

Beispiel 4

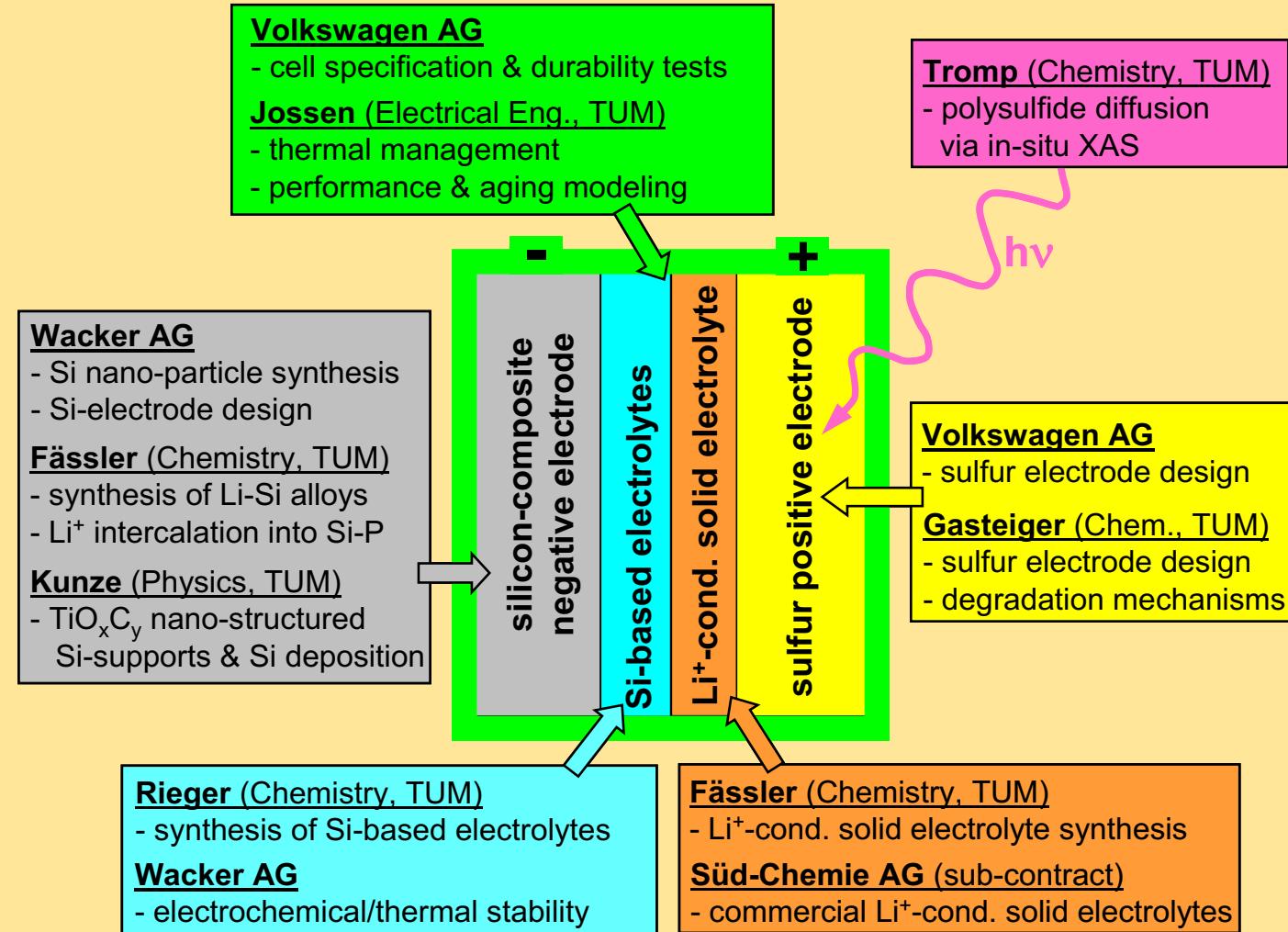
Elektrochemie



Hubert Gasteiger

Lithium-Sulfur/Silicon Battery Research

- ❑ coordinating a collaborative project on Li-S/Si battery materials development & design
 - up to 2-fold higher energy content (Wh/kg) compared to lithium-ion batteries



