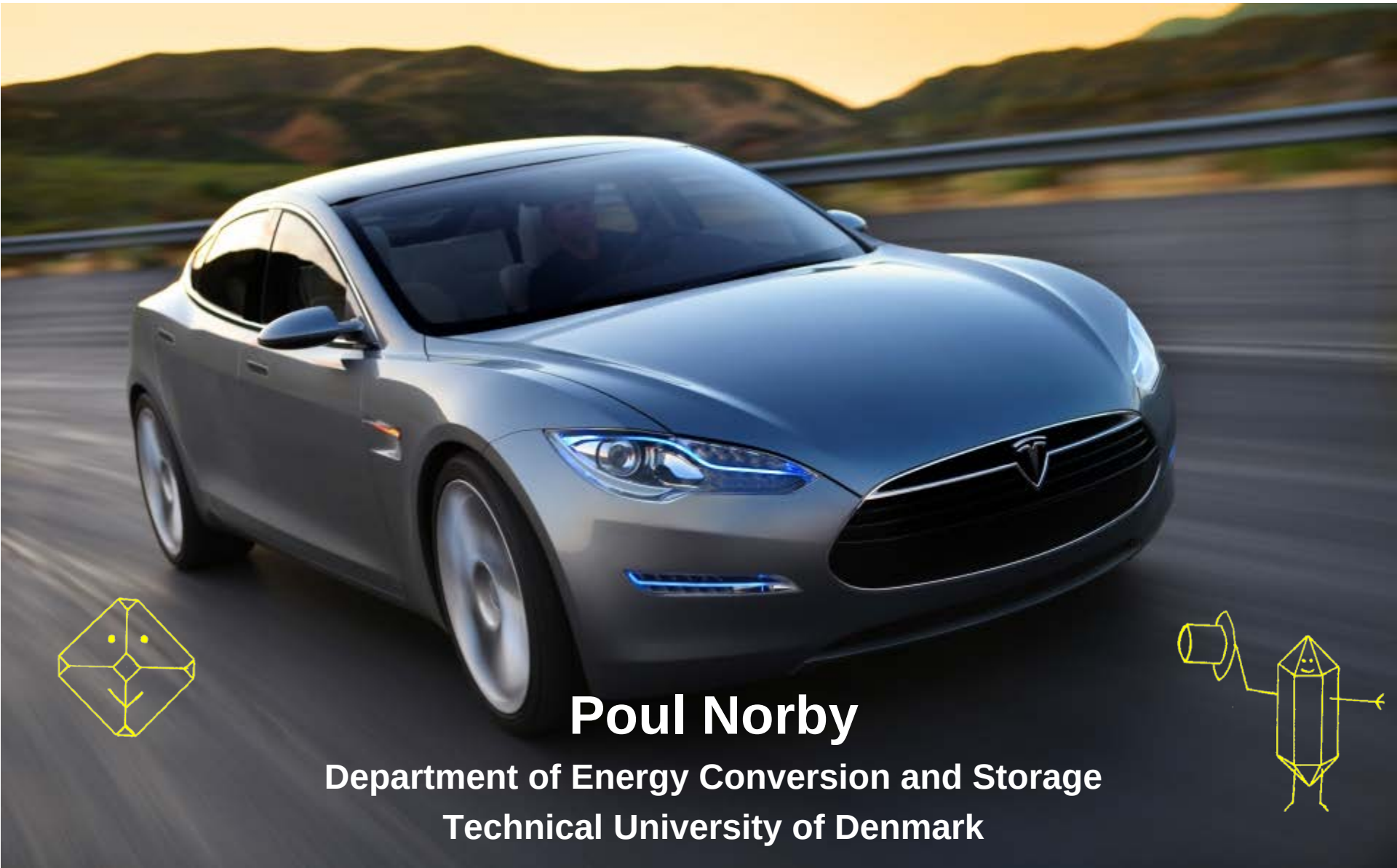
Lithium Batterier til transport; perspektiver og status



Poul Norby

Department of Energy Conversion and Storage

Technical University of Denmark

Western Europe Electric Passenger Car Sales by Market

Market	Sep 2013 Electric	Sep 2013 Electric Share	Sep 2012 Electric	Sep 2012 Electric Share	% Electric Change	9-Mths 2013 Electric	9-Mths 2013 Electric Share	9-Mths 2012 Electric	9-Mths 2012 Electric Share	% Electric Change
France	644	0.45%	514	0.37%	25.3%	6,318	0.48%	4,339	0.30%	45.6%
Norway	1,044	8.58%	583	5.24%	79.1%	4,250	4.02%	2,983	2.86%	42.5%
Germany*	556	0.22%	207	0.08%	168.6%	4,156	0.19%	2,730	0.12%	52.2%
United Kingdom*	538	0.13%	322	0.09%	67.1%	2,538	0.14%	1,494	0.09%	69.9%
Netherlands*	431	1.37%	368	1.15%	17.1%	2,477	0.82%	2,800	0.66%	-11.5%
Sweden	94	0.39%	189	0.86%	-50.3%	1,090	0.56%	603	0.30%	80.8%
Switzerland	126	0.56%	78	0.37%	61.5%	695	0.31%	621	0.25%	11.9%
Italy	69	0.06%	20	0.02%	245.0%	588	0.06%	358	0.03%	64.2%
Spain	43	0.10%	16	0.05%	168.8%	433	0.08%	288	0.05%	50.3%
Austria	68	0.27%	49	0.18%	38.8%	414	0.17%	309	0.12%	34.0%
Belgium	87	0.25%	36	0.11%	141.7%	352	0.09%	580	0.15%	-39.3%
Denmark	86	0.59%	44	0.32%	95.5%	331	0.24%	415	0.32%	-20.2%
Portugal	9	0.12%	5	0.08%	80.0%	126	0.16%	39	0.05%	223.1%
Finland	9	0.11%	6	0.07%	50.0%	68	0.08%	88	0.10%	-22.7%
Eire	4	0.13%	3	0.12%	33.3%	40	0.06%	132	0.17%	-69.7%
Greece	0	0.00%	0	0.00%	-	0	0.00%	0	0.00%	-
Western Europe	3,808	0.34%	2,440	0.23%	56.1%	23,876	0.27%	17,779	0.20%	34.3%

** = Germany 2012 EV sales adjusted as Opel Ampera included, UK 2012 EV sales adjusted as official figures adjusted, Netherlands 2012 revised figure*

