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Overview on current status of lithium-Ion batteries

Andreas Jossen, Margret Wohlfahrt-Mehrens

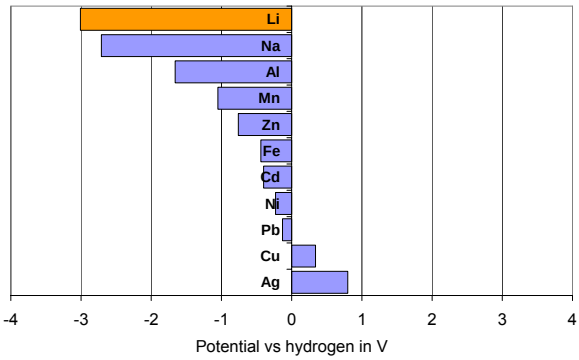
Zentrum für Sonnenenergie- und Wasserstoff-Forschung (ZSW)
Helmholtzstrasse 8, 89081 Ulm, Germany

Contact: andreas.jossen@zsw-bw.de

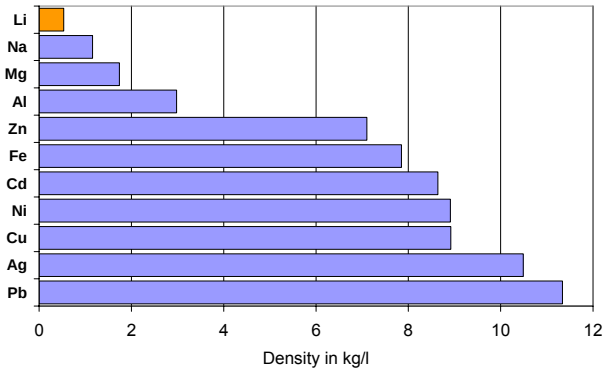
Overview

- Why is Lithium an interesting material for batteries?
- Principle of Li-Ion batteries
- Possible Material combinations
- Today's driving forces for Li-Battery development
- State of the art technologies
- Chances and risks of using large lithium batteries for stationary applications
- R&D required
- Lifetime, costs and economical aspects

Why Lithium?

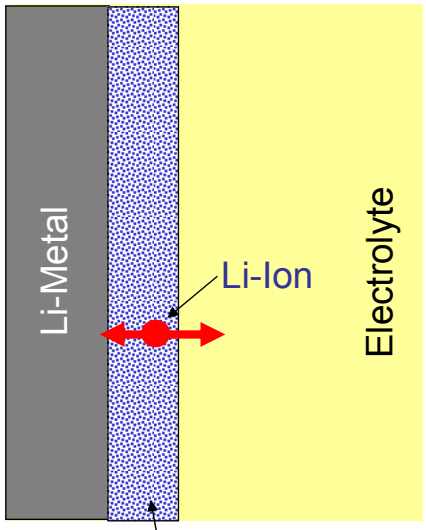


Lithium is the material with the most negative voltage → **high cell voltage**



Lithium is the metal with the lowest density. → **high specific Energy**

Why Lithium?



Lithium is able to form a protection layer that allows the transport of Li-Ions

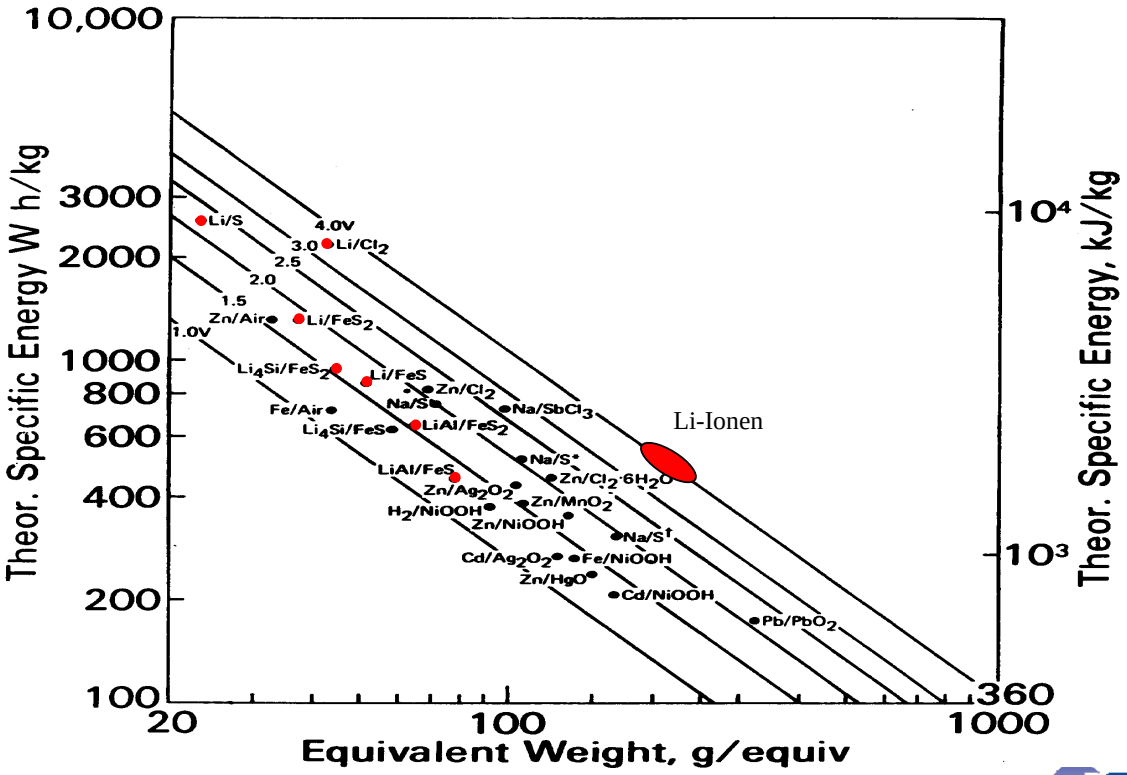
→ **Layer does not block current flow**

→ **Layer protects electrode**
→ **good lifetime is possible**

Lithium can be used for Batteries with **high cell voltage** and **high specific energy**

