Estimating the Practical Energy Content of Next Generation Battery Systems

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Strommarkttreffen, DIW Berlin, May 10, 2019

Next Generation Batteries: A Battery Revolution?

Power to our homes and transport: super BATTERY revolution moves closer after new findings

New revolutionary battery could increase electric car range by two says specialist

ANALYSIS

The wait is over. The battery revolution is here

Theory *vs.* Practice

Theoretical Energy Content:
- only active material
- ideal conditions

Practical Energy Content:
- cell level: with electrolyte, separator, cell housing, *etc*.
- realistic conditions

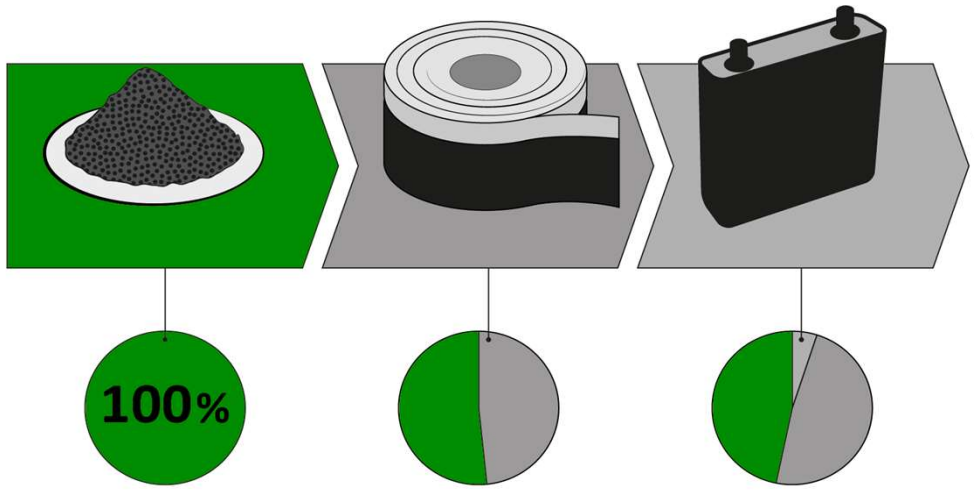
Battery Systems:

Lithium Ion Battery

All-Solid-State Battery

Lithium/Sulfur Battery

Lithium/Sulfur Battery



Betz, Bieker *et al.*, *Adv. Energy Mater.,* **2018**, *9*, 1803170.
Schmuch *et al.*, *Nature Energy,* **2018**, *3*, 267.

Lithium Ion Battery

Anode

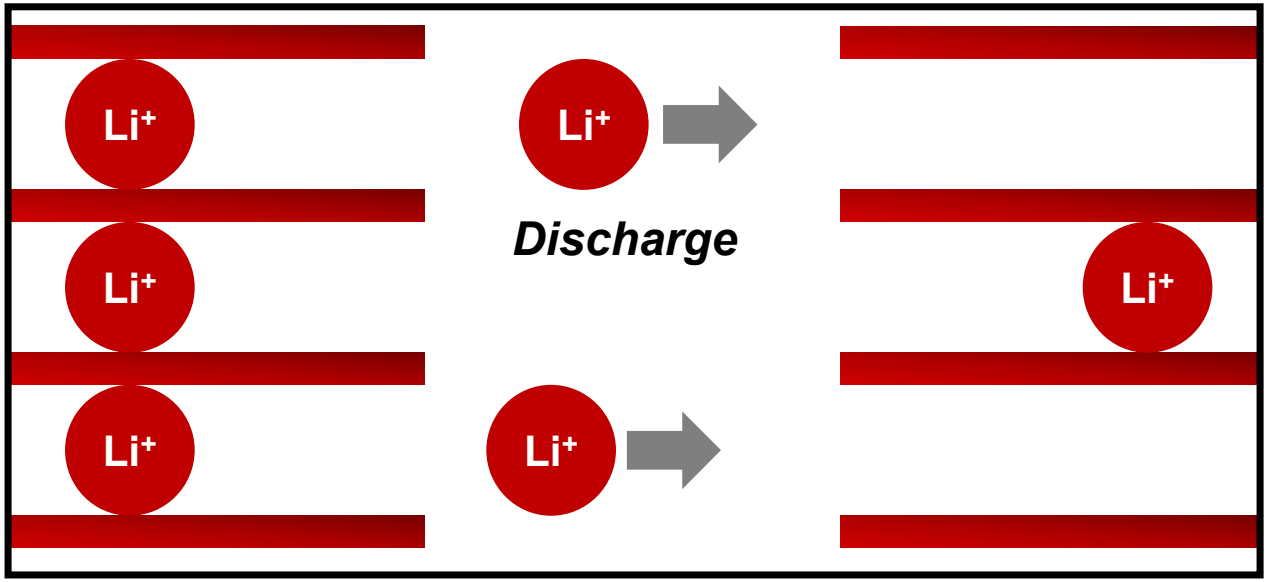
Cell voltage: **3.8 V**

Cathode

Graphite
(372 mAh/g)

Electrolyte

E.g. NCA
(279 mAh/g)



Additives:

Silicon
(+ energy)

NCA = $LiNi_{0.80}Co_{0.15}Al_{0.05}O_2$

Alternatives or combinations:

NMC111 = $LiNi_{0.33}Mn_{0.33}Co_{0.33}O_2$

NMC811 = $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$

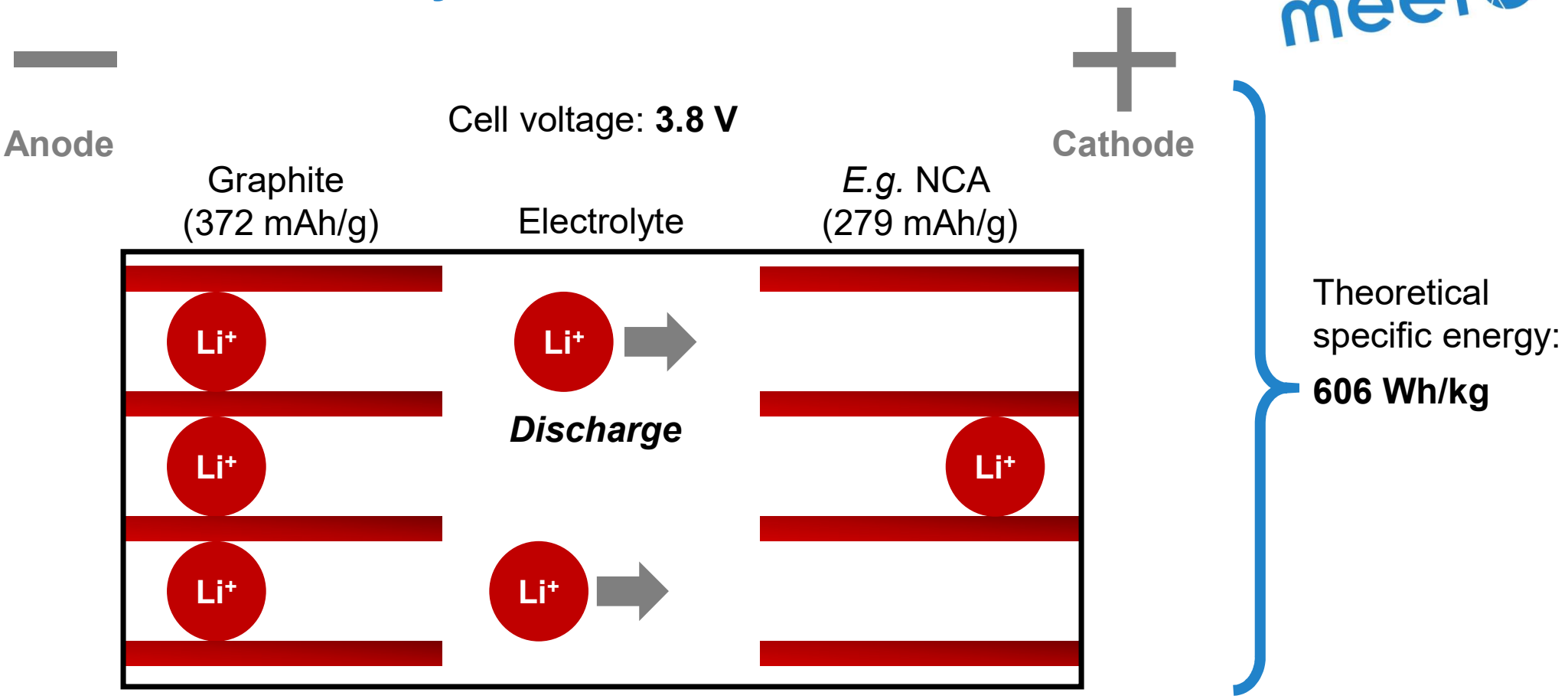
LMO = $LiMn_2O_4$

LFP = $LiFePO_4$

➡ Tuning of energy, power, cost

Schmuch *et al.*, *Nature Energy,* **2018**, *3*, 267.

Lithium Ion Battery



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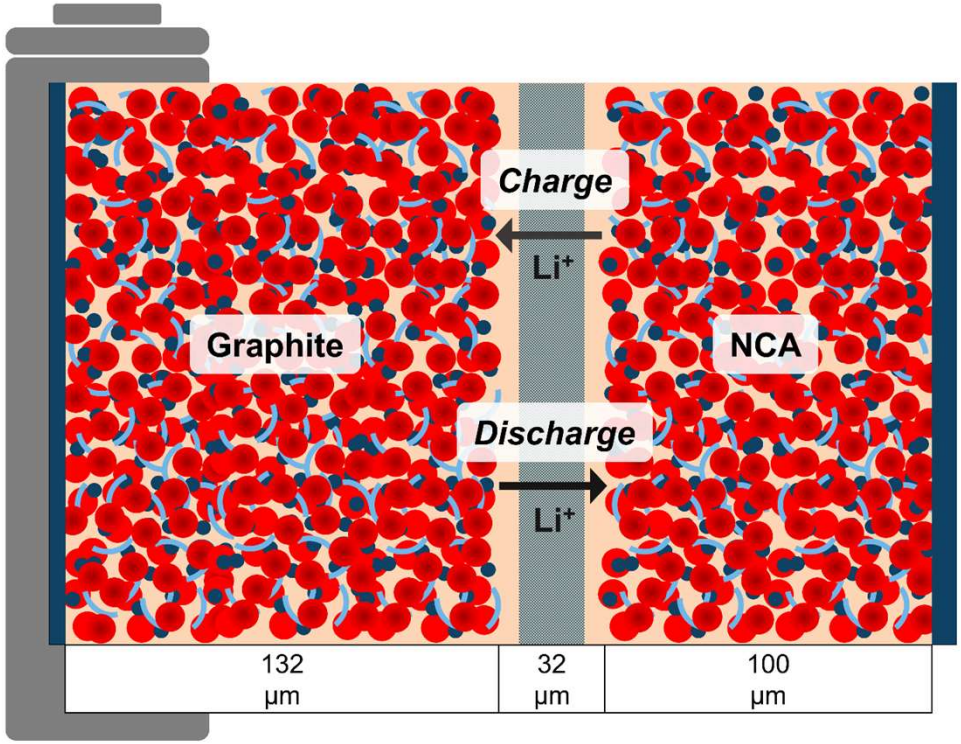
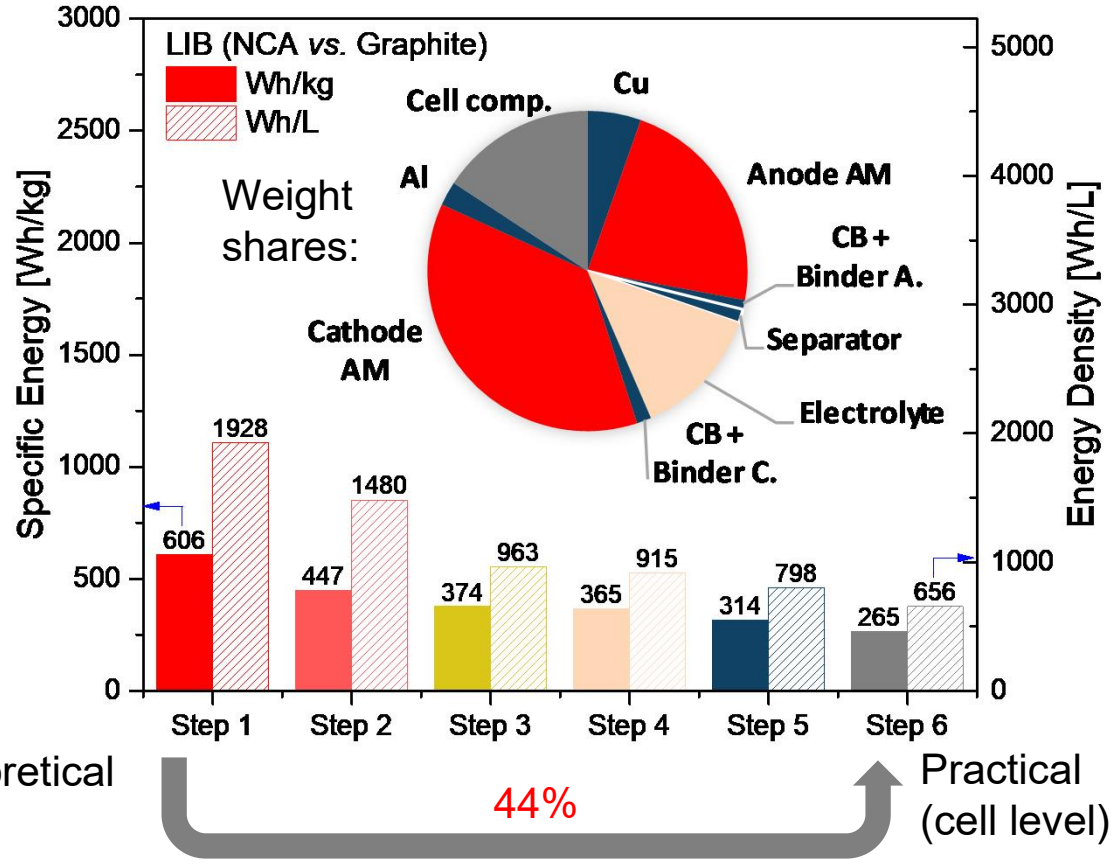
Lithium Ion Battery