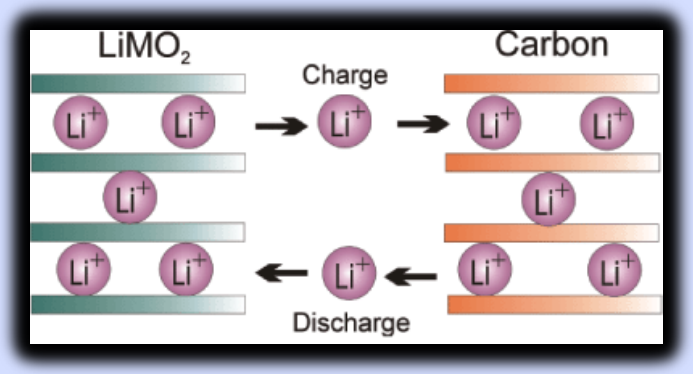
Source: AID/Industry Sources

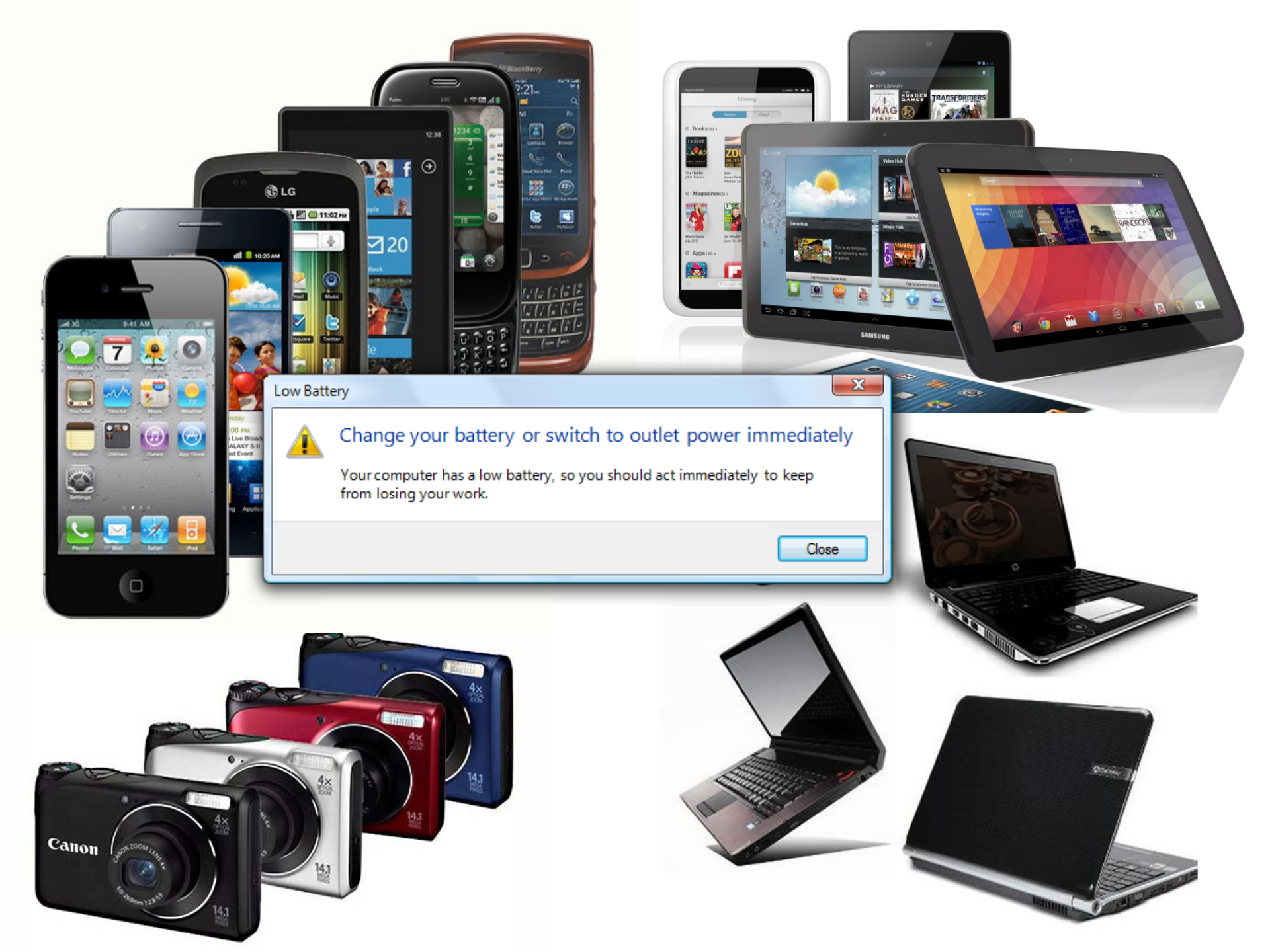
Norge: Mest solgte bil i: oktober 2013: Nissan Leaf

september 2013: Tesla S

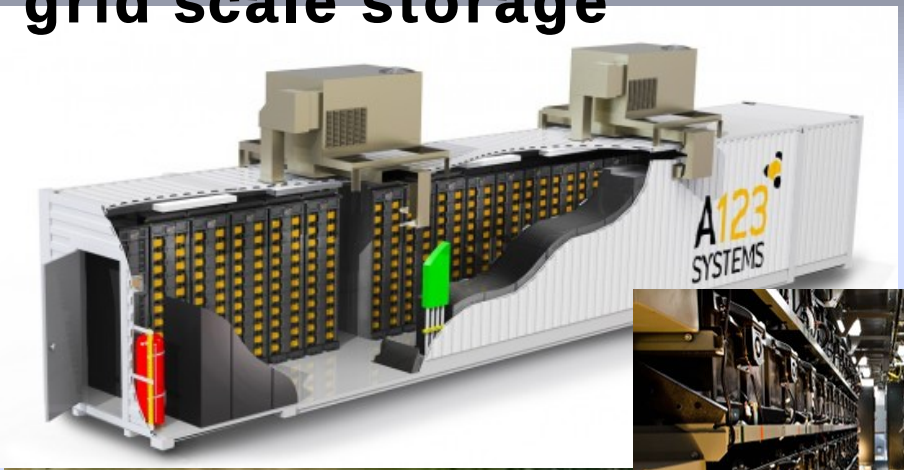
Lithium-based batteries

- Lithium batteries
  - Primary lithium batteries uses metallic lithium
  - Rechargeability hindered by dendrites
- Lithium-ion batteries
  - Secondary battery
  - Uses intercalation of Li^+ ions into carbon electrodes
  - Commercialized in 1991
  - Invention is credited to John Bannister Goodenough and Rachid Yazami