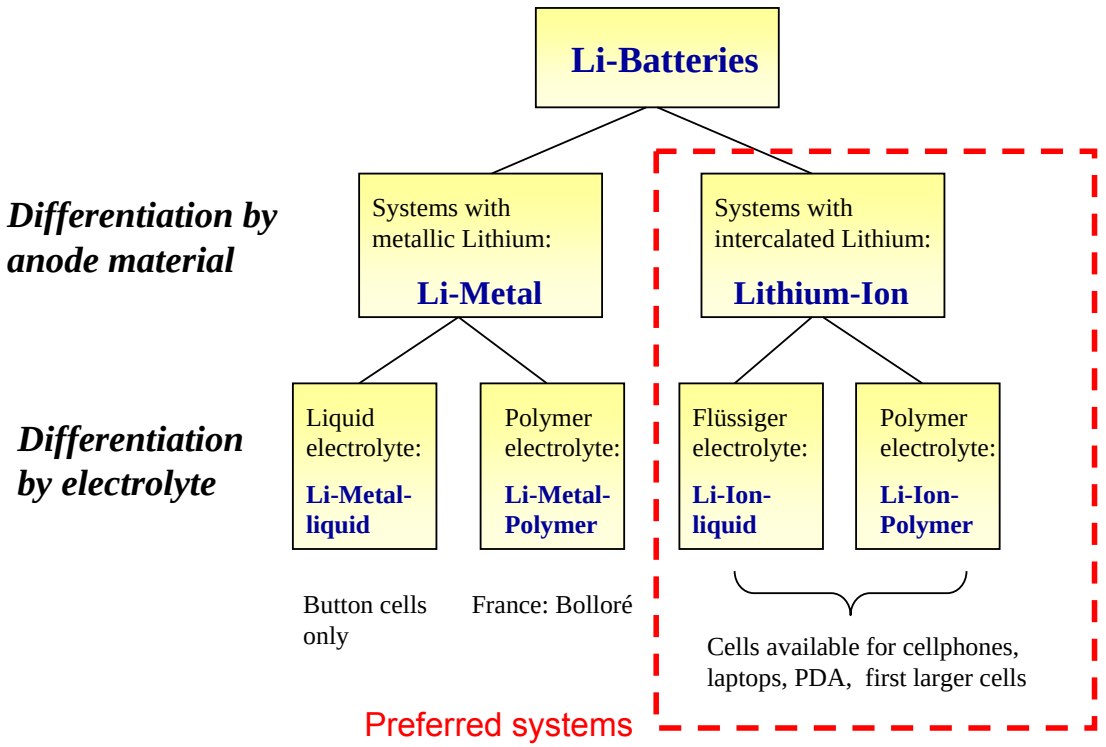
Protection Layer protects Lithium for further dissolution (Solid electrolyte interface / SEI)

Possible Lithium Systems

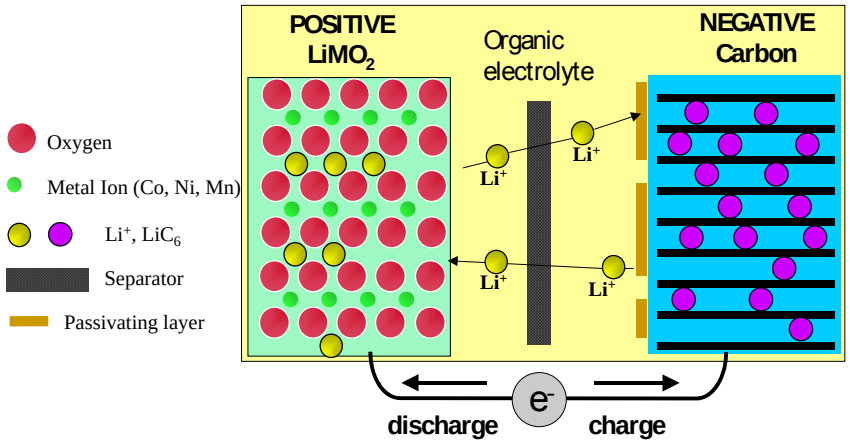


*E. J. Cairns, in “Lithium Battery Technology”, ed. by H. V. Venkatasetty, John Wiley & Sons (1984) 179

Types of Lithium Batteries



The Lithium-Ion System



Cell reactions: Discharged Charged

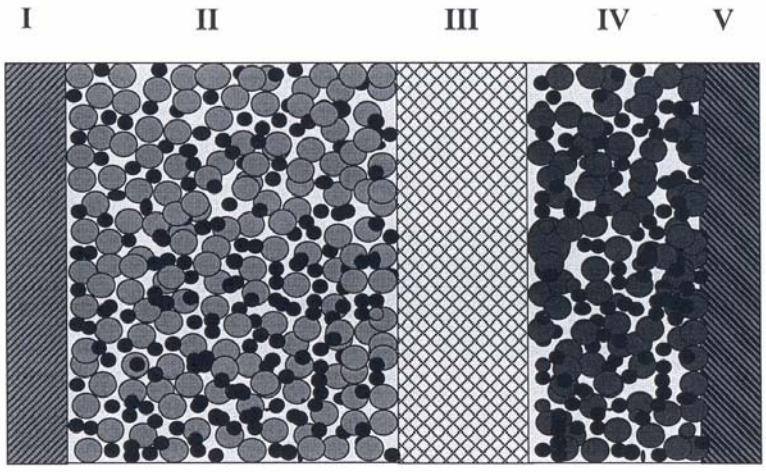
Positive: $LiCoO_2 \leftrightarrow Li_{1-x}CoO_2 + x\ Li^+ + x\ e^-$

Negative: $x\ Li^+ + C_6\ (graphite) + x\ e^- \leftrightarrow Li_xC_6$

Total reaction: $LiCoO_2 + 0.6\ C_6 \leftrightarrow Li_{0.4}CoO_2 + 0.6\ LiC_6$

No Li metal in the cell. The electrolyte does not participate in the cell reaction. It constitutes only a vehicle for Li-Ion transfer. No excess of electrolyte is therefore required.

