ELECTRIC MOBILITY FORUM

ENGAGE
Connecting Big Ideas To Action

UNDERSTANDING BATTERIES FOR ELECTRIC VEHICLES (EVS)

Technology and Performance Aspects

WRI INDIA
ROSS CENTER

SHAKTI
SUSTAINABLE ENERGY FOUNDATION

Date: 26th August 2019

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DISCUSSION POINTS

- Which is the most preferred type of battery for electric vehicles?
- Why are these batteries the most preferred choice for EV applications?
- How safe are these batteries?
- What is the future of these batteries for EV applications?
- What are the environmental impacts of the preferred batteries?

HISTORY: BATTERY POWERED VEHICLES

Late 1800 – Early 1900

- ❖Golden period for the EVs
- ❖Lead-acid powered Vehicles

By 1920

- ❖Market dominated by ICE vehicles
- ❖Long Range & High horsepower

2017 Onwards: EV30@30

- ❖Environmental Concerns
- ❖Renewed Interest In EVs

➢ **Reason for EV to ICE Transition**

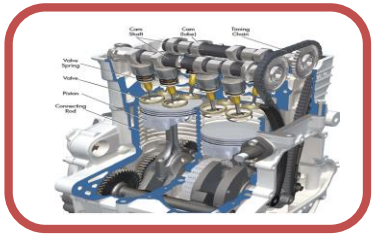
- ❖ Heavy weight of batteries
- ❖ Short trip range
- ❖ Long charging time
- ❖ Poor battery life

ICE to EV Transition

BATTERY: COMPLEX FUEL TANK

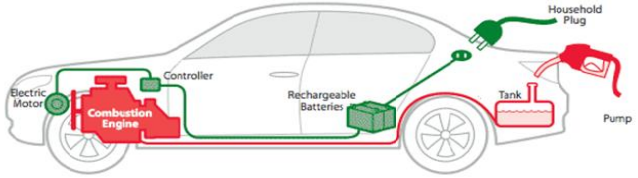
Gasoline Powertrain

- More Complex
- > 20,000 moving parts
- High Maintenance Cost



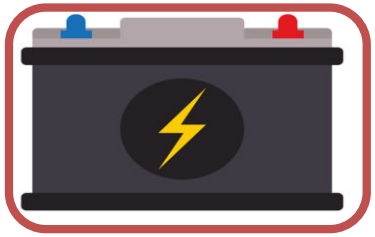
Simple Fuel Tank

Petrol / Diesel



Electric Powertrain

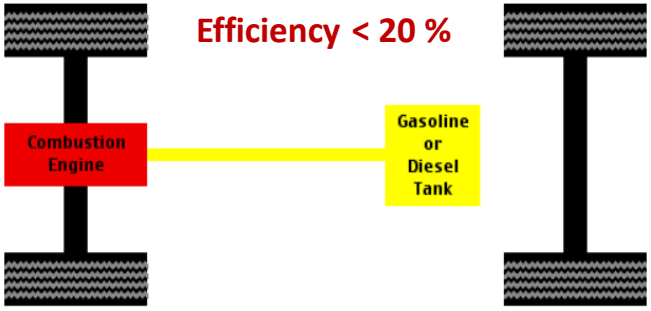
- Less Complex
- < 20 moving parts
- Low Maintenance Cost



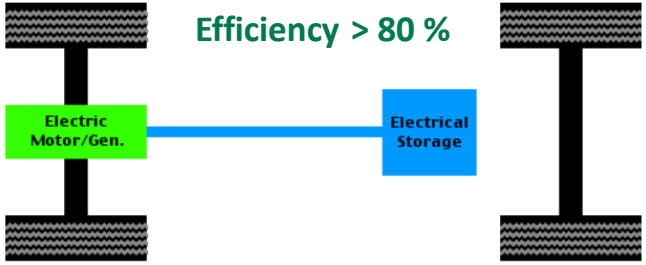
Complex Fuel Tank

http://www.circuitstoday.com/working-of-electric-cars; Images from Web

PERFORMANCE: EV VERSUS ICE VEHICLE

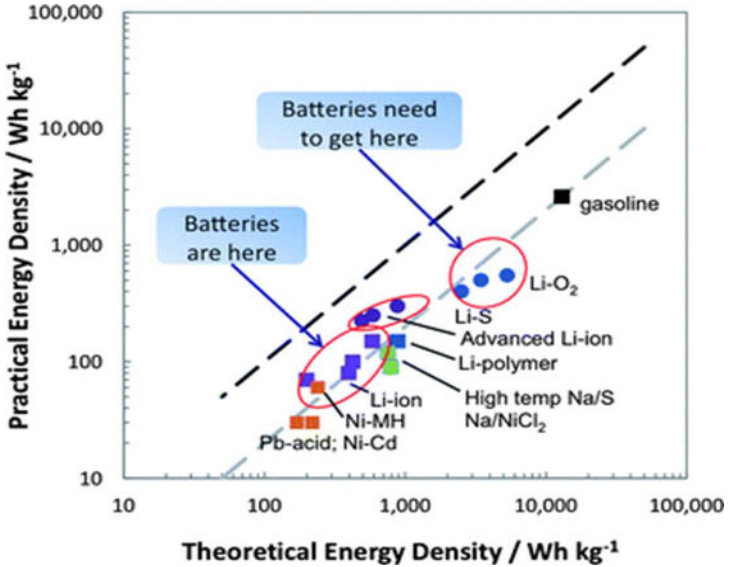


Stored Energy in Gasoline ~ 48 MJ/kg



Stored Energy in Battery ~ 0.4 MJ/kg

- Efficiency of EV is 5 to 6 times higher than that of ICE (Internal Combustion Engine) vehicles
- Gasoline is 100 times more energy dense than a battery