GEFÖRDERT VOM



Bundesministerium
für Bildung
und Forschung

Battery and Fuel Cell Research Challenges for Electric Vehicle Applications

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- All-Electric Vehicle Challenges (FCEV, BEV)
- Lithium-Ion Battery (LiB) Limitations
- Lithium-Air Batteries
 - stability towards superoxide (O_2^-)
 - effect of gas & electrolyte impurities
 - reactions during charging

Fuel Cell Electric Vehicle Constraints

since ≈2008: 500 km (70 MPa H₂)

→ H₂-refueling in < 5 minutes

↳ H₂ generation & distribution infrastructure...

□ catalyst cost & supply (100kW car):

current cars: $\approx 0.5 \text{ g}_{\text{Pt}}/\text{kW} \equiv 50 \text{ g}_{\text{Pt}}/\text{car}$ → >10x vs. automotive emission catalysts

long-term: $< 0.1 \text{ g}_{\text{Pt}}/\text{kW} \equiv < 10 \text{ g}_{\text{Pt}}/\text{car}$ → large-scale commercial viability



□ catalyst durability:

2800/4000 h (average/projected)^{*)} vs. 6000 h target → C-support corrosion & Pt-dissolution

→ advanced catalysts & controls

↳ key technology enablers: *ultra-high activity Pt catalysts or non-Pt catalysts*

^{*)} DOE test fleet data: Jennifer Kurt; “Analysis of Laboratory Fuel Cell Technology Status – Voltage Degradation”;

Excerpt from the 2011 Annual Progress Report. (November 2011):

http://www.nrel.gov/hydrogen/proj_fc_analysis.html

Electromobility Challenges: BEVs

❑ battery system weight & cost:

$120 \text{ Wh}_{\text{name-plate}}/\text{kg}_{\text{system}}$ (Tesla) → highest Wh/kg battery pack, but complex system
→ **400 km range** ($53 \text{ kWh}_{\text{name-plate}}$): $\approx 450 \text{ kg}$ and $\geq 13000 \text{ €}$ (2030 projection^{*)})

❑ safety:

short-term: complex hardware and controls

long-term: less flammable active-materials & electrolytes



Tesla EV (2009)