Low Battery
Change your battery or switch to outlet power immediately
Your computer has a low battery, so you should act immediately to keep from losing your work.
Close
LG
SAMSUNG
Canon

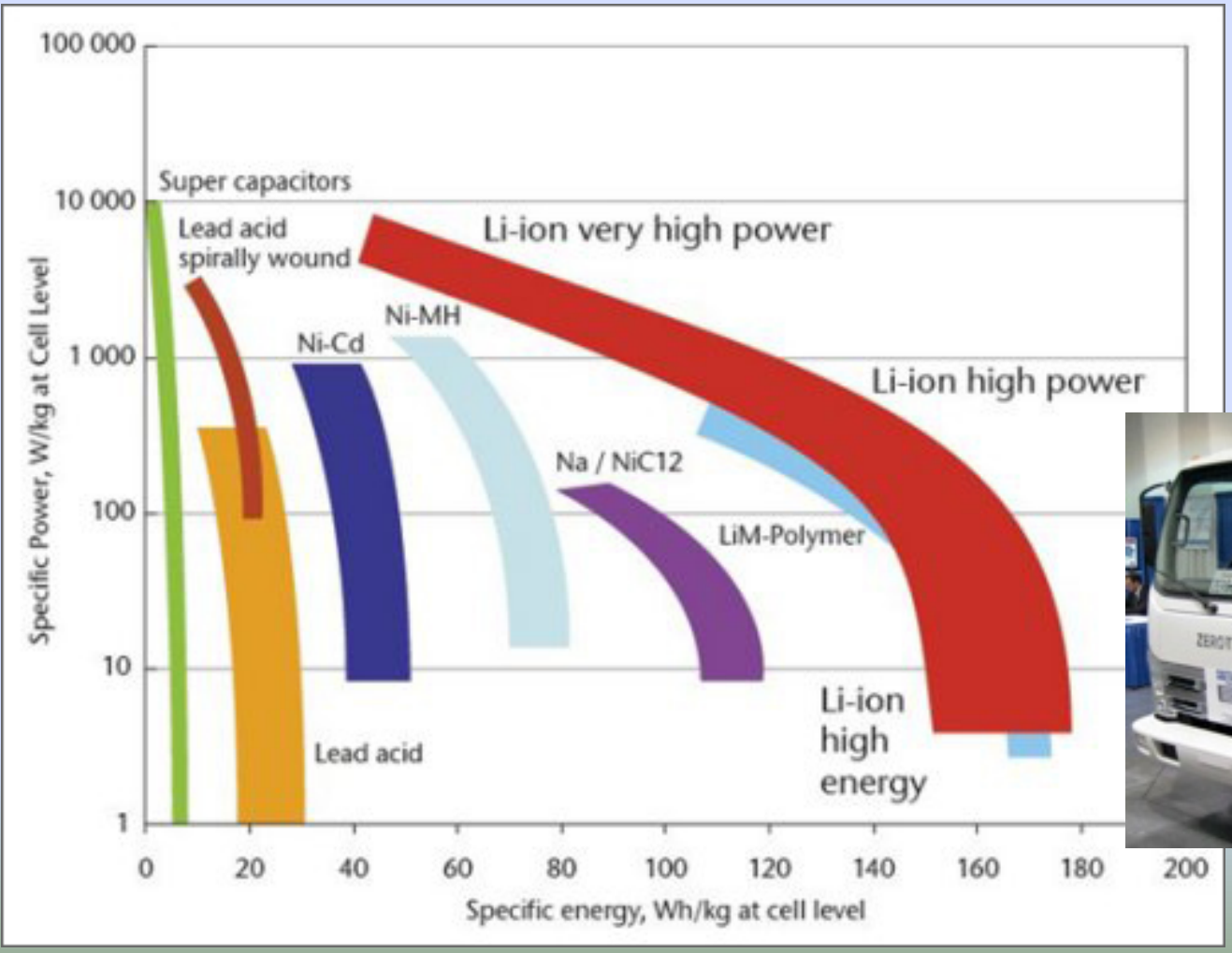
Lithium batteries for large grid scale storage



Lithium batterier til transport:

Høj energitæthed – høj energieffektivitet – lav selvafladning -

Fremtidens løsning, men stadig mange udfordringer.



- Pris
- Sikkerhed
- Energitæthed (kWh/kg og kWh/L)
- Effekttæthed (W/kg)
- Bæredygtighed/grundstofressourcer

Priserne for lithium batterier falder hurtigere end forventet

Det er vanskeligt at finde priser for lithium batterier til elbiler.

Forudsigelserne af batteripriser varierer meget, men priserne er igennem de seneste få år faldet mere end forventet.

Nylige forudsigelser forventer priser på 250-350$/kWh i løbet af de næste få år (2015) og et fald til 180$ i 2020.