Source: ***Energy Environ. Sci.***, 2012,**5**, 7854; http://www.altfuels.org/backgrnd/altdrive.shtml; https://www.aps.org/publications/apsnews/201208/backpage.cfm

UNDERSTANDING PERFORMANCE INDICATORS

Environmental impact → Battery material and recycling potential

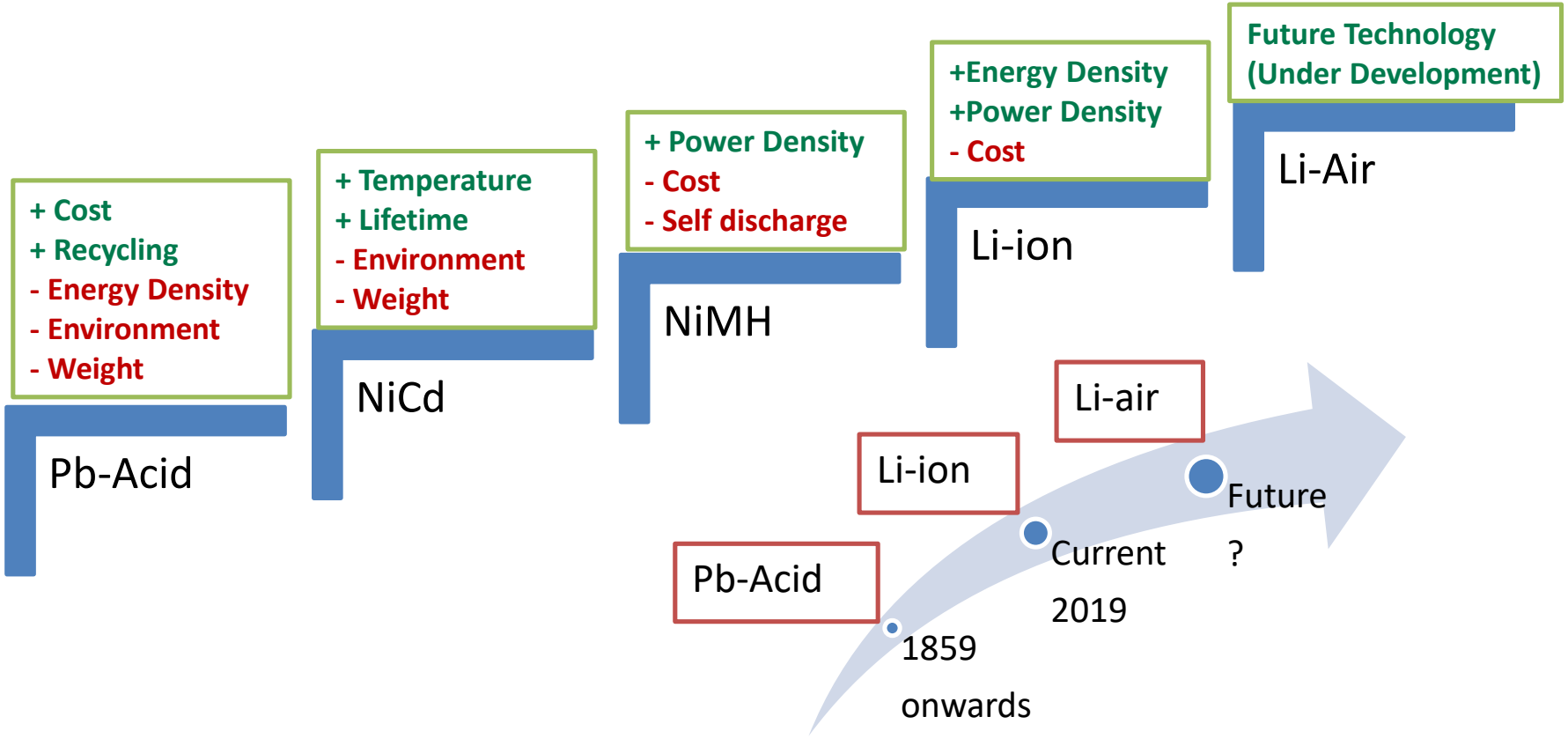
Pb-acid / Ni-Cd / NiMH / LIB

- Safety
- Cost
- Battery Life

Specific Energy (Wh/kg) – Range & Weight
Energy Density (Wh/l) – Range & Size
(Total amount of energy an energy storage device holds)

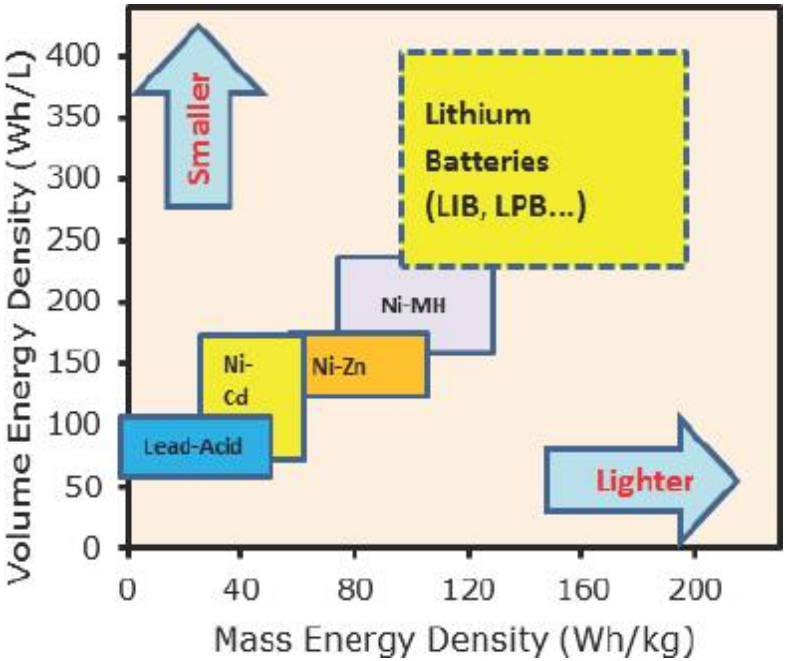
Specific Discharge Power (W/kg) – Acceleration & Weight
Discharge Power Density (W/l) – Acceleration & Size
(Speed at which the power can be discharged)