higher energy content, improved safety, & low-cost batteries are needed

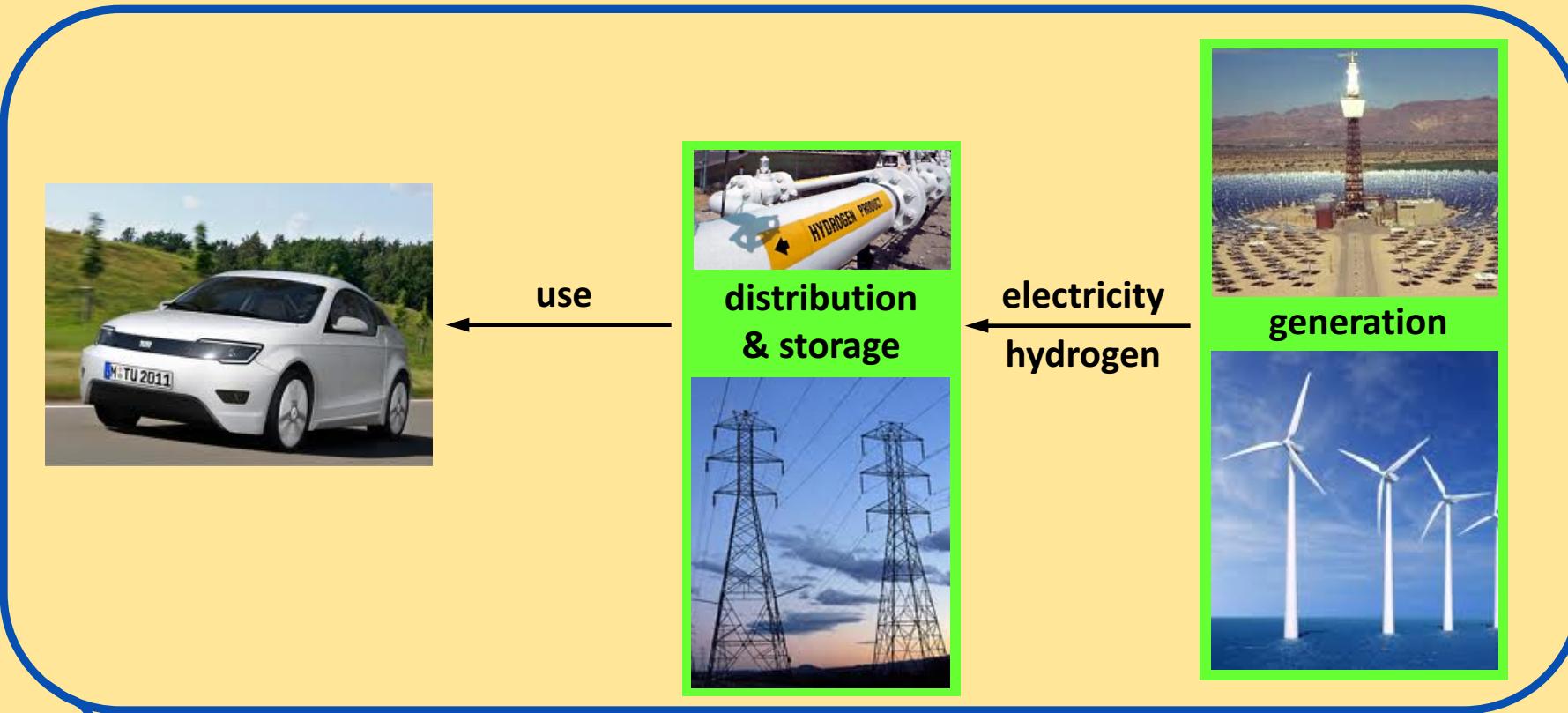
^{*)} “Transitions to Alternative Transportation Technologies – Plug-In Hybrid Electric Vehicles”,

National Research Council (2010); see: www.nap.edu/catalog/12826.html

Electromobility

Electromobility = car + ... + ...

- **demand:**
 - ◆ lowered/zero fossil fuel consumption
 - ◆ significant reduction of CO₂ emissions



$$\text{life-cycle CO}_2 \text{ savings} \times \text{market-penetration} = \text{societal benefit}$$

BEV Battery Weight & Cost

- projected performance of today's LiB technology:**
 - 200 Wh/kg_{battery-pack}^{*)}
 - 95% discharge efficiency
 - 80% state-of-charge range
 - 250 €/kWh_{name-plate}^{**)}
- energy required for small 4-passenger car:**
 - 100 Wh/km^{*)}

	150 km range	500 km range
required net energy:	15 kWh _{net}	50 kWh _{net}
required name-plate energy:	20 kWh _{name-plate}	66 kWh _{name-plate}
battery weight:	100 kg	330 kg
battery cost:	5000 €	16500 €



