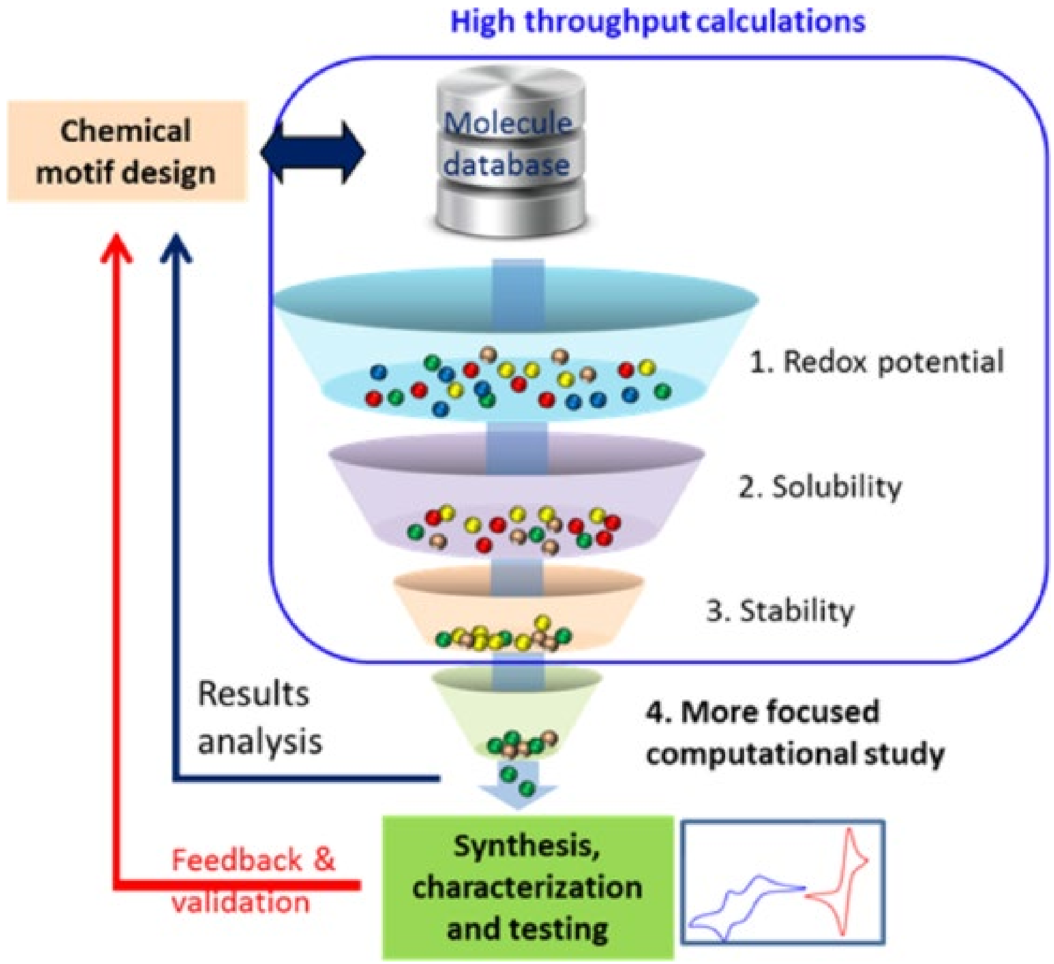


Theoretical Does Not a Practical Battery Make

More R&D needed to enable these chemistres

Hard to Beat Liquid Fuels for High Energy… if They are Soluble





Is there a new GHG-free reversible molecule to discover?

Summary of RDD&D Needs

>1000 Wh/kg

INCREASING SPECIFIC ENERGY OR POWER

Today (180 Wh/kg_p)

BASIC RESEARCH	APPLIED RESEARCH	SYSTEM LEVEL RESEARCH

Extreme high specific energy technology. Path unknown.

Next generation Li with extreme power, ultra long cycle life

Advanced Li-ion/metal (e.g.,Si|NMC) with high power capability

Safety at all levels (materials, cells, packs)

Standardization (e.g., mission profiles)

Battery swapping

Mechanical recharge

New integration approaches (Hybrids)

▨ Leverage EV R&D

🟩 Aviation specific R&D