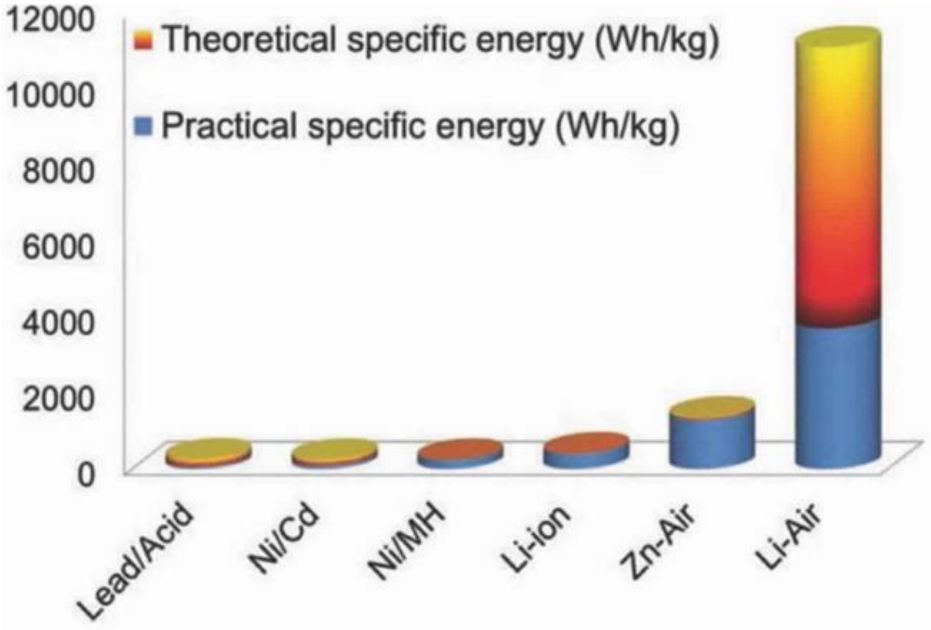
BATTERIES USED IN EVS



WHY LIB FOR EVS?

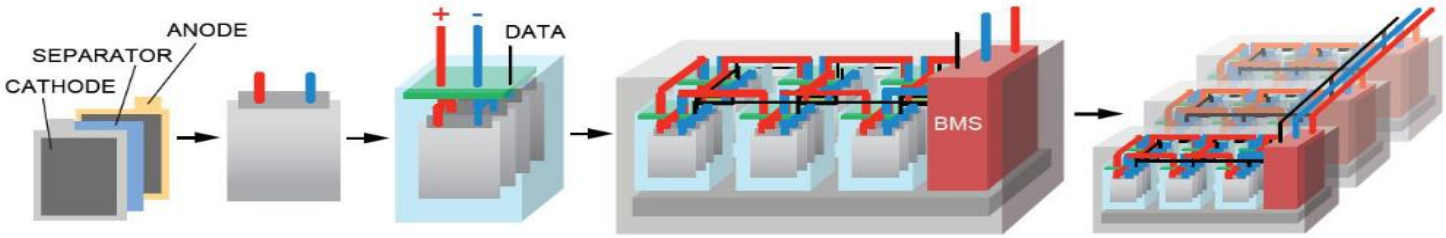
Key Performance Requirements: High Energy Density, Long Cycle Life, Light Weight, Small Size





https://www.sciencedirect.com/science/article/pii/S1369702114000741; Others from Web

INSIDE LIB BATTERY



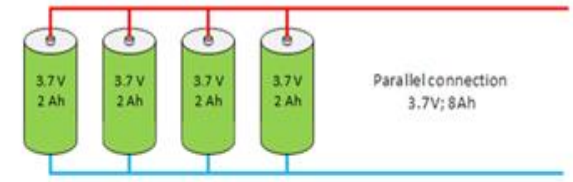
MONO-CELL
- BASIC CELL CHEMISTRY
- BASIC VOLTAGE LEVEL

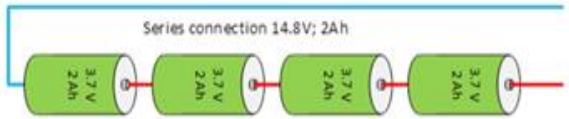
CELL
- STACK OF (e.g., 20) MONO-CELLS CONNECTED IN PARALLEL