current cost & weight >2x higher

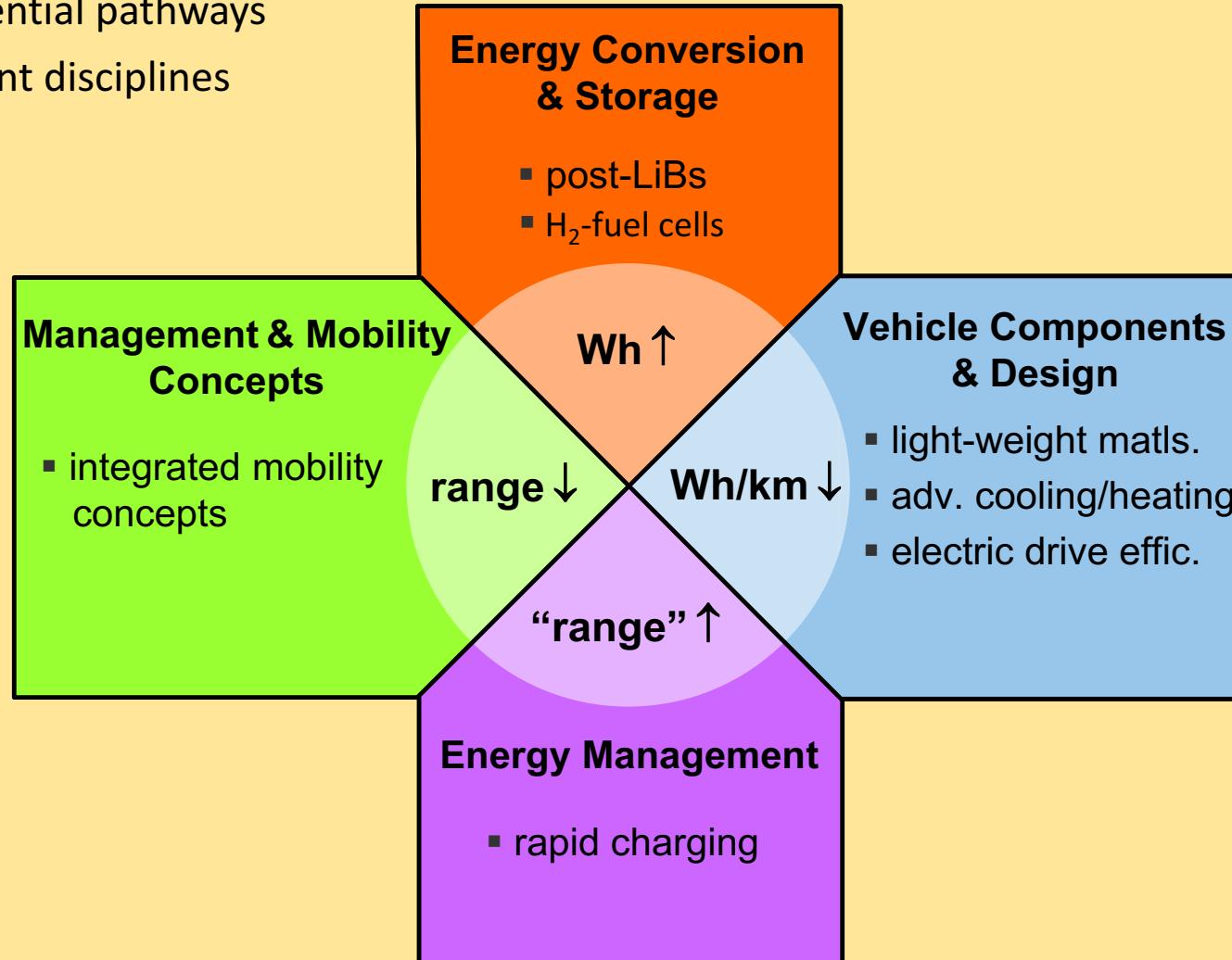
→ market penetration limited by “range anxiety” ?