Cell design of Li-Batteries



I: Al-Collector (18-25 µm)
II: Positive Electrode (40-200 µm)
III: Separator (16 – 35 µm)
IV: Negative Electrode (30-150 µm)
V: Cu-Collector (12-20 µm)

Thin electrodes are necessary!

Source: LTC-GAIA

Cell design of Li-Batteries

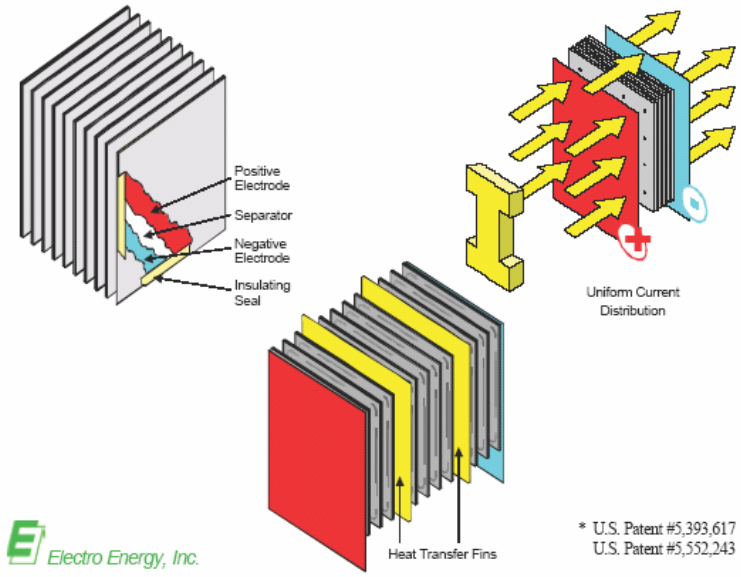
Cylindrical cell

Coffee bag cells

Prismatic cells

Cell design of Li-Batteries

Electro Energy Inc. received 1.5 Mio US $ for developing of a bipolar Li-Battery



Quelle: http://www.greencarcongress.com/ , 10. Nov 2005

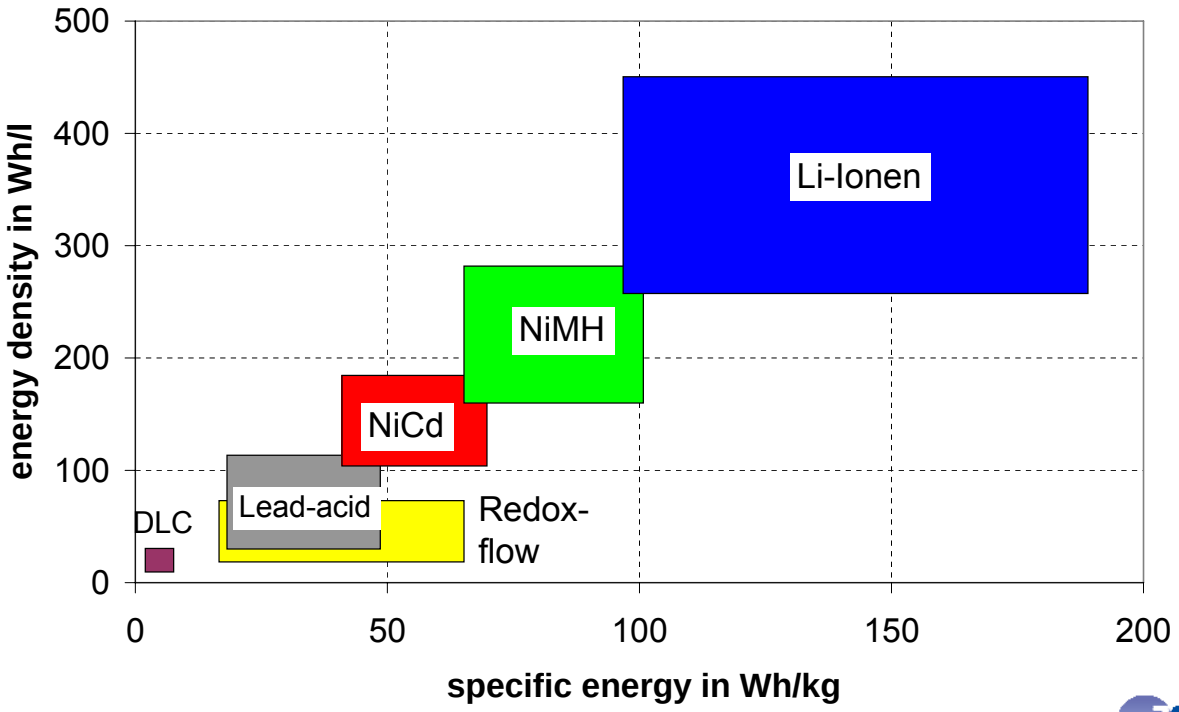
Battery System for Plug-In Hybrid

Li-Ion Battery
63 cells ($LiFePO_4$)
200V / 35Ah (7 kWh)

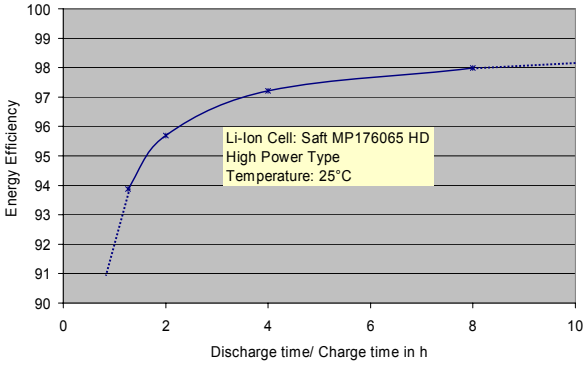
Battery-management with single cell voltage monitoring and charge-equalizing is required.