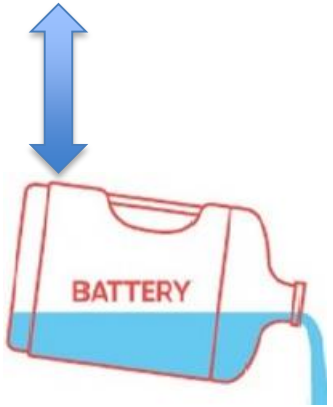
MODULE
- MANY CELLS IN SERIES

BATTERY PACK
- SEVERAL MODULES OR
- MANY CELLS
- VOLTAGE: 400 V

BATTERY SYSTEM
- SEVERAL BATTERY PACKS IN PARALLEL
- ENERGY: >15 KWH

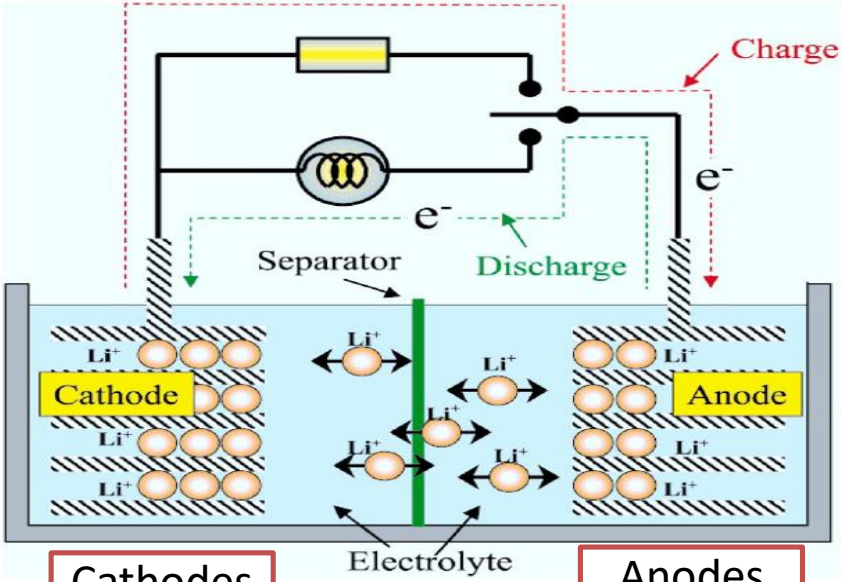






https://brandogsikring.dk/files/Pdf/FogU/Project%20BLUE%20BATTERY%20-%20Part%20I.pdf

HOW LIB WORKS?