^{*)} F.T. Wagner, B. Lakshmanan, M.F. Mathias; J. Phys. Chem. Lett. 1 (2010) 2204

^{**)} “Transitions to Alternative Transportation Technologies – Plug-In Hybrid Electric Vehicles”, National Research Council (2010); see: www.nap.edu/catalog/12826.html

Range Extension – Approaches

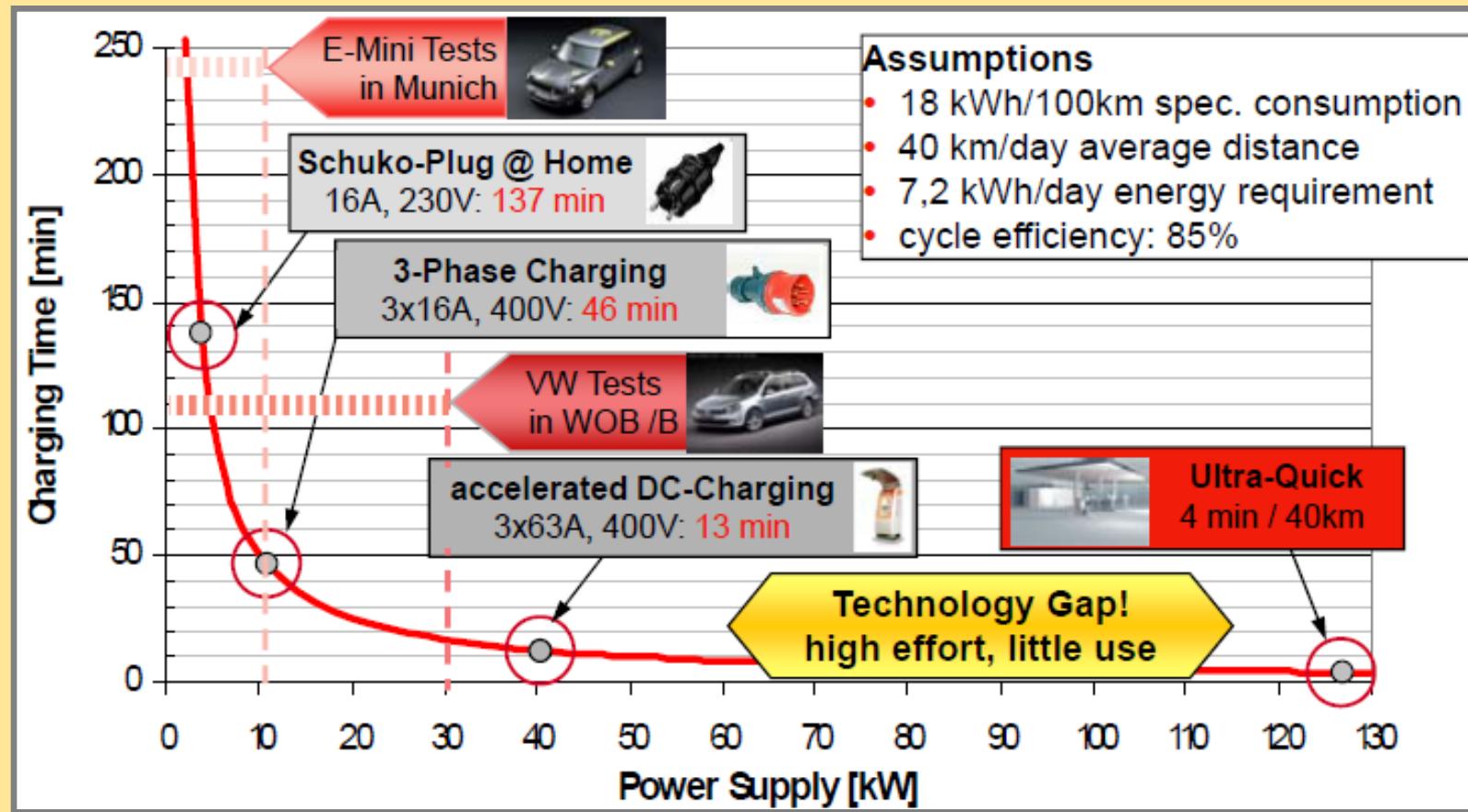
- ☐ multiple potential pathways
within different disciplines



⌚ multi-variate problem with many inter-dependencies !