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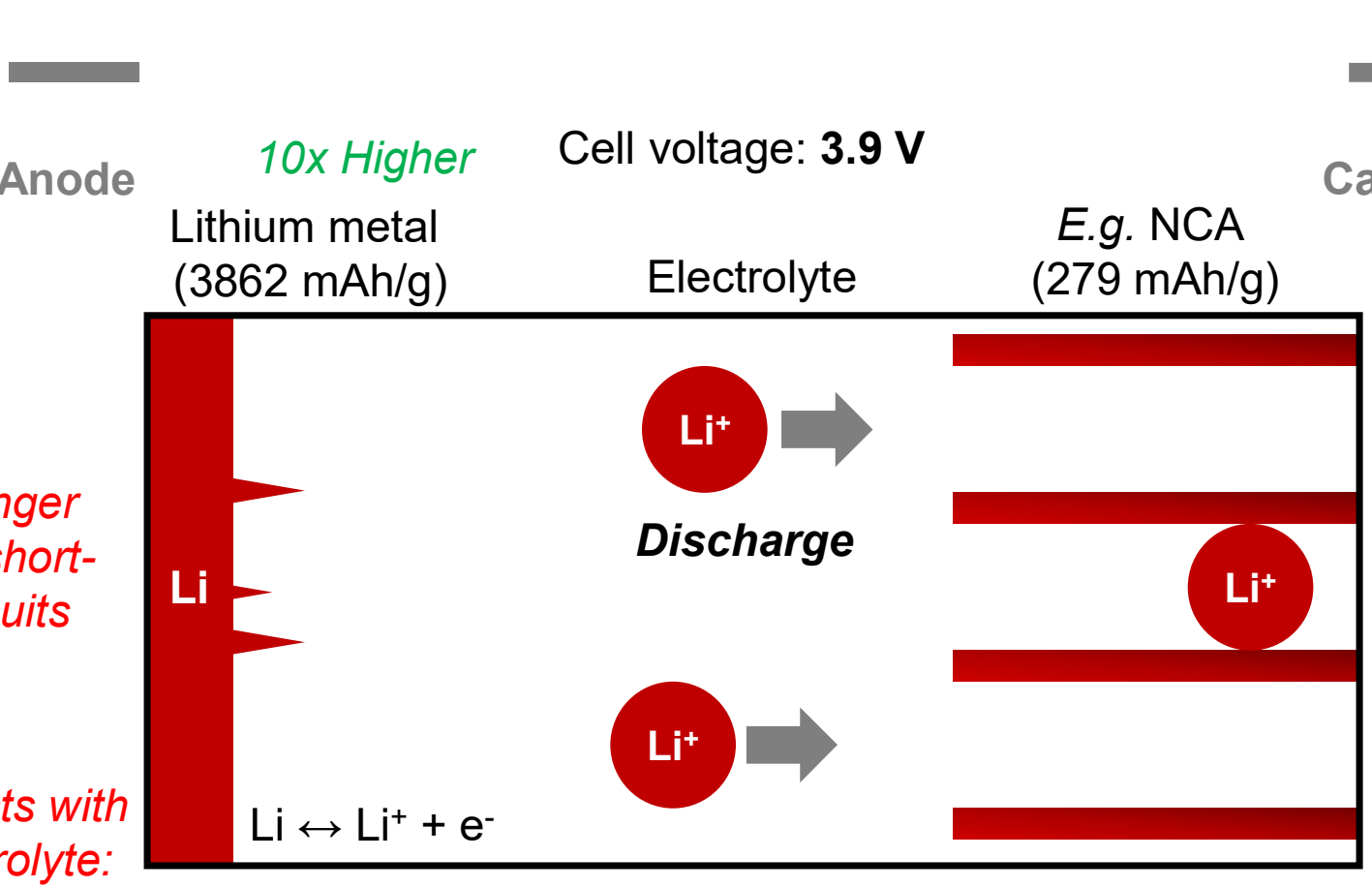
Lithium Metal Battery



Danger of short-circuits

Reacts with electrolyte: self-discharge

Theoretical specific energy:

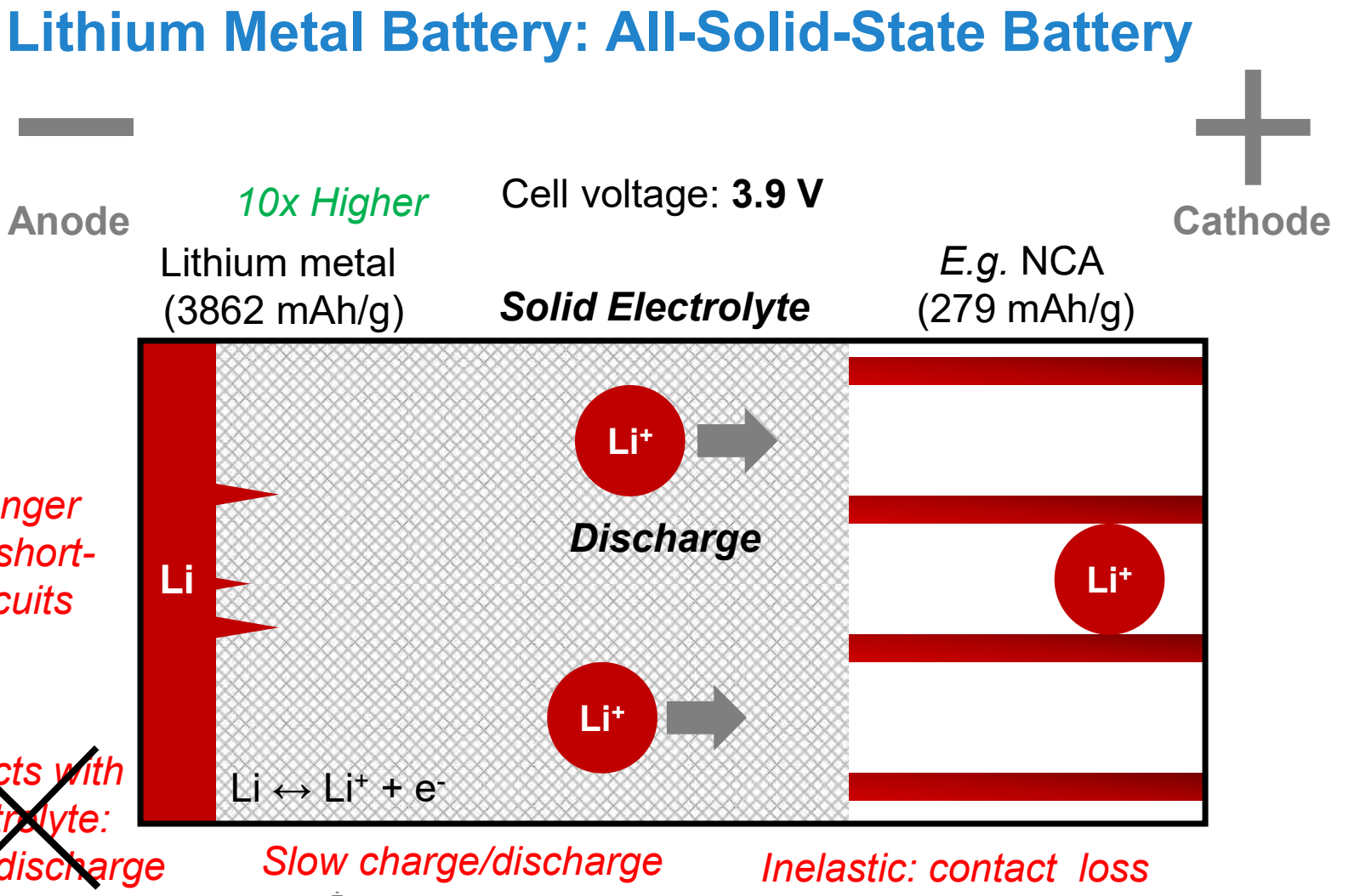
1088 Wh/kg

2x Higher

But: *Fundamental issues* remain!

Bieker *et al.*, *Phys. Chem. Chem. Phys.*, **2015**, *17*, 8670.

Lithium Metal Battery: All-Solid-State Battery



Theoretical specific energy:

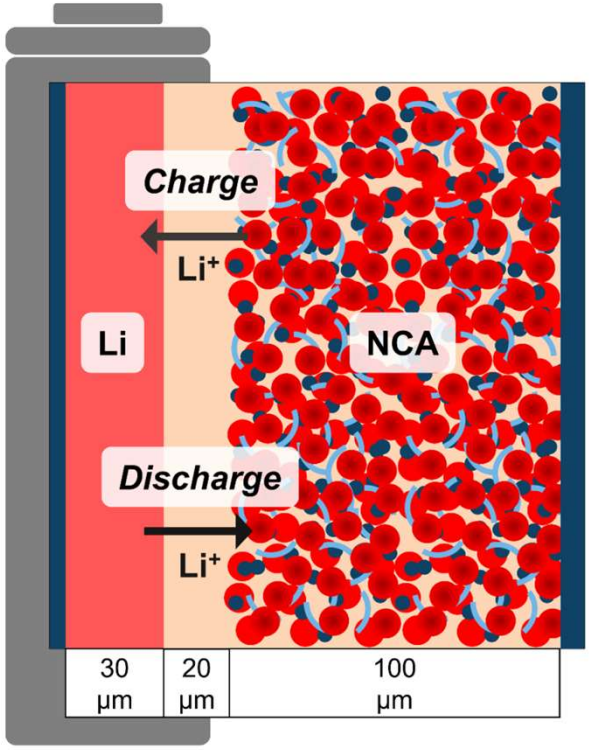
1088 Wh/kg

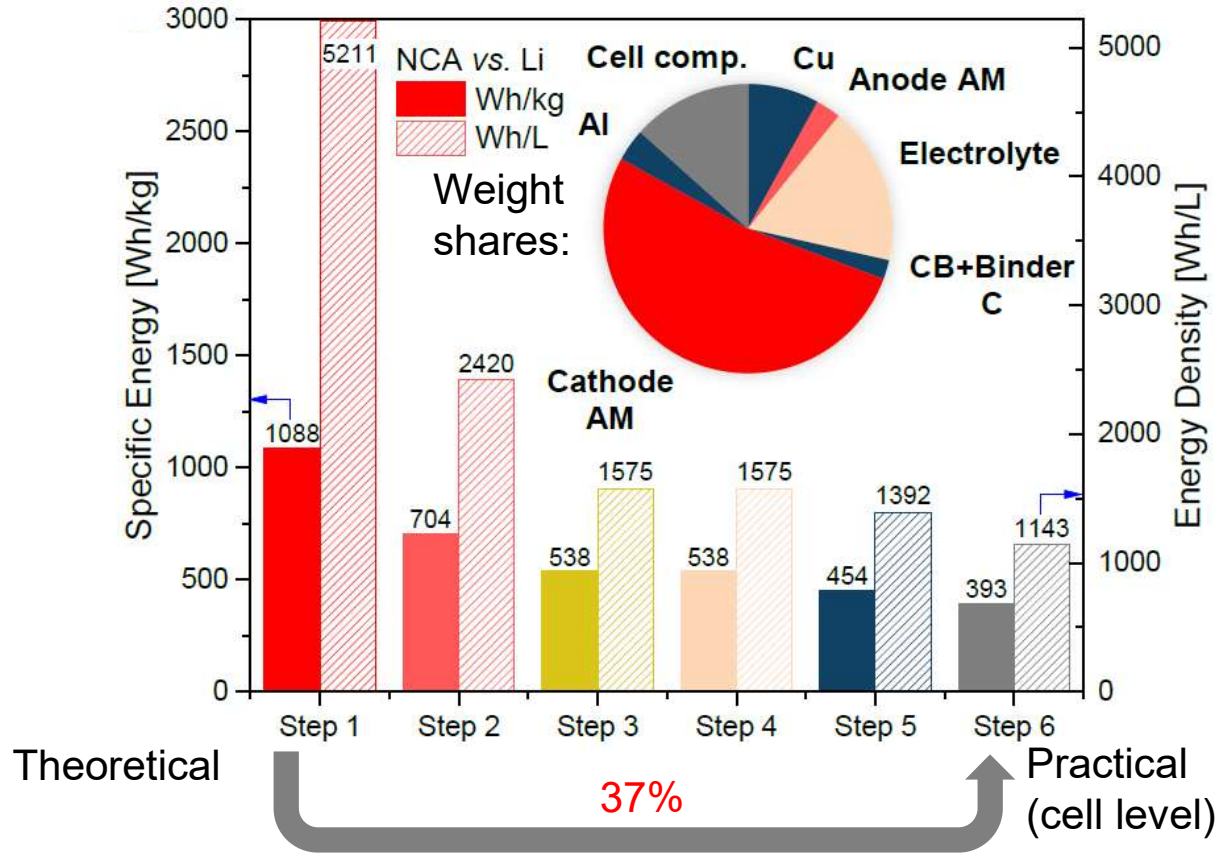
2x Higher

But: *Fundamental issues* remain!

Question: How high would the practical energy content be?

Lithium Metal Battery: All-Solid-State Battery





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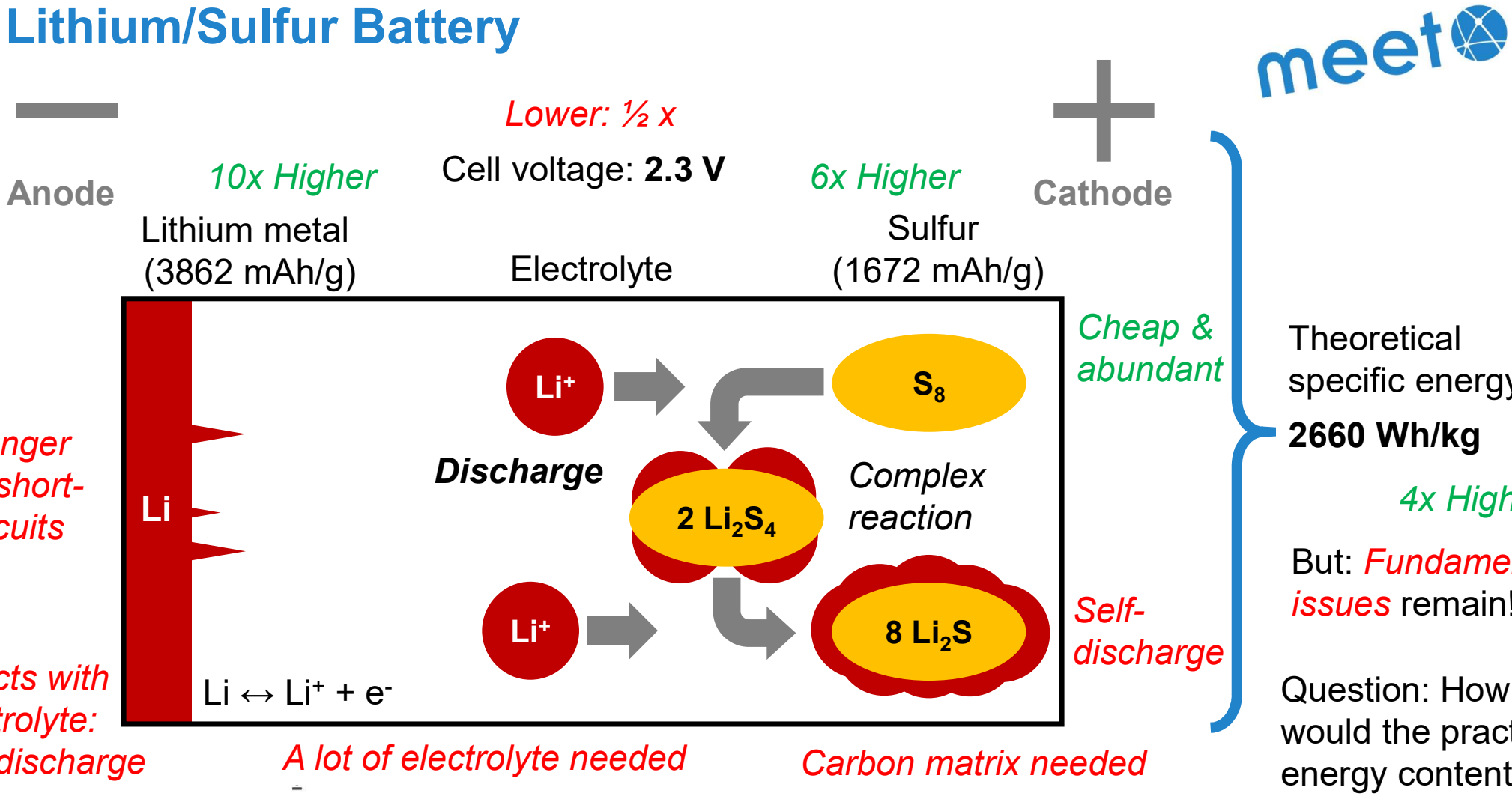
Lithium/Sulfur Battery



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Bieker *et al.*, *Phys. Chem. Chem. Phys.*, **2017**, *19*, 11152.