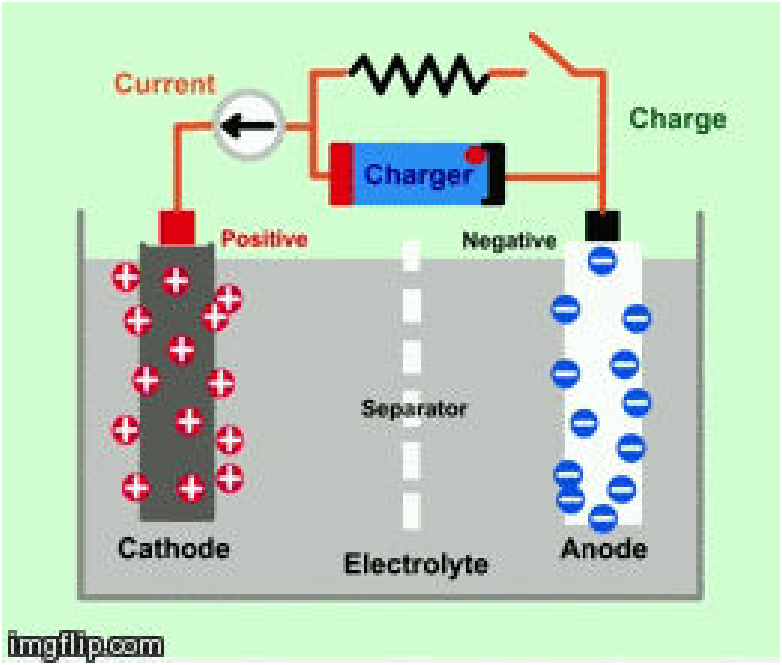


Cathodes

LCO/ NCA/ NMC/ LMO/ LFP

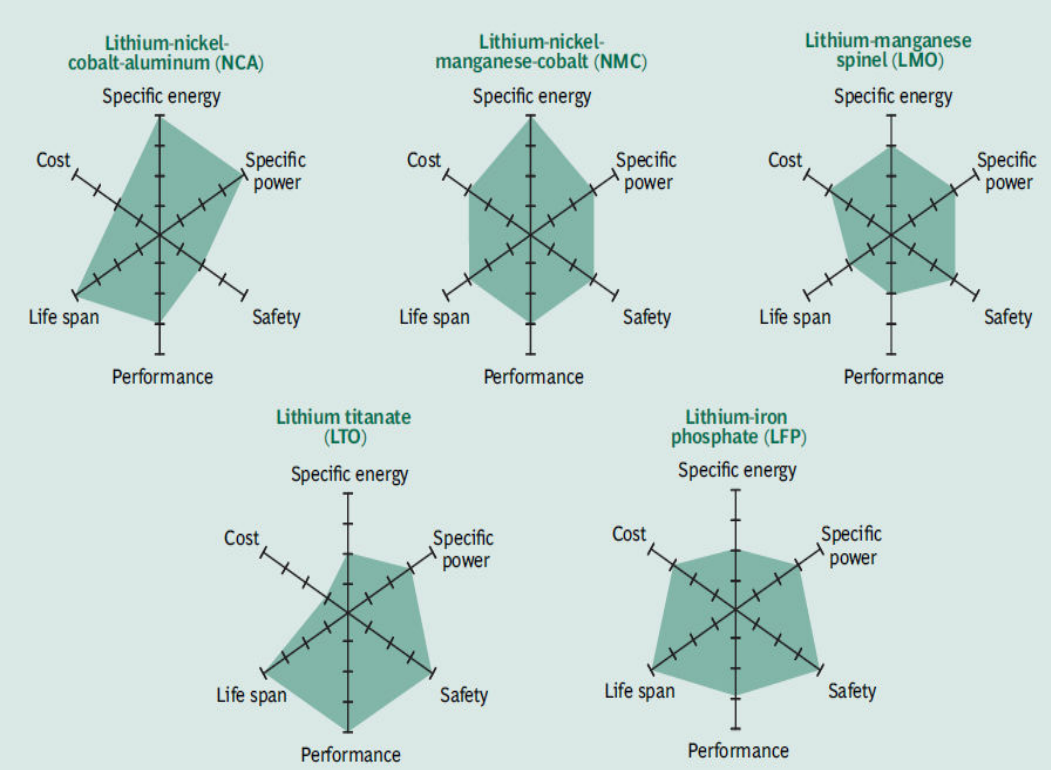
Anodes

Graphite/ LTO



GIF: https://gifer.com/en/LCEZ; Other images from Web

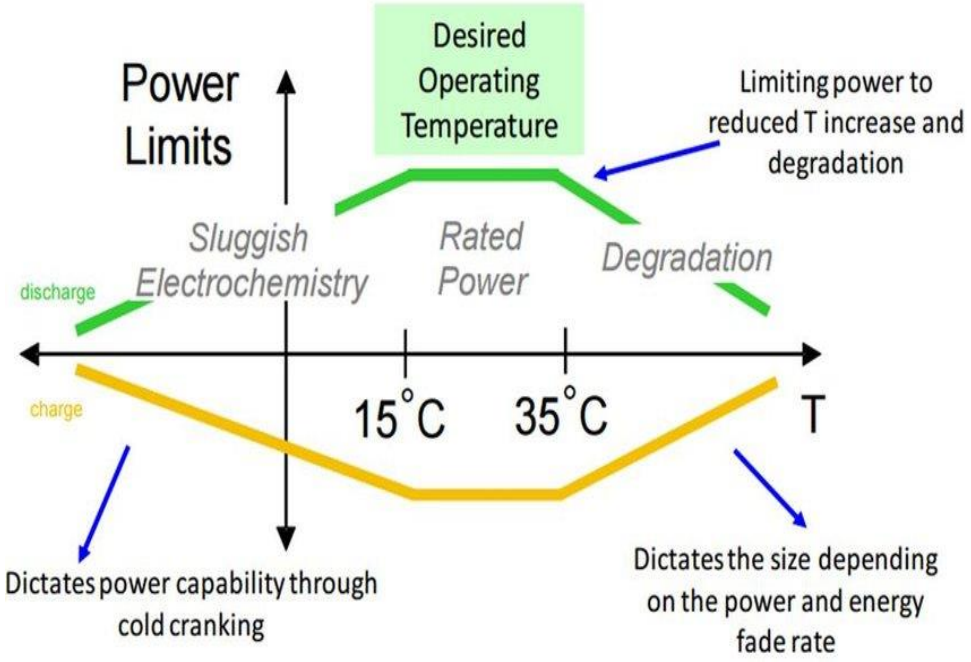
LIB VARIANTS: KEY PERFORMANCE PARAMETERS

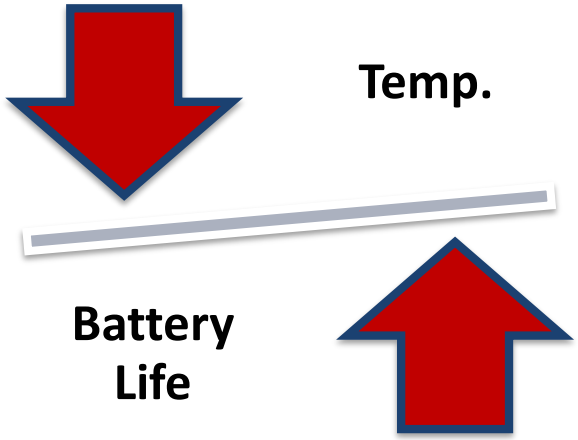


Balancing key performance parameters involves managing many trade-offs

https://www.greencarcongress.com/2010/01/bcg-20100108.html

LIB: EFFECT OF TEMPERATURE





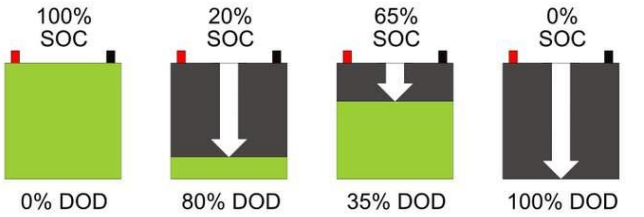
https://www.sciencedirect.com/science/article/pii/S1364032116301435

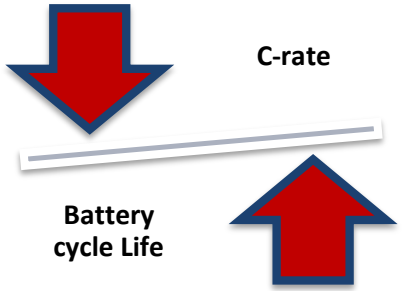
LIB: EFFECT CHARGE RATE & DOD

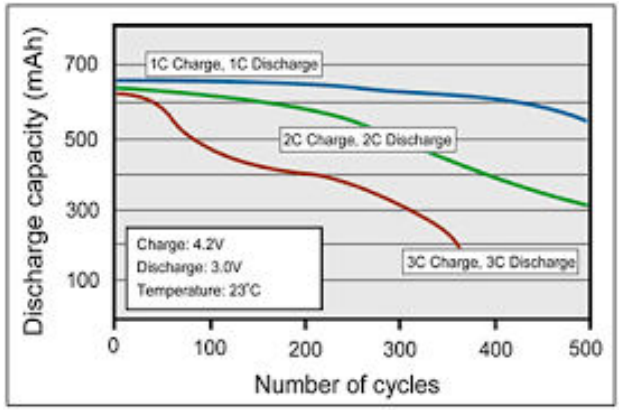
C-rate : Rate at which battery is charged / discharged