Rapid Charging

□ charging time: $t_{\text{charging}} = \frac{\text{kWh}_{\text{battery}}}{\text{kW}_{\text{supply}}}$ → ≈50 kWh in 5 mins. ≡ 0.6 MW !



from:
E.ON presentation
at the IAS Opening
by J. Eckstein
(Oct., 2010)

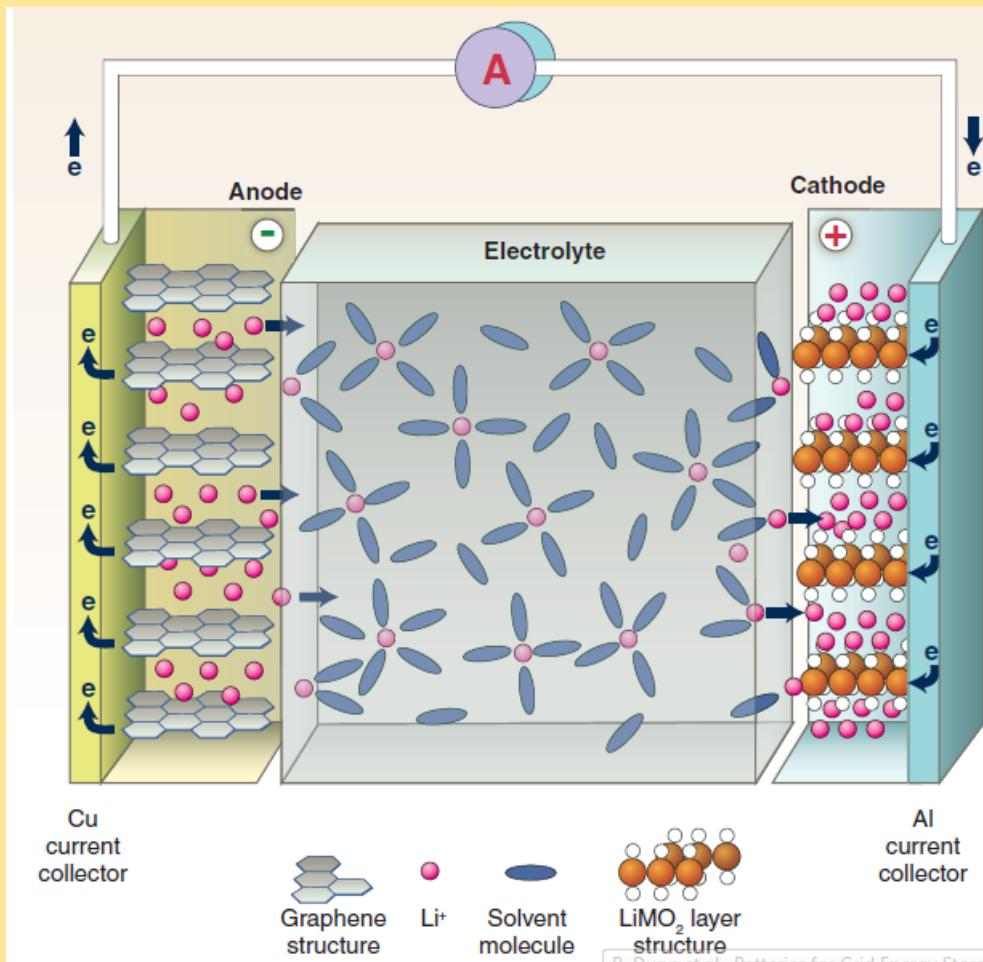


- rapid charging:
 - lowers battery life and charging efficiency
 - questionable business case for electric utilities
- long-range BEVs: post-LiBs

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Li-Ion Battery Principle

intercalation / deintercalation of Li^+ ions in host structures



from: B. Dunn et al., *Science* 334
(2011) 928



$$(E_0 \approx 0.1 \text{ V vs. Li/Li}^+)$$



$$(E_0 \approx 4.2 \text{ V vs. Li/Li}^+)$$

Limit of Lithium-Ion Batteries

specific energy, E_{\pm} , of $\text{LiNi}_{1/3}\text{Mn}_{1/3}\text{Co}_{1/3}\text{O}_2$ / Graphite (+/-):