Source: GAIA

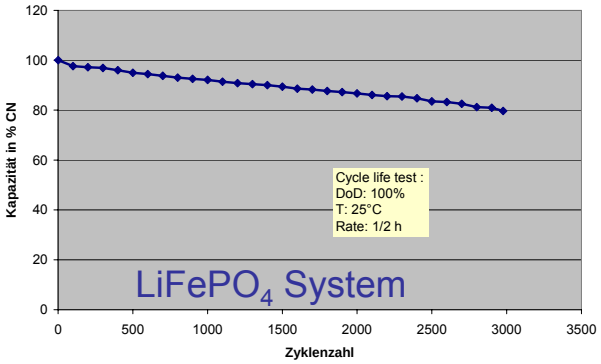
High Energy Storage



Good Performance Achieved

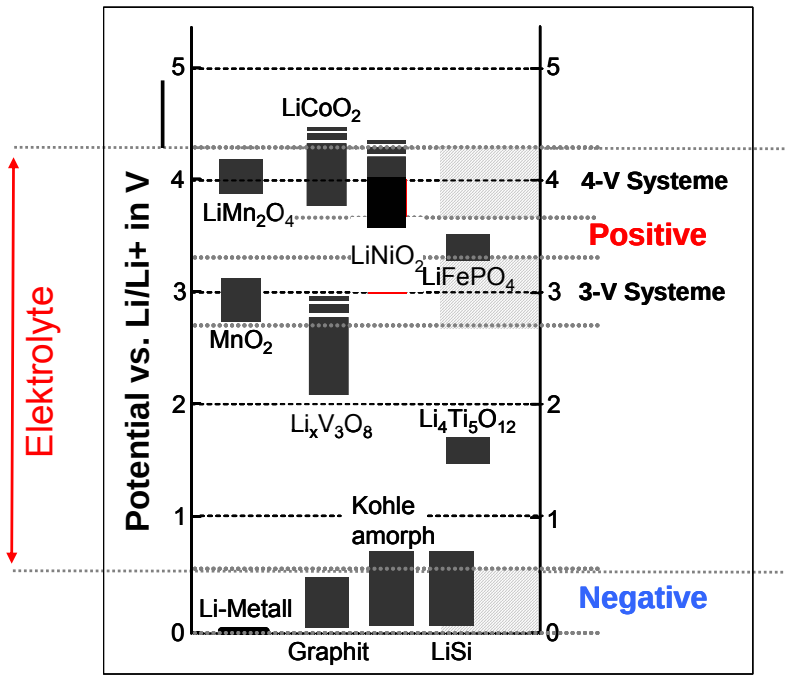


Lithium Batteries show an
excellent energy efficiency.
> 95% (2 h Rate)
> 98% (10 h Rate)