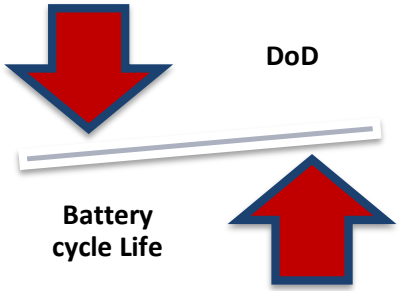
SOC : State of Charge (SoC) describes how full a battery is

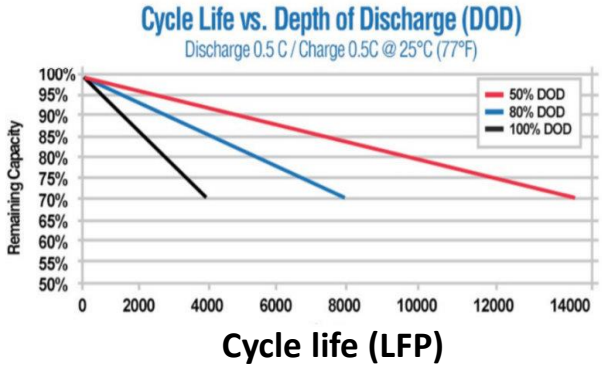
DoD : Depth of Discharge (DoD) measures how much of stored energy is used at each cycle







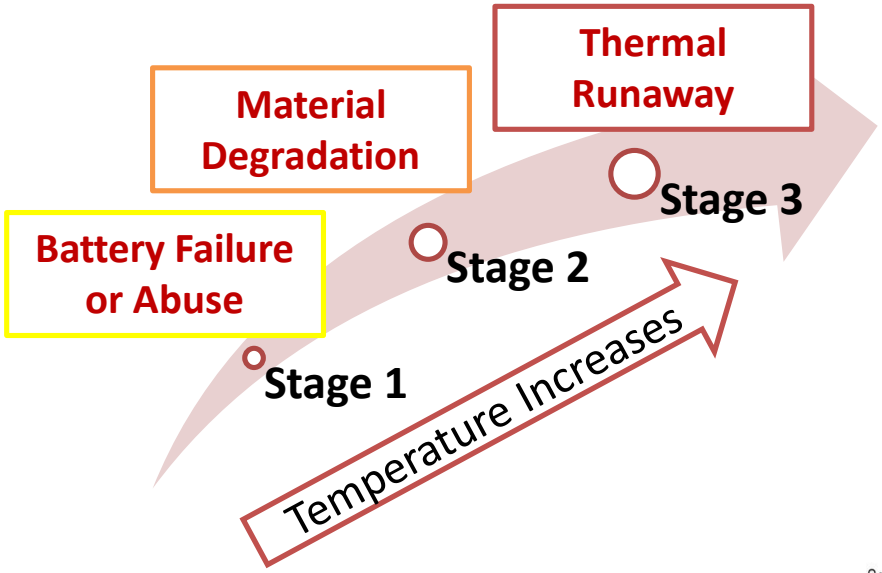


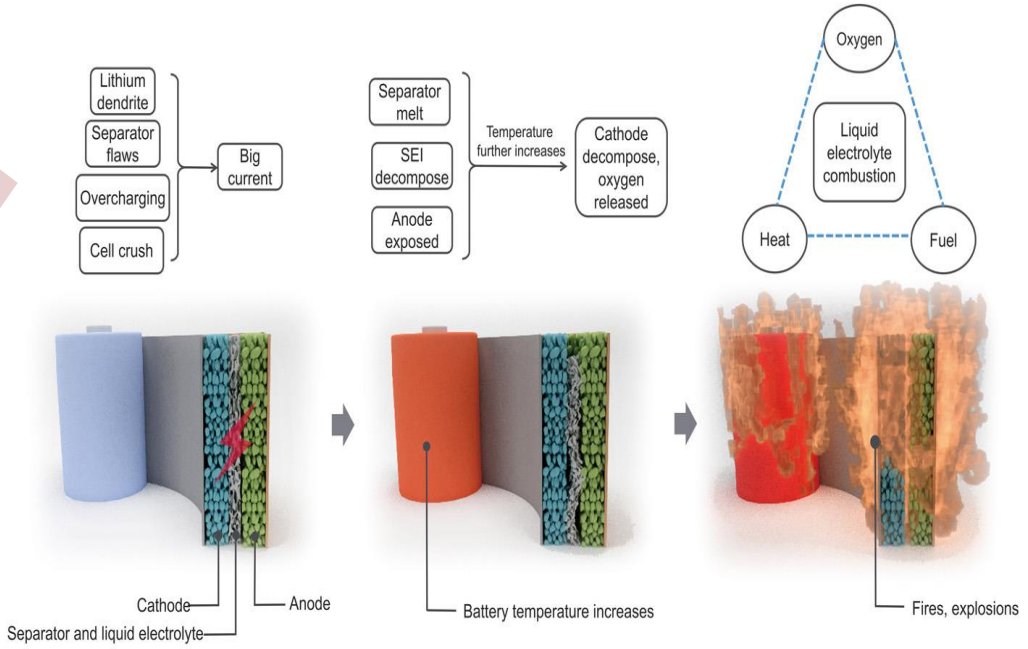


Cycle life (LFP)

https://batteryuniversity.com/learn/article/ultra_fast_chargers; https://modernsurvivalblog.com/alternative-energy/lithium-iron-phosphate-battery-cycles/; https://solarbuildermag.com/energy-storage/know-your-battery-specs-nameplate-capacity-10-kwh-vs-usable-capacity-7-kwh/