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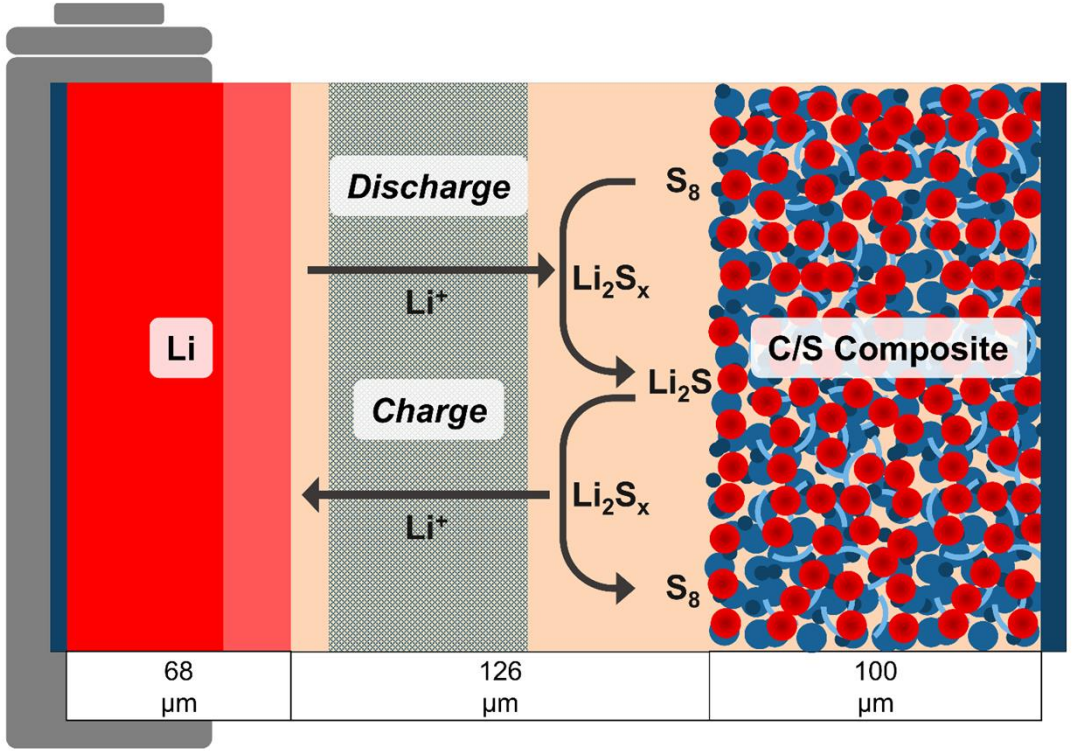