Sikkerhed

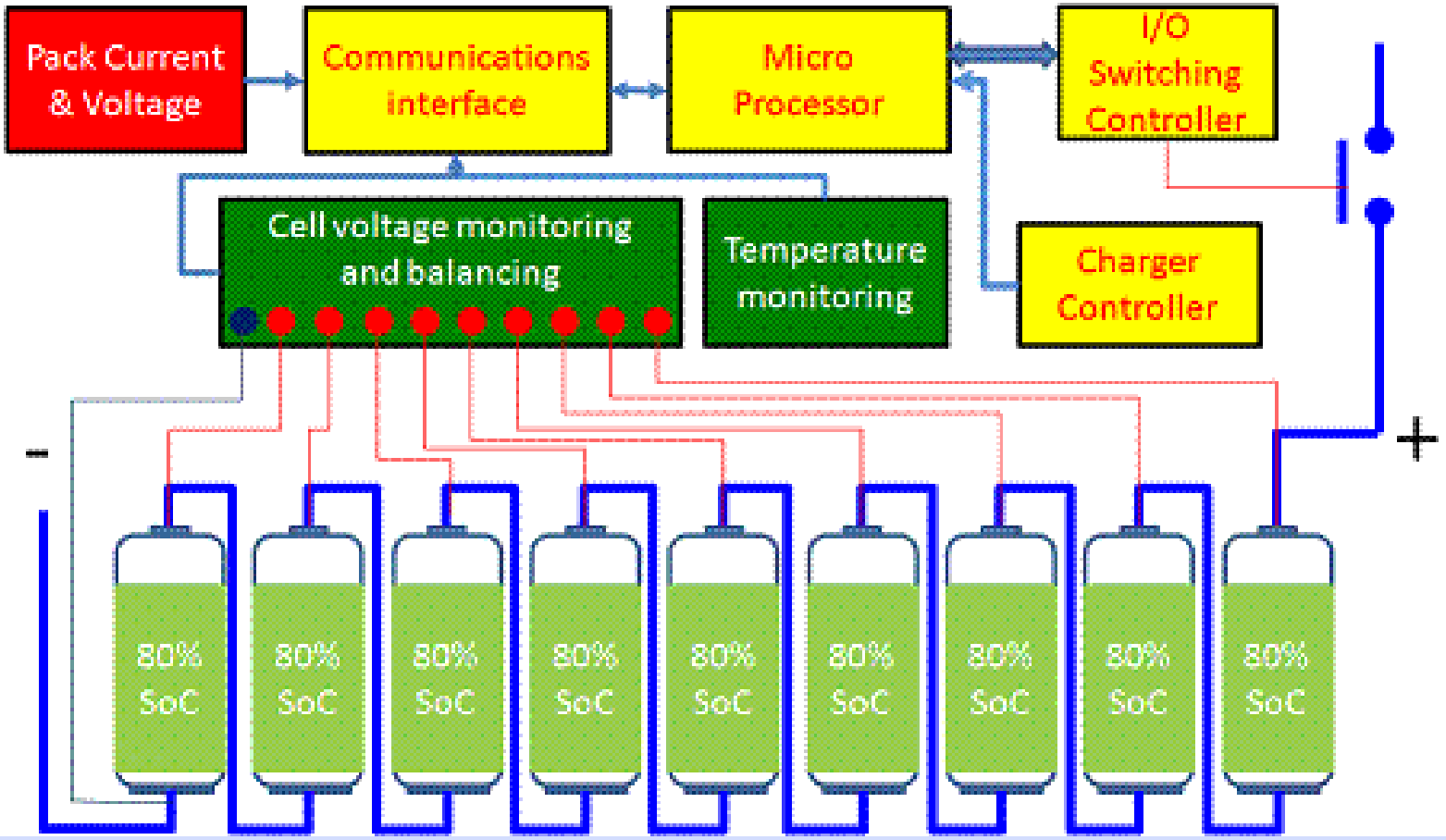
Jo højere energitæthed, des mere energi kan der potentielt frigives!

Sikkerheden for batterier i biler er meget vigtig, med tæt på nul-tolerance for fejl. Dette er en udfordring ved større batteripakker, som består af mange celler.

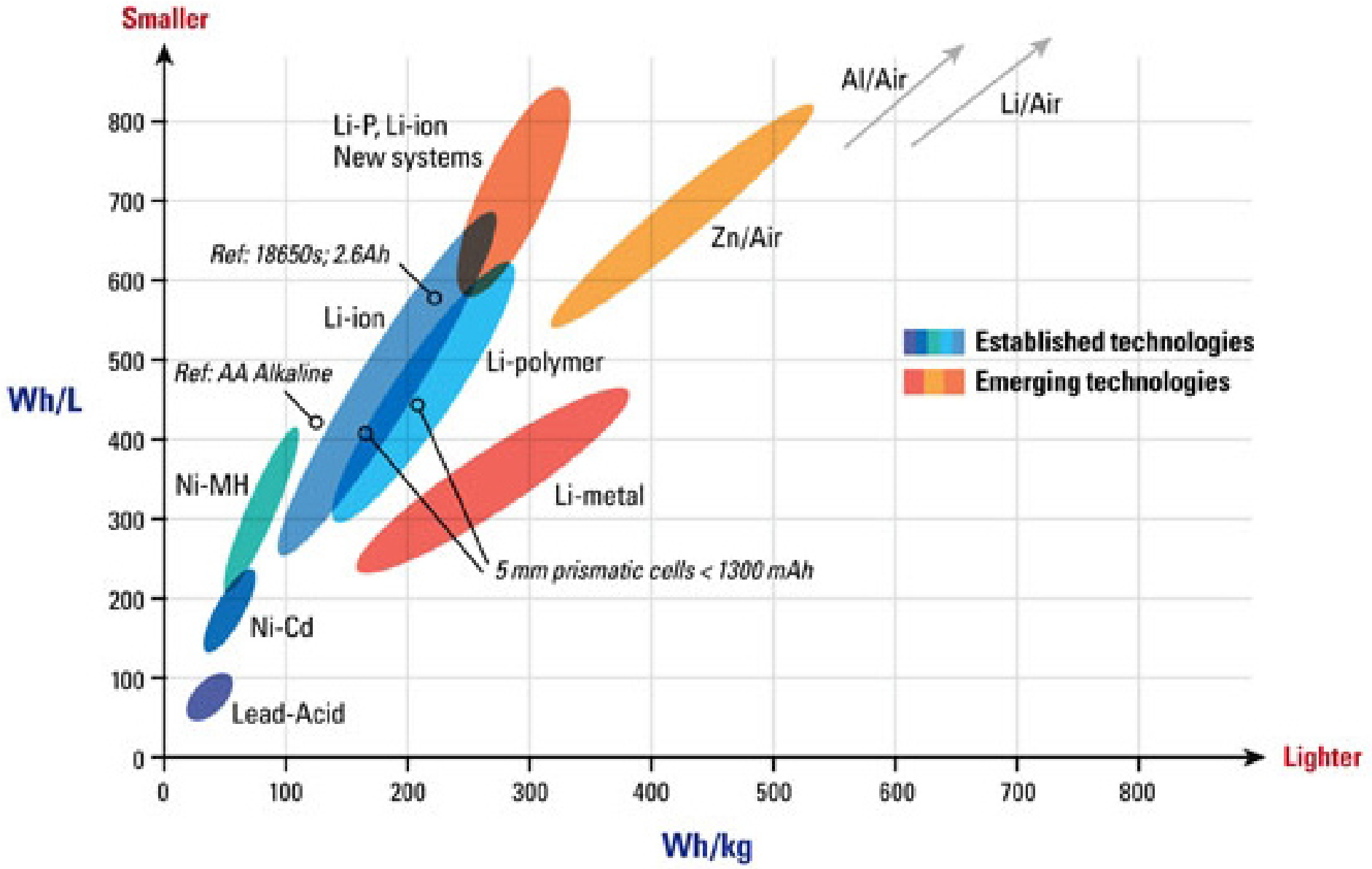
Lithium batterier kræver et batteristyresystem (BMS, Battery Management System) for at fungere sikkert, effektivt og med minimum af slid på batteriet.