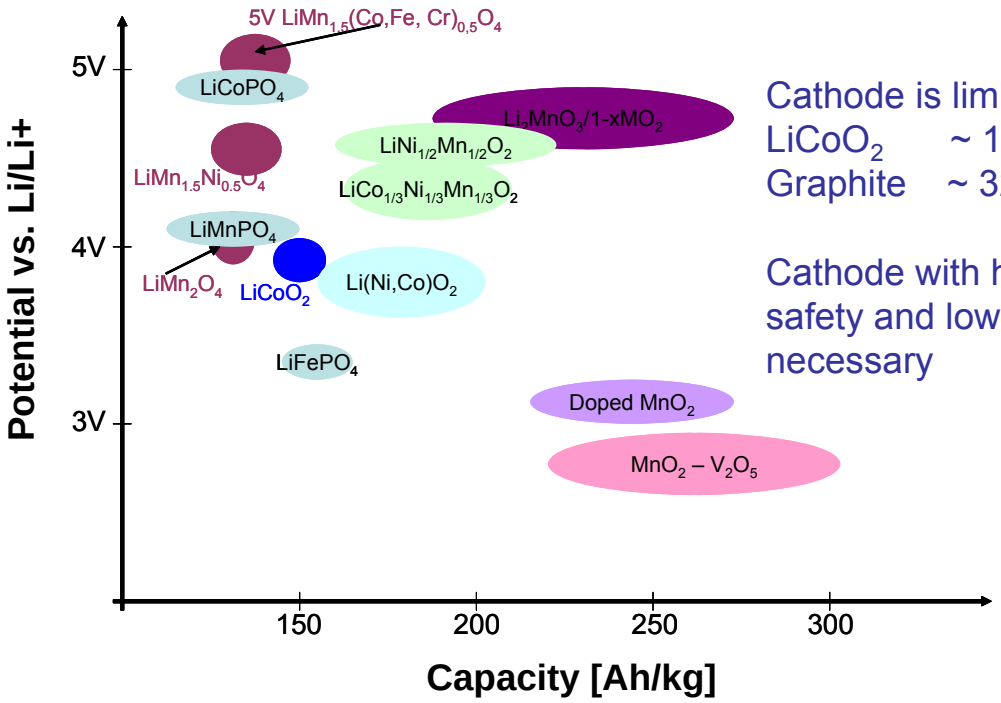


Lithium Batteries show a
long cycle life.
3000 cycles today

Materials for Lithium-Ion-Batteries



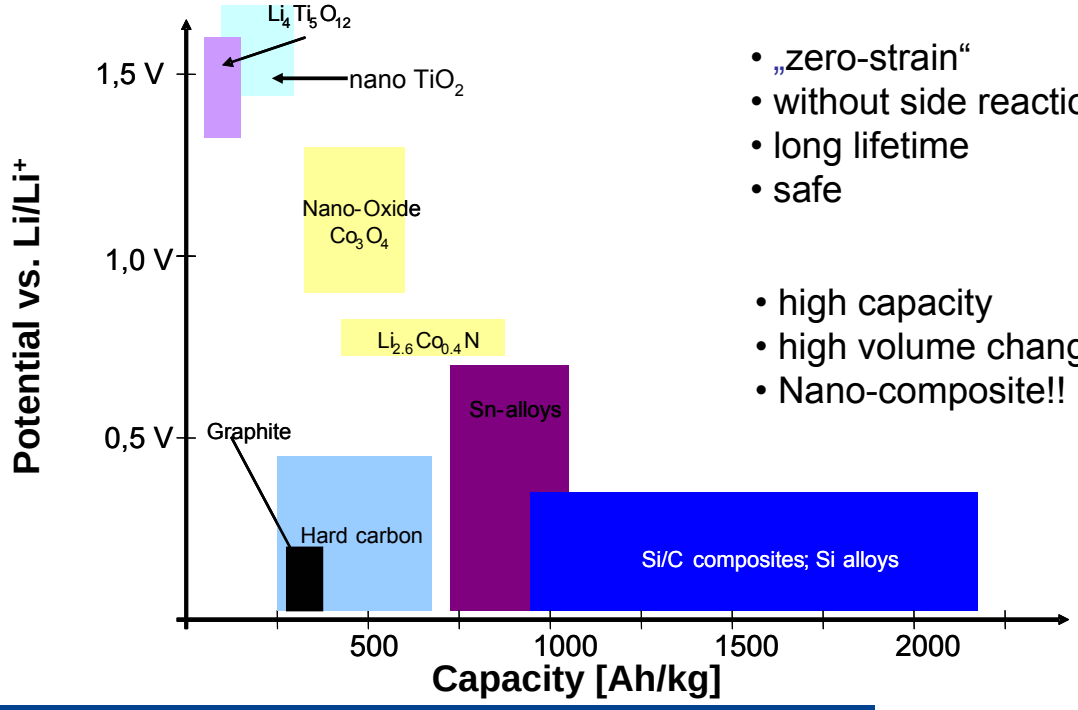
New Cathode Materials



Cathode is limiting
$LiCoO_2$ ~ 150 mAh/g
Graphite ~ 320 mAh/g

Cathode with higher capacity safety and lower costs necessary

New Anode Materials



- „zero-strain“
- without side reaction
- long lifetime
- safe

- high capacity
- high volume change
- Nano-composite!!

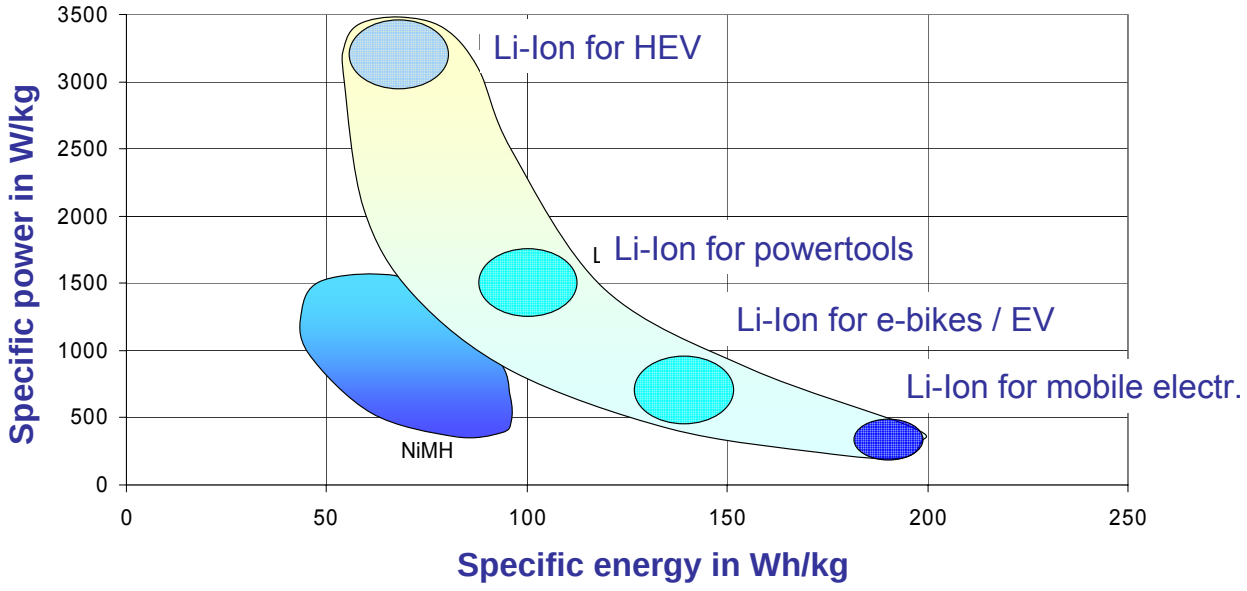
Today's Driving Forces in Li-Battery development

Mobile electronics (cellular phone, Laptop etc.) // < 100Wh
very high specific energy,
low cost,
2-3 years/200 cycles lifetime

Hybrid Electric Vehicle (HEV) // 1 kWh
high specific power,
low cost, safety,
>12 years lifetime@ shallow cycling

Plug in Hybrid Electric Vehicle (PHEV) // 5-20 kWh
medium specific power,
high specific energy
low cost, safety,
> 12 years lifetime@ deep cycling (4000 cycles)

Power and Energy of Li-Ion Batteries for different target applications



Technology Trends for Mobile Electronics

Increase off Cell capacity

- New anode materials

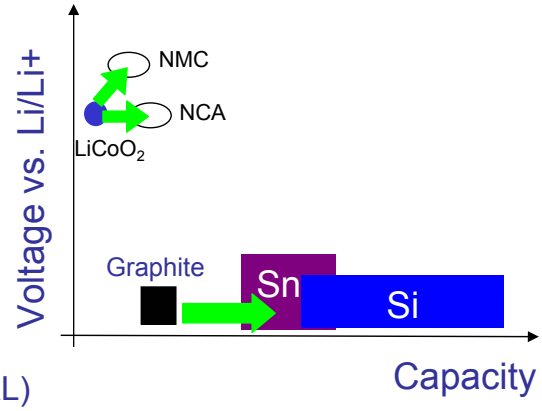
Si (Panasonic) based materials

Sn (Sony) based materials

- New Cathode Material to achieve higher cell voltage/higher capacity

NCA (Panasonic, Sony)

NMC (Sanyo)



Increase of battery safety

- Development of **heat resistance layer** (HRL)