	$\text{LiNi}_x\text{Mn}_y\text{Co}_z\text{O}_2/\text{C}$
specific capacity of electrodes [Ah/kg _{electrodes}]:	110
cathode voltage (positive) [V]	4.0
anode voltage (negative) [V]	0.1
battery voltage [V]	3.9
specific energy of electrodes [Wh/kg_{electrodes}]:	430

specific of cells and battery-packs:

- electrodes: $\approx 70\%$ of cell weight
(rest: current collectors & electrolyte)
- $\rightarrow \text{LiNi}_{1/3}\text{Mn}_{1/3}\text{Co}_{1/3}\text{O}_2/\text{C}: \approx 300 \text{ Wh/kg}_{\text{cell}}$

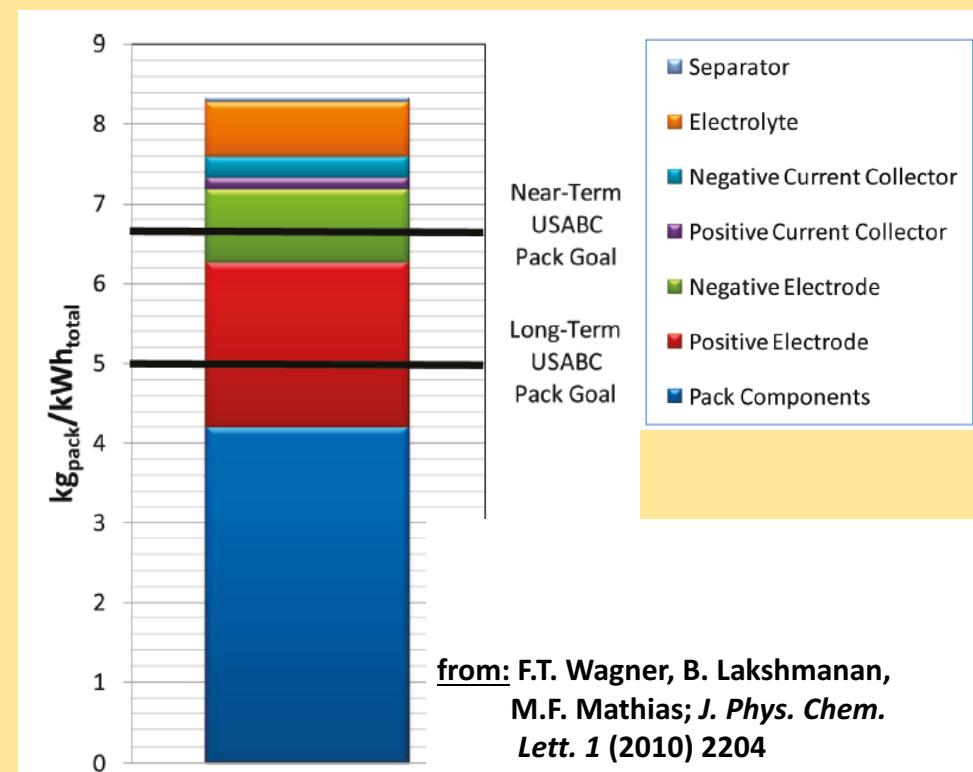


long-term projection:

200 Wh/kg_{battery-pack}

(from F.T. Wagner et al.)

alternative batteries – “post-LiBs” ?