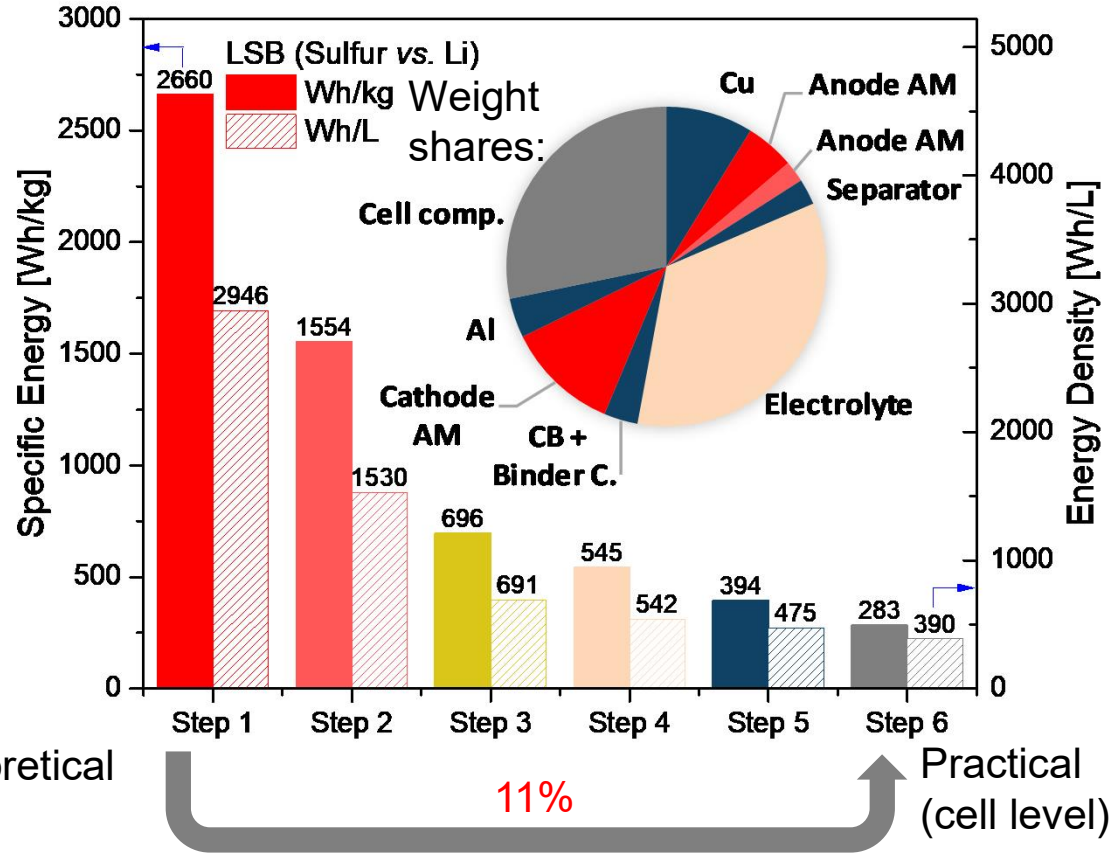

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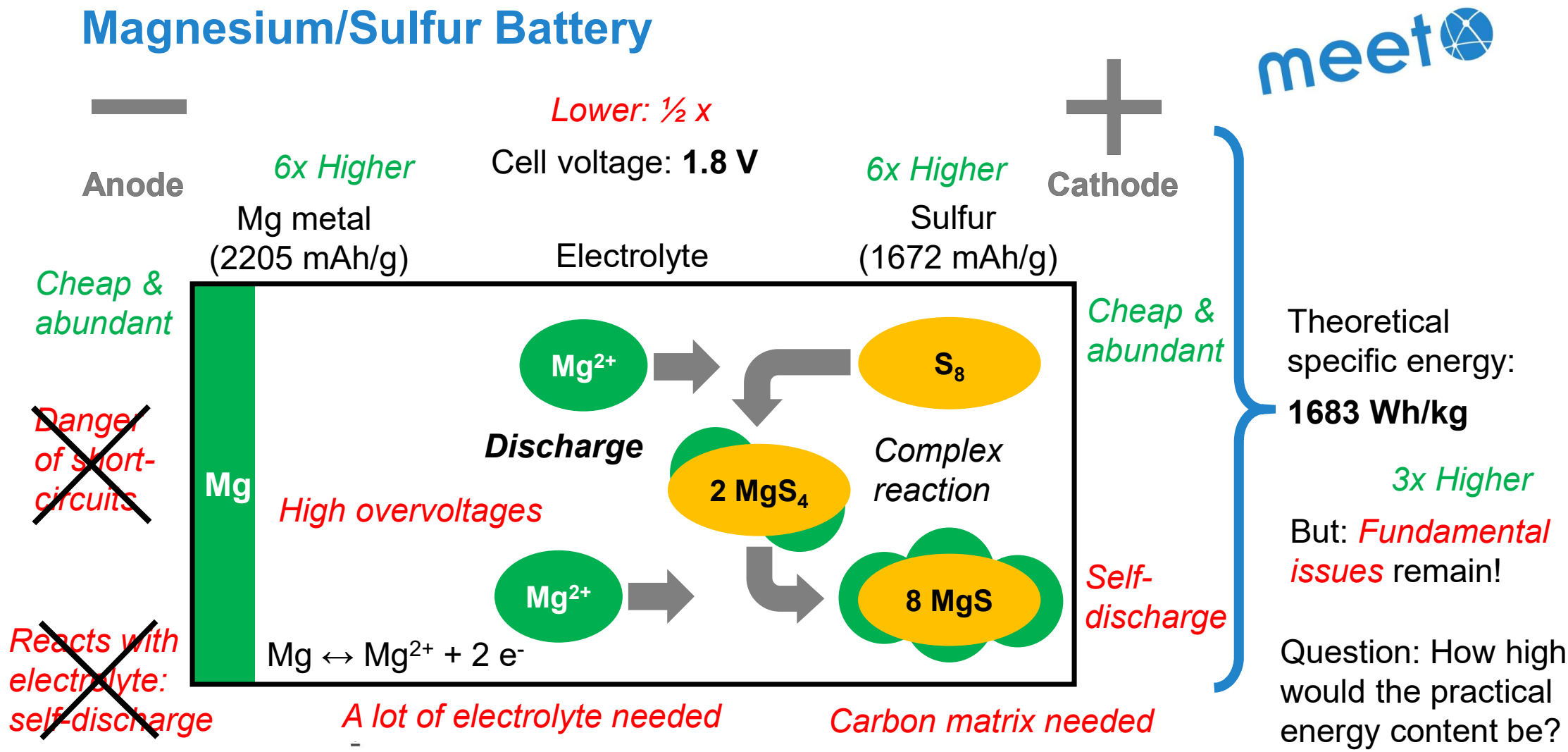
Magnesium/Sulfur Battery