Kontrollerer ladetilstand, advarer ved fejl og afbryder batteritilslutning ved f.eks. uheld.

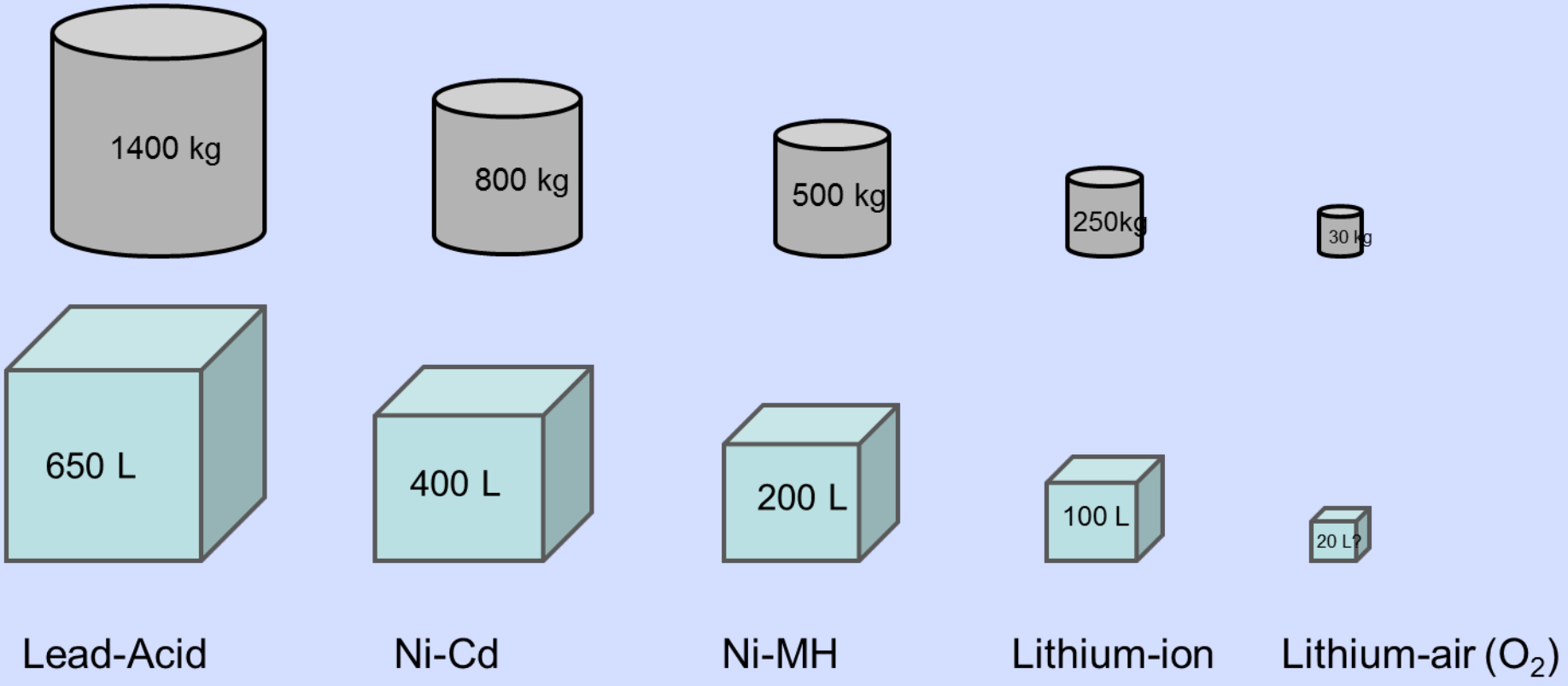
Generic BMS Elements



From: LiTHIUM BALANCE (lithiumbalance.dk)


Smaller
Lighter
Wh/L
Wh/kg
0
100
200
300
400
500
600
700
800
Li-P, Li-ion
New systems
Ref: 18650s; 2.6Ah
Li-ion
Li-polymer
Ref: AA Alkaline
Ni-MH
Ni-Cd
Lead-Acid
Li-metal
5 mm prismatic cells < 1300 mAh
Zn/Air
Al/Air
Li/Air
Established technologies
Emerging technologies

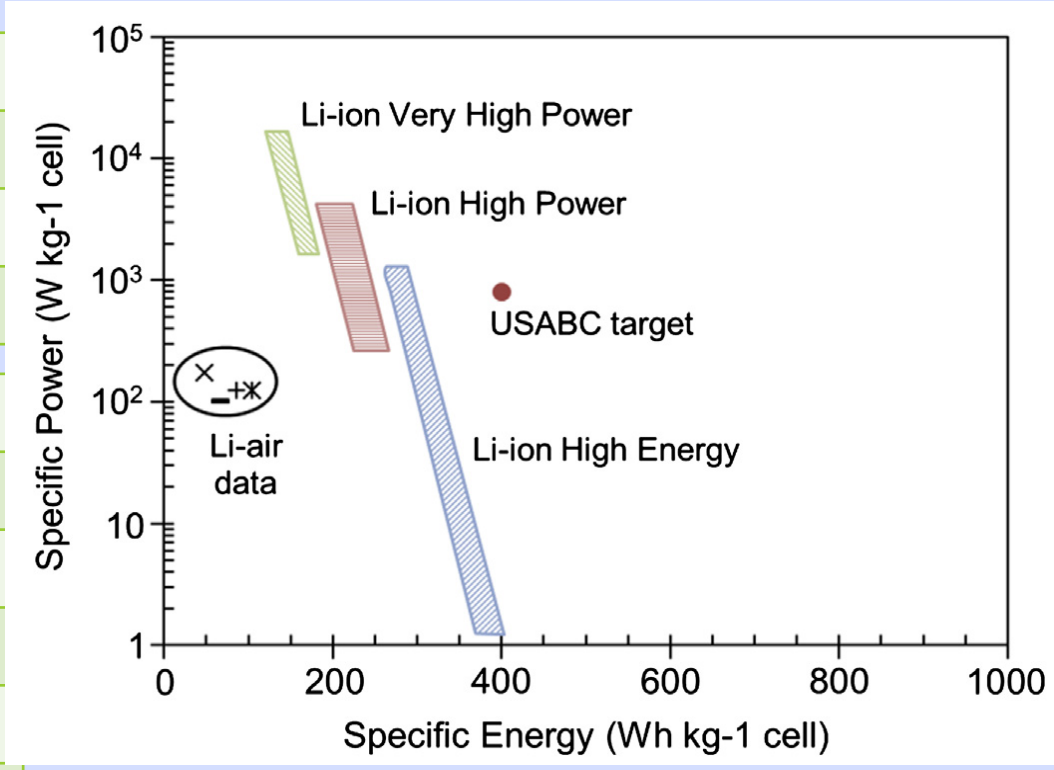
Batteries for electrical vehicles:
Example: 50kWh battery (ca. 200 km driving range)