All-Electric Vehicle Challenges (FCEV, BEV)

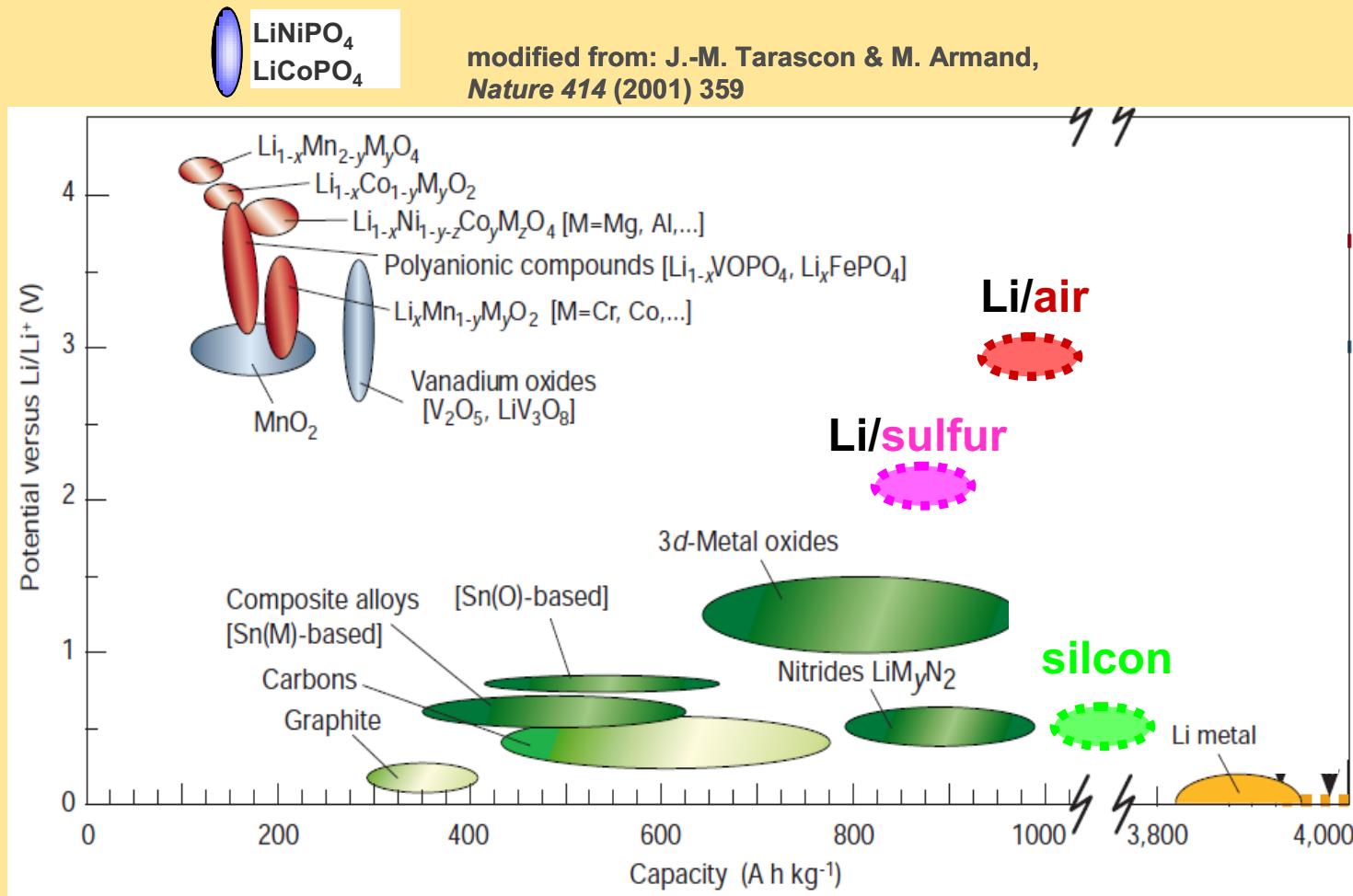
Lithium-Ion Battery (LiB) Limitations

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Post-Lithium-Ion Batteries

□ compound formation / alloying rather than intercalation in host structure



“post-LiB”: Li/air and Li/S batteries with Si or Li anodes