LIB SAFETY: THERMAL RUNAWAY





Battery Management System (**BMS**) – To monitor and protect Li-ion battery during operation

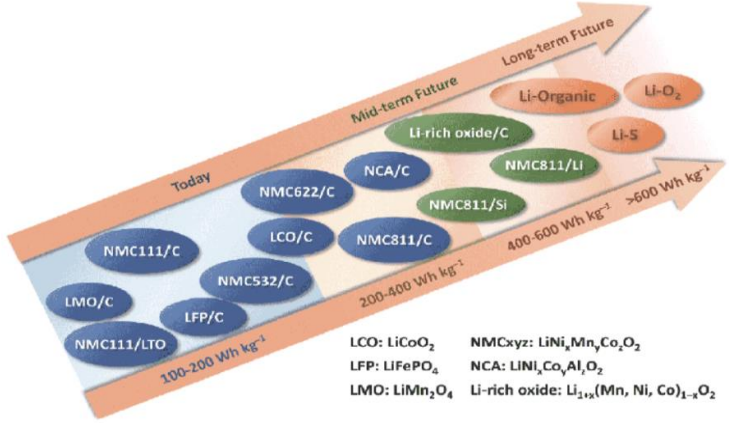
https://advances.sciencemag.org/content/4/6/eaas9820.full;

R & D OPPORTUNITIES

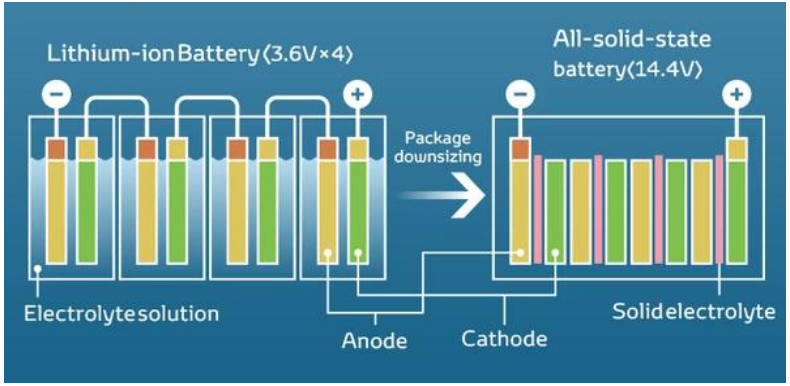
- **Path 1: Innovation in Li-battery technology**
  - Development of novel electrode and electrolyte materials
  - Nanotechnology to improve the performance existing Li-ion battery
- **Path 2: New Battery technologies**
  - Alternative to Li-ion battery
- **Path 3: Innovation using hybrid technology**
  - Hybrid of existing battery technology (e.g. LIB-Pb acid hybrid, LIB – Supercapacitor hybrid, Pb acid – supercapacitor hybrid, etc)

PATH 1: INNOVATION IN LIB TECHNOLOGY

- **Novel electrode and electrolyte materials to develop LIB with high energy and power density, high safety**