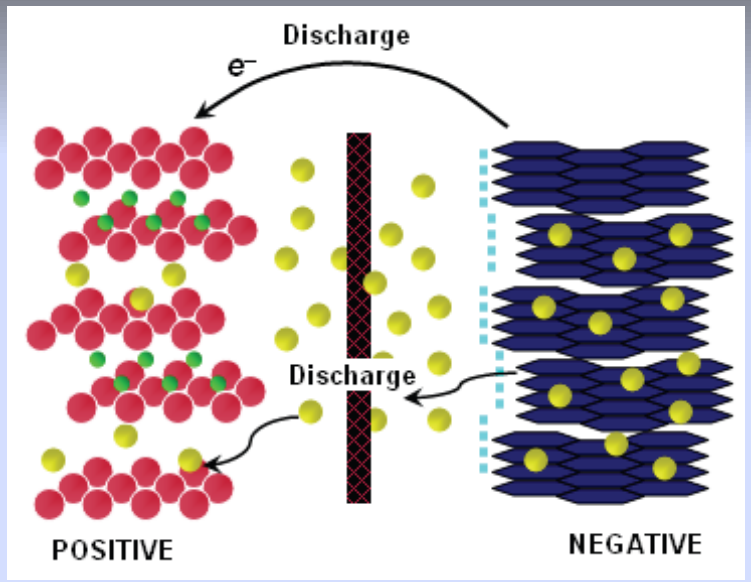
Outlook

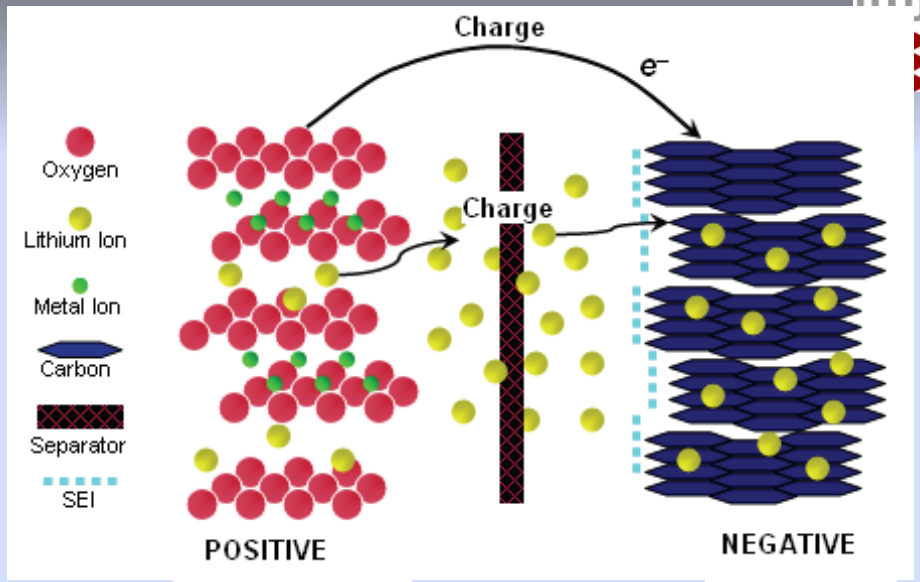
Assumed EV requirements	
Range	600 km
Engine power	150 kW
Voltage	360 V

Derived battery requirements	
Pack size	120 kWh
Number of cells	125
Cell capacity	350 Ah
Peak current	420 A
Peak C-rate (driving)	1.2 C



Source: J. Adams et al., "Evaluation and electrochemical analyses of cathodes for lithium-air batteries," *Journal of Power Sources*,239,132–143,2013





Anode: Grafit, $LiTi_2O_7$...

Elektrolyt: Organisk (f.eks. karbonater) eller polymer

+ Li-salt (f.eks. $LiPF_6$)

Katode:

Li_xCoO_2, $Li_xMn_2O_4$, Li_xFePO_4

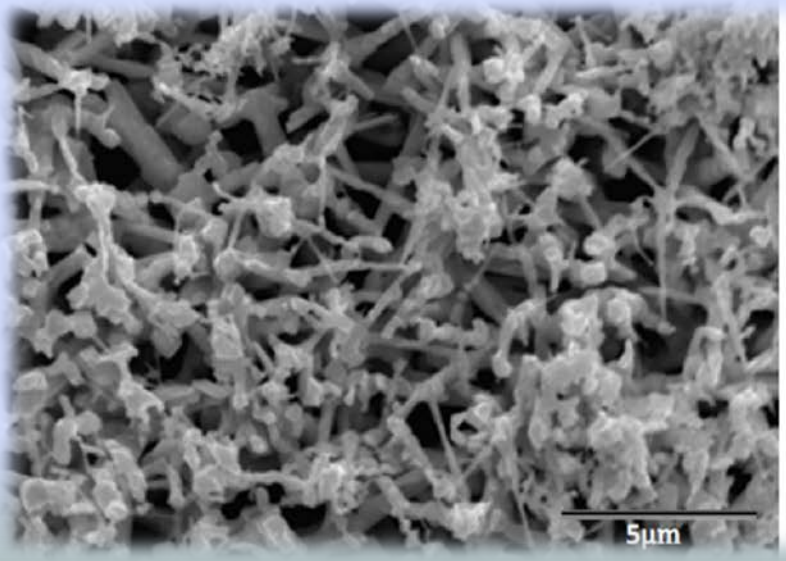
NMC: $Ni_{1/3}Mn_{1/3}Co_{1/3}O_2$

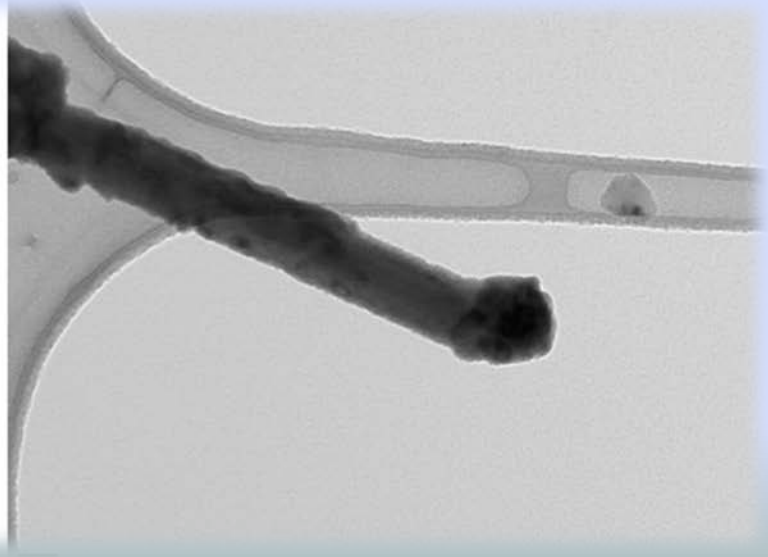
Advanced Lithium-ion batteries

Increasing the specific energy:

- Increase the voltage (→ 5V technology)
- Use high-capacity anodes (silicon, tin…)
- Use more than one electron/transition metal ion (e.g. Fe(II)-Fe(III)-Fe(IV))
- Use other types of chemistry (non-transition metal)