Ceramic coated anode or cathode

Heat resistance polymer

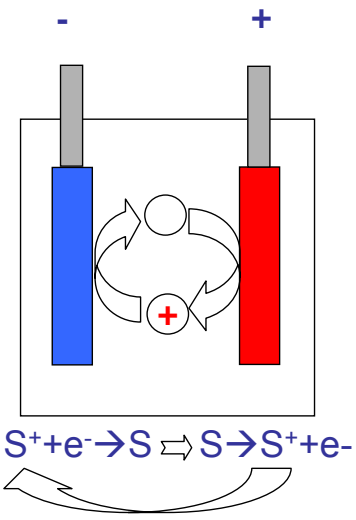
Ceramic coated Separator

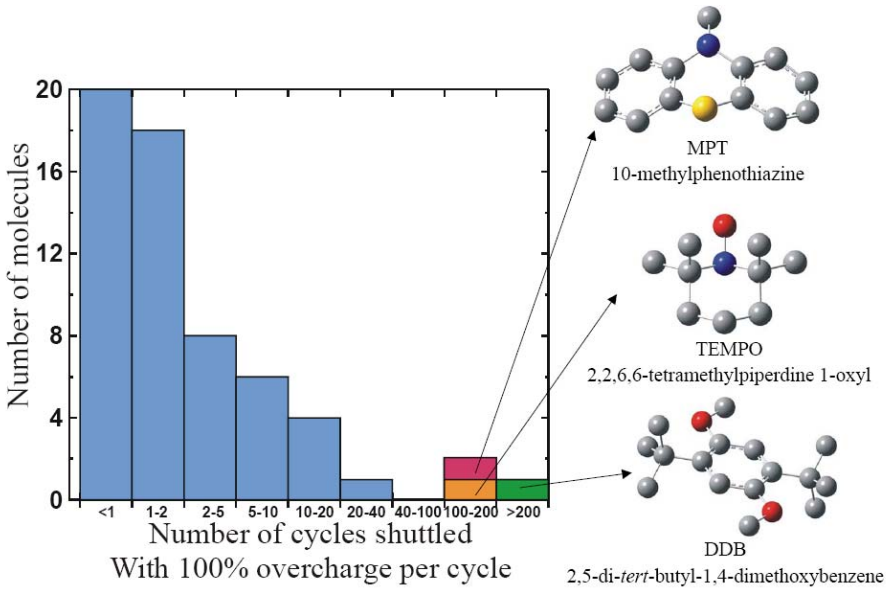
Lifetime is no critical factor

The increase of cell capacity will **reduce lifetime**

- 2 years calendar life
- 200 cycles

Additive for Shuttle-Process in Li-Ion Batteries as substitute for electronic charge equalization systems





J.R. Dahn, The Electrochemical Society Interface. Winter 2005

Technology Trends for Hybrid Electric Vehicles

Increase in power

- Increase of conductivity

Coating of Active material with carbon

- Increase of active area

Smaller particles and nano size particles

Increase in low temperature performance

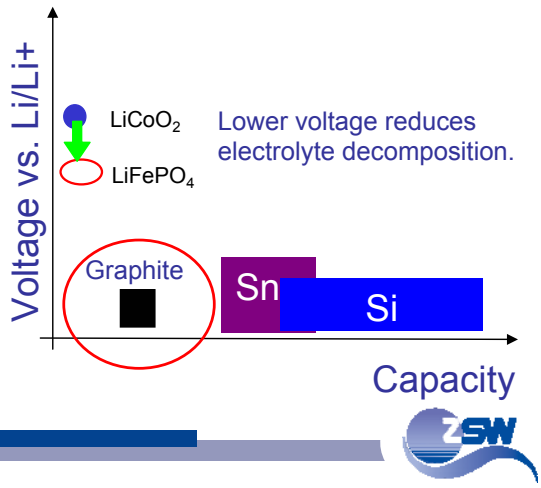
- New electrolytes
- smaller particle size

Increase in battery safety

- New cathode materials ($LiFePO_4$)
- New separator
- Safer electrolyte

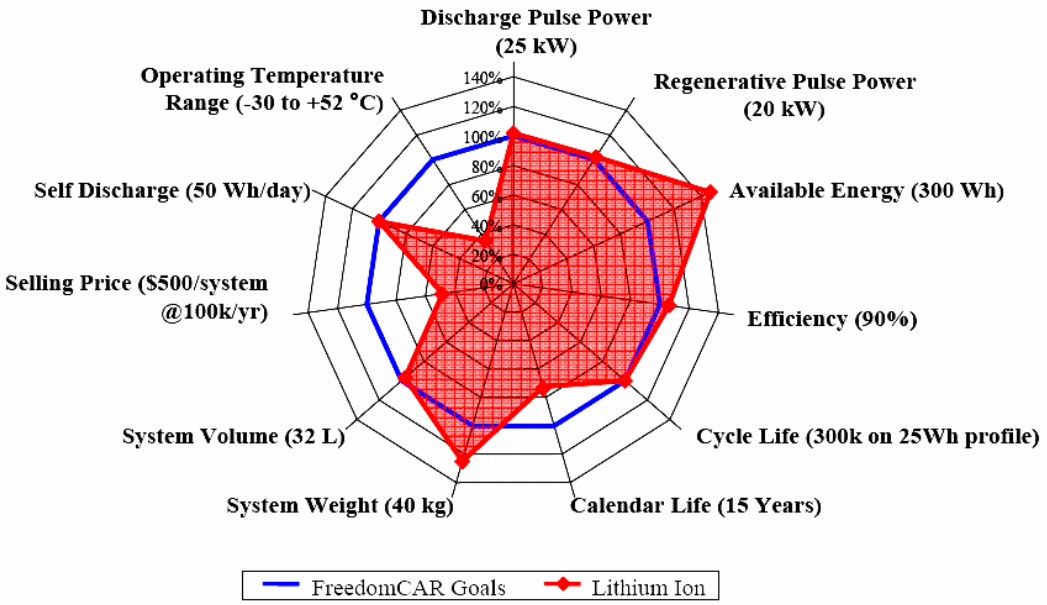
Increase in Lifetime

- Stable cathode ($LiFePO_4$)
- Improved electrolyte
- Optimized control strategy
- Calendar life at high SOC maybe critical