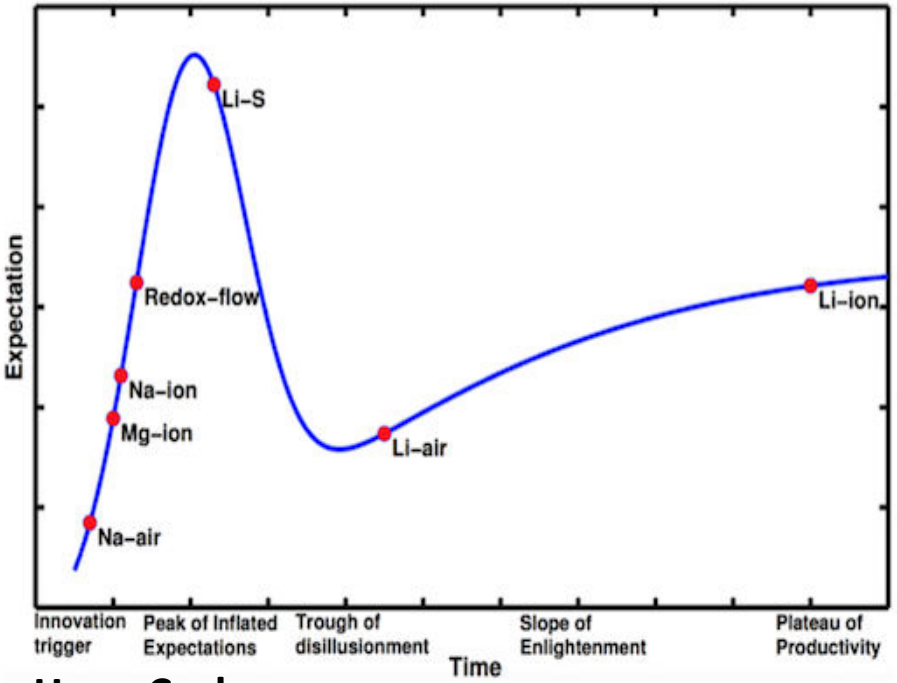


- **Develop solid state Li-ion battery for high safety**



PATH 2: NEW BATTERY TECHNOLOGIES

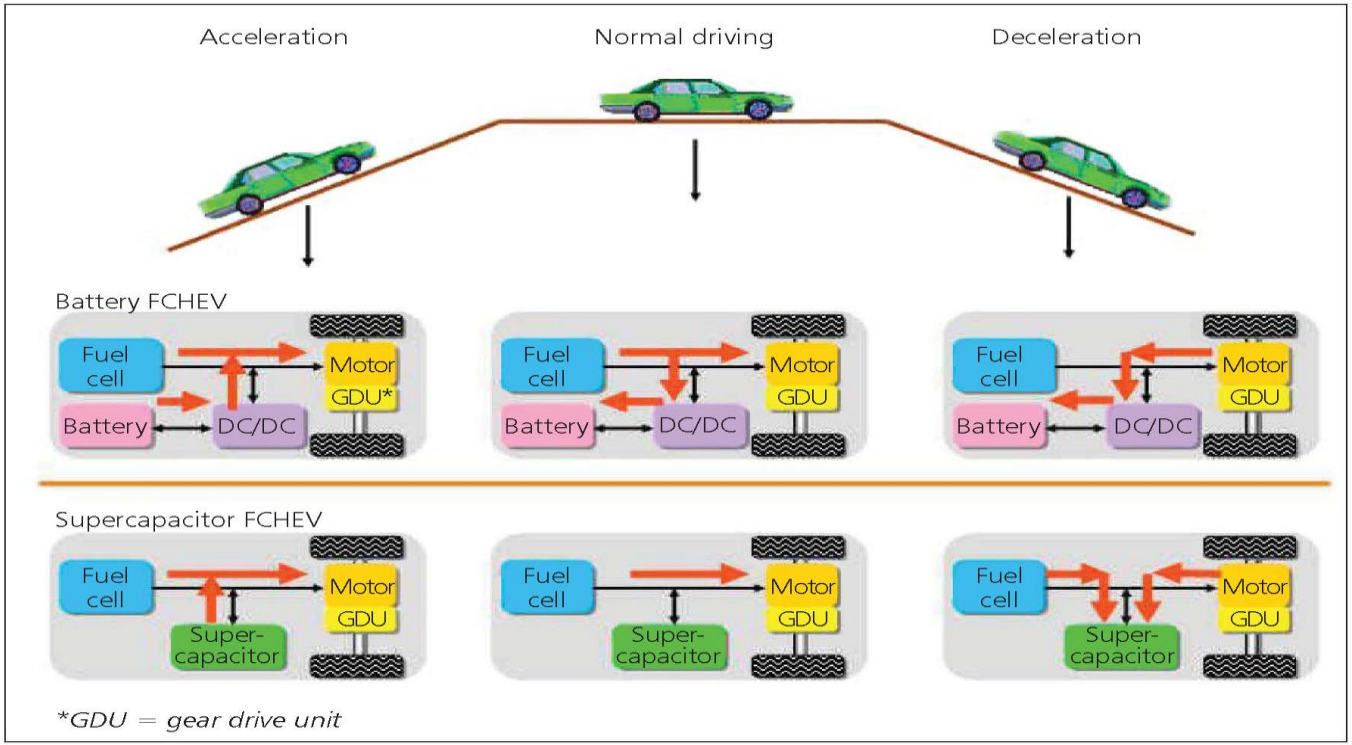
- **Basic R & D to explore new material to develop alternative to Li-ion battery technology**



Hype Cycle

https://blogs.scientificamerican.com/plugged-in/beyond-the-hype-what-s-the-future-of-batteries/; Both Images from Web

PATH-3: BATTERY HYBRID



Regenerative Braking System

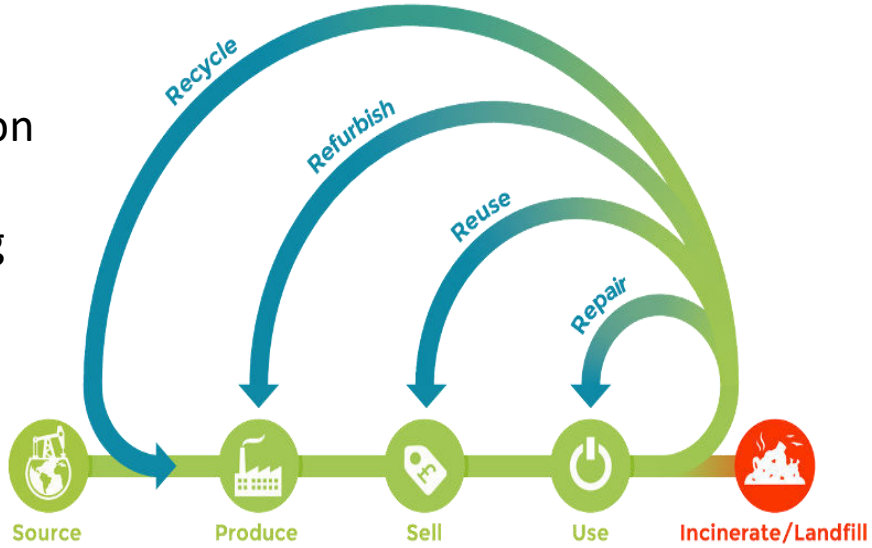
Fuel Cell & Battery Hybrid

Fuel Cell & Supercapacitor Hybrid

Image from Web.

ENVIRONMENTAL IMPACT

- Recycling Ecosystem for EV batteries
- Efficient utilization of resources
- Usage of non-toxic material for next-generation batteries
- Green technologies for battery manufacturing
- Use of clean source of energy



Linear economy → **Circular economy**

https://circulartayside.co.uk/what-is-the-circular-economy/

- Thank You