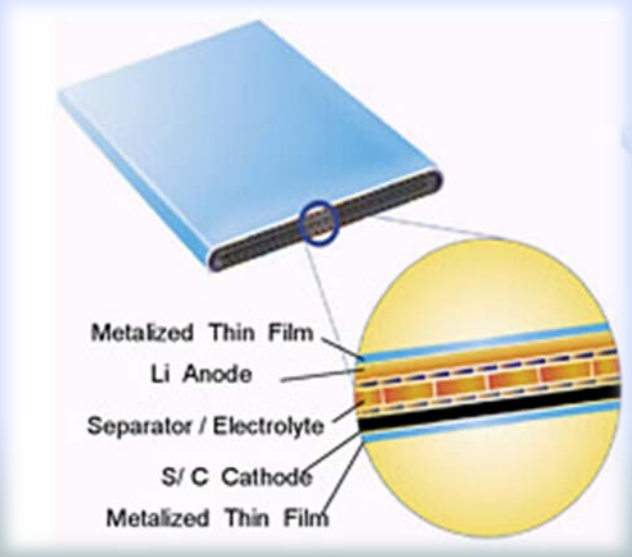
Specific energy target: ~400 Wh/kg

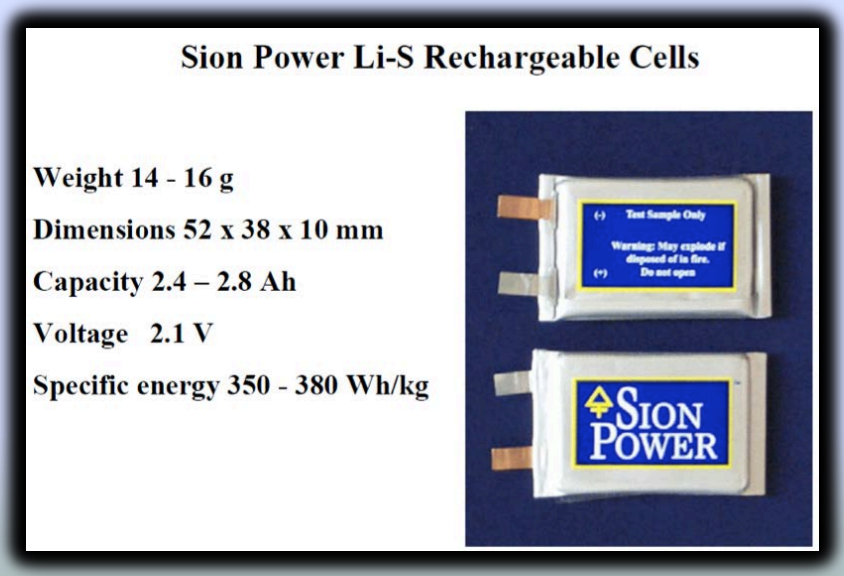


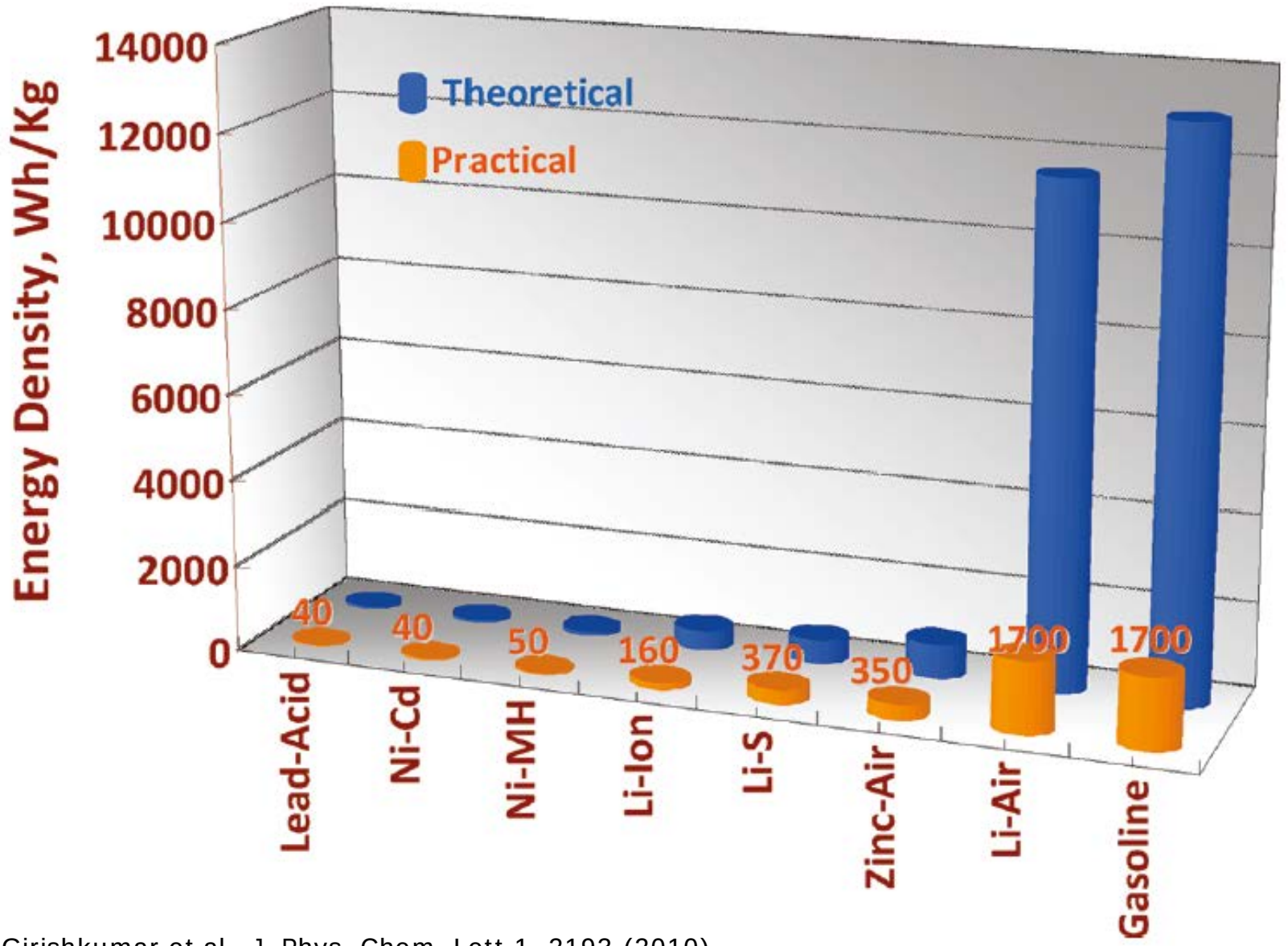


Lithium-SULFUR batteries

- Uses metallic lithium and lithium-sulfur electrodes
- Current generation has low voltage and limited power capabilities
- The cycle life is not well documented, current research states ~1000 cycles





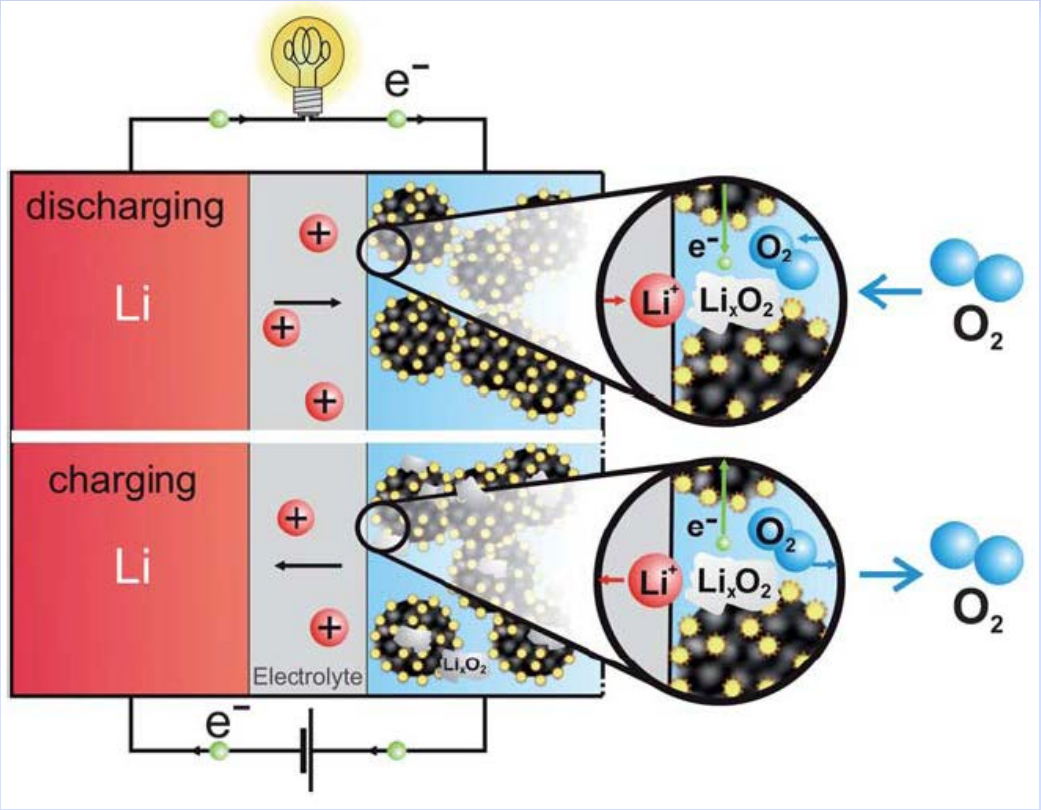


Girishkumar et al., J. Phys. Chem. Lett.1, 2193 (2010)

Reversible Metal-Air batteries

Lithium-air battery

(Lithium-oxygen)



Operating principle:

- During discharge O_2 is consumed
- During charge O_2 is released

ReLiable: Reversible Lithium-Air Batteries

The Danish Council for Strategic Research

Future batteries, overview

- Lithium-ion
  - Optimization of materials and electrolyte
  - Possible high-voltage lithium-ion batteries, ~5V
- Lithium-sulfur
  - Intermediate stage of development, few commercial cells
  - May end up replacing lithium-ion in ~5 years
- Lithium-air
  - Early stage of development, no commercial products
  - At least 10 years before commercially mature

Konklusioner

- Batterier til elbiler bliver stadig billigere og bedre.
- Prisen på batterier er stadig den største hindring for en hurtig udbredelse af elbiler.

- Nødvendige elementer i udvikling af batterier:
  - Pris: Billigere materialer og fremstilling, volumen fordele.
  - Energitæthed/rækkevidde. Forskning og udvikling er nødvendig
    - Kort sigt: Konventionel Li-ion teknologi med højere spænding, hurtigere op- og afladning
    - Mellemlangt sigt: andre teknologier, som er på vej til kommercialisering, f.eks. Li-S
    - Langt sigt: revolutionerende teknologier, metal-luft (lithium-luft)