Li-Ion Batteries for Power Assist HEV

Status: Comparison with FreedomCar targets



Quelle: 2006 Annual progress report FreedomCar Group

Requirements for Stationary Li-Batteries

Increase of power → low priority

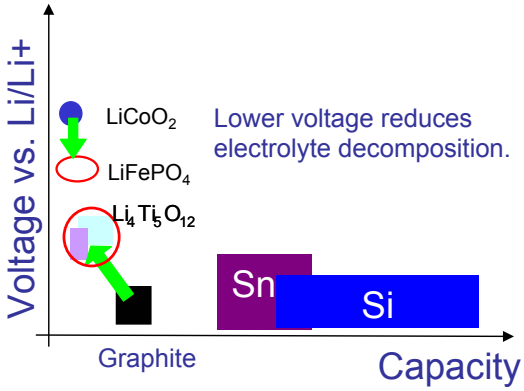
Increase of low temperature performance → low priority

Increase of battery safety → important

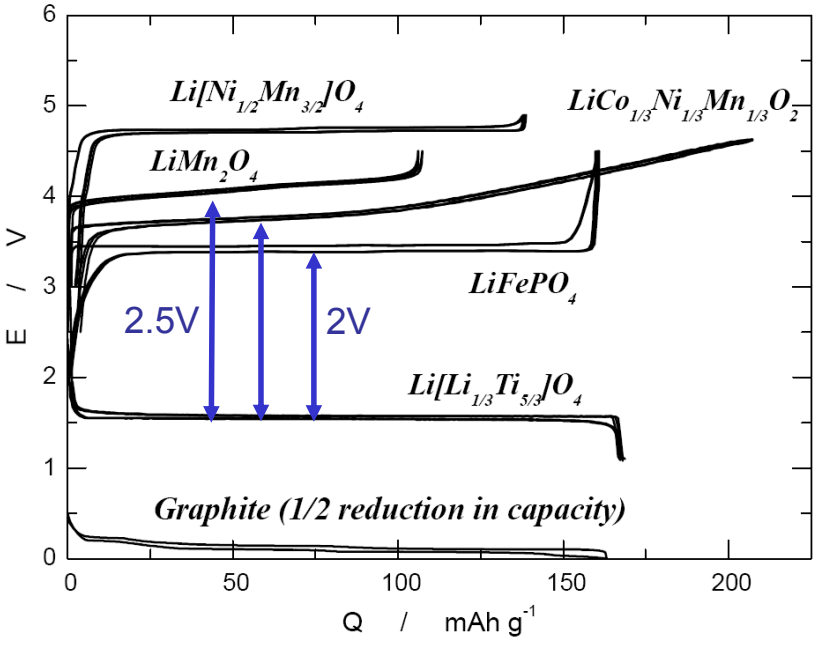
- New cathode materials ($LiFePO_4$)
- New separator
- Safer electrolyte

Increase of Lifetime → important

- Increase in cycle life
  Zero strain anode? Gives low cell voltage!
- Increase in calendar life at high state of charge
  Stable cathode ($LiFePO_4$)
  Improved electrolyte
  Optimized control strategy



Long Life 2V Lithium Battery



Long cycle life possible
(10 000 cycles + ?)

Long calendar lifetime
at high state of charge
(10 years + ?)

But
- only 50% of energy
- higher costs per Wh
- more resources necessary
- more cells necessary

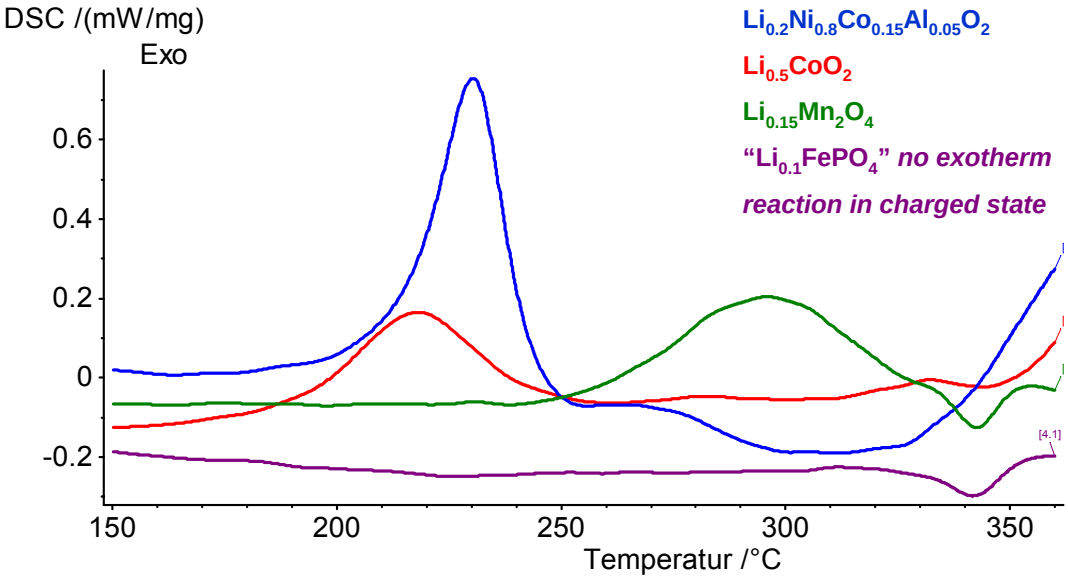
Source: Tsutomu Ohzuku, IMLB 2006

Battery Safety

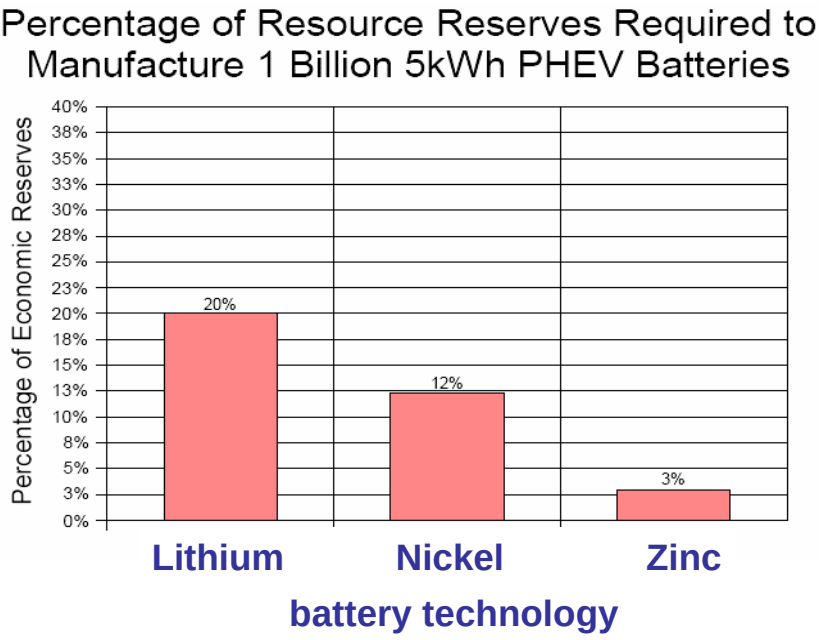
The safety of Li-batteries can be critical. Million of batteries were recalled in the last 2 years.

For large stationary systems safety is more critical.
Must be solved by
- new cathode materials
- new electrolytes
- Battery / cell design

Thermal Stability of different Cathode Materials

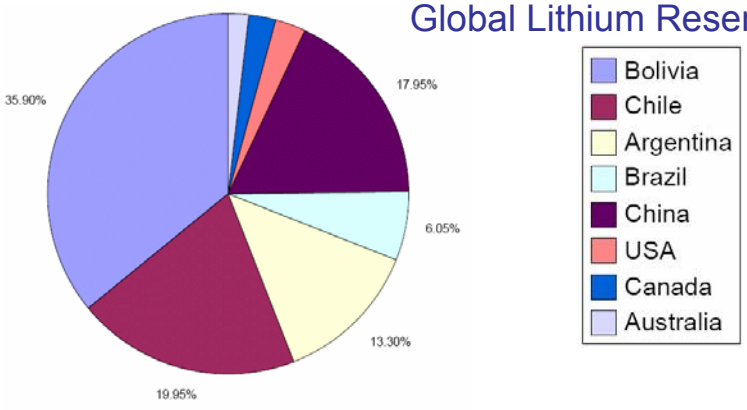


A lithium-economy has some limitations



Source: Meridian International Research

The trouble with Lithium

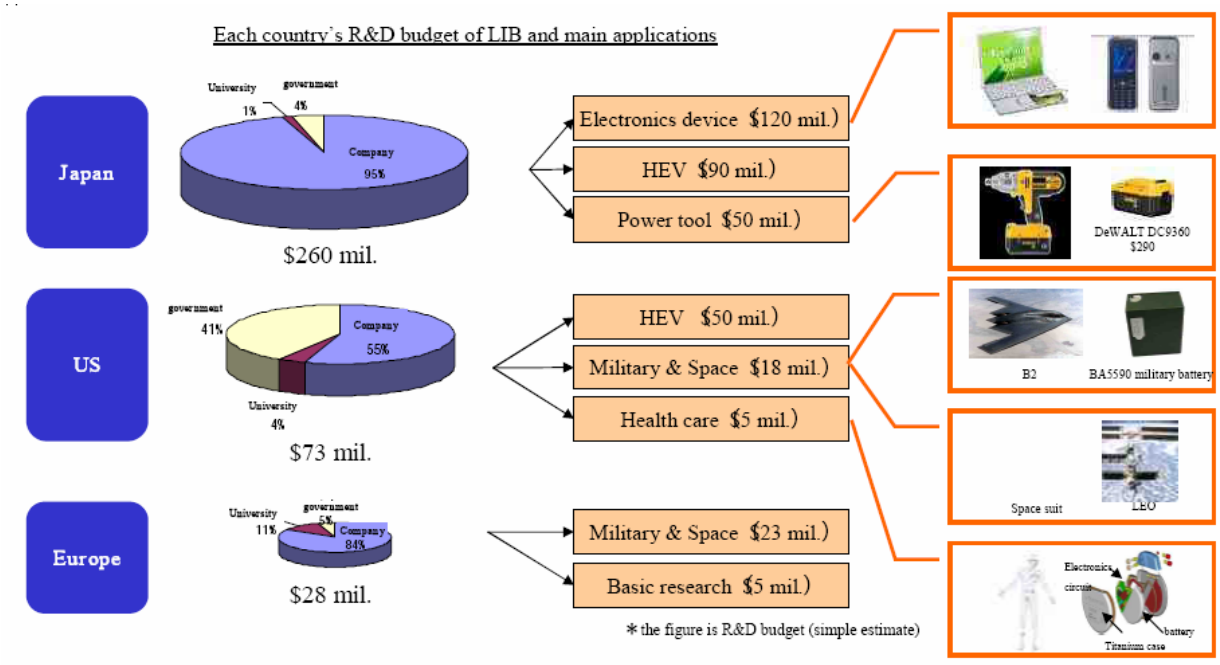


If Li batteries will enter automotive an stationary applications in relevant Market share we have to work on:

- Recycling of Li from used batteries
- Activating of Li resources
- Developing of Li batteries with high cell voltage
- Looking for none Li battery technologies

Source: Meridian International Research

R&D in Li-Batteries



Source: Namura-Report 2006

R&D required for large stationary Li-Batteries

- Further improvement of intrinsic battery safety by use of new cathode materials and improved electrolytes and separators.
- Cost reduction, by new cathode materials, improved engineering and finally mass production.
- Development of Li-batteries that are optimized for stationary applications. Today most R&D is concentrated on mobile electronics and automotive applications.
- Development of new, long-life generation of lithium batteries (2V types are maybe an option).
- Control strategy for lithium ion batteries is totally different from that of other battery technologies.
- Battery state determination methods for $LiPFO_4$ and other systems with flat discharge voltage curve.

Summery

- Li-batteries show the highest specific energy (up to 200 Wh/kg) of available rechargeable battery systems.
- Today Li-batteries are market leader in portable power sources
- Li-batteries have a high technology potential for further improvement. Today >90% of battery R&D is done on Li-batteries.
- Upscaling of lithium batteries from 100 Wh storage to large stationary systems requires further R&D with the targets:
  - lower costs
  - improved battery safety
  - longer lifetime
- New Li-battery technologies optimized for stationary applications will show excellent performance, but some technologies will have higher specific costs.
- A “Lithium economy” is maybe limited by the available Li-resources.
- Lithium battery R&D in Europe low
- Worldwide no Li-battery R&D focus on stationary applications