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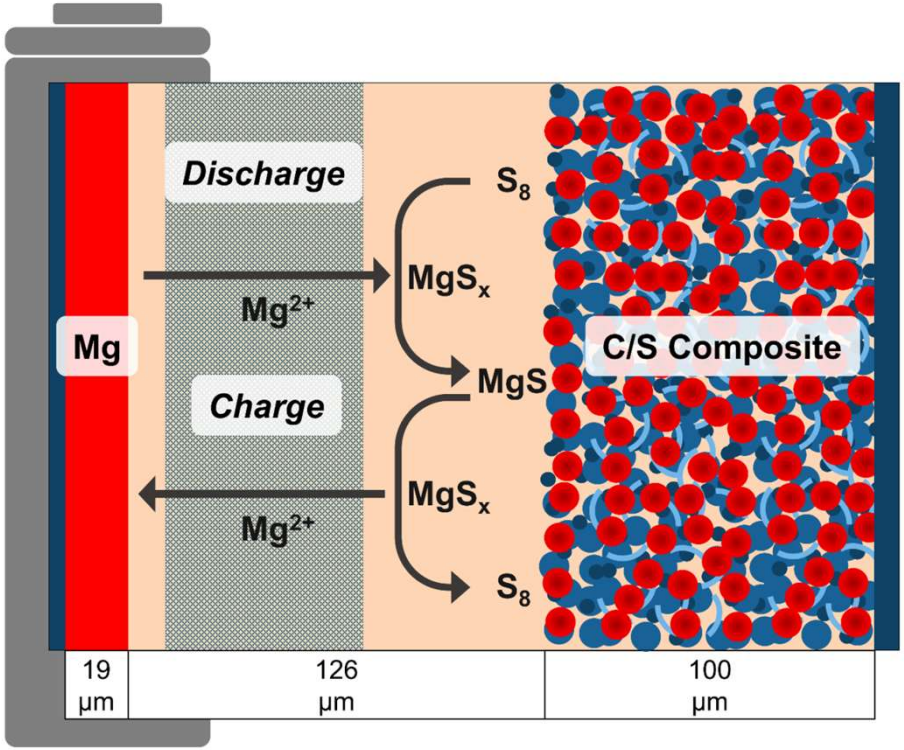
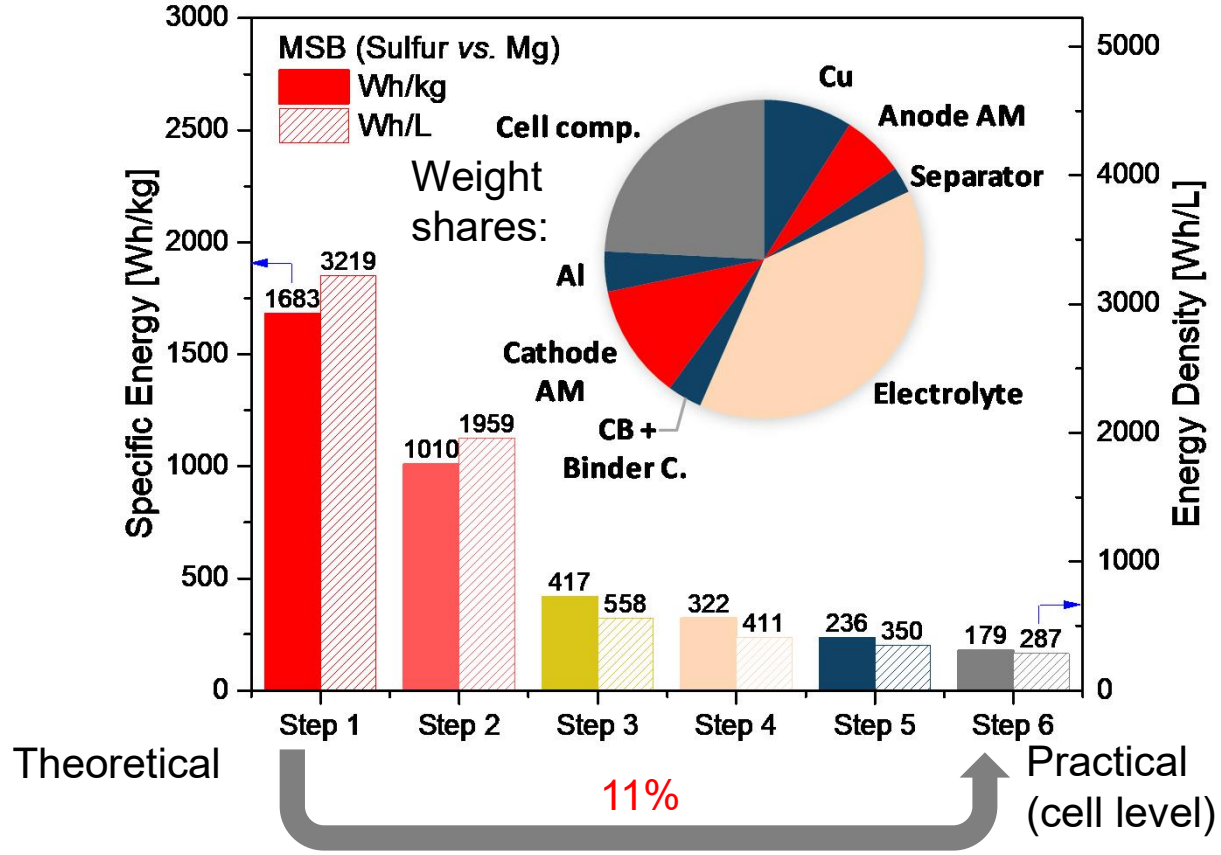
Magnesium/Sulfur Battery





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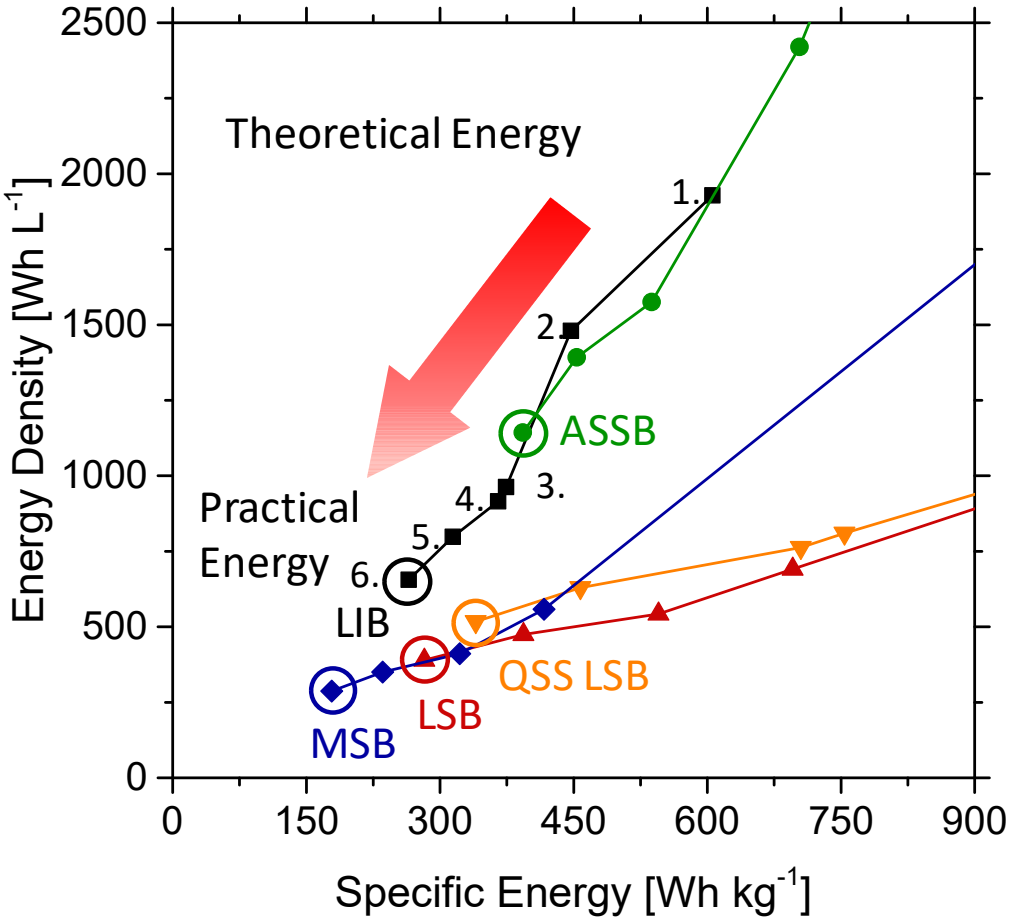
Summary



Specific Energy [Wh/kg]	Theoretical Level (Step 1)		Cell Level (Step 6)
LIB	606	↘ 44%	264
ASSB	1088	↘ 37%	393
LSB	2660	↘ 11%	284
MSB	1683	↘ 11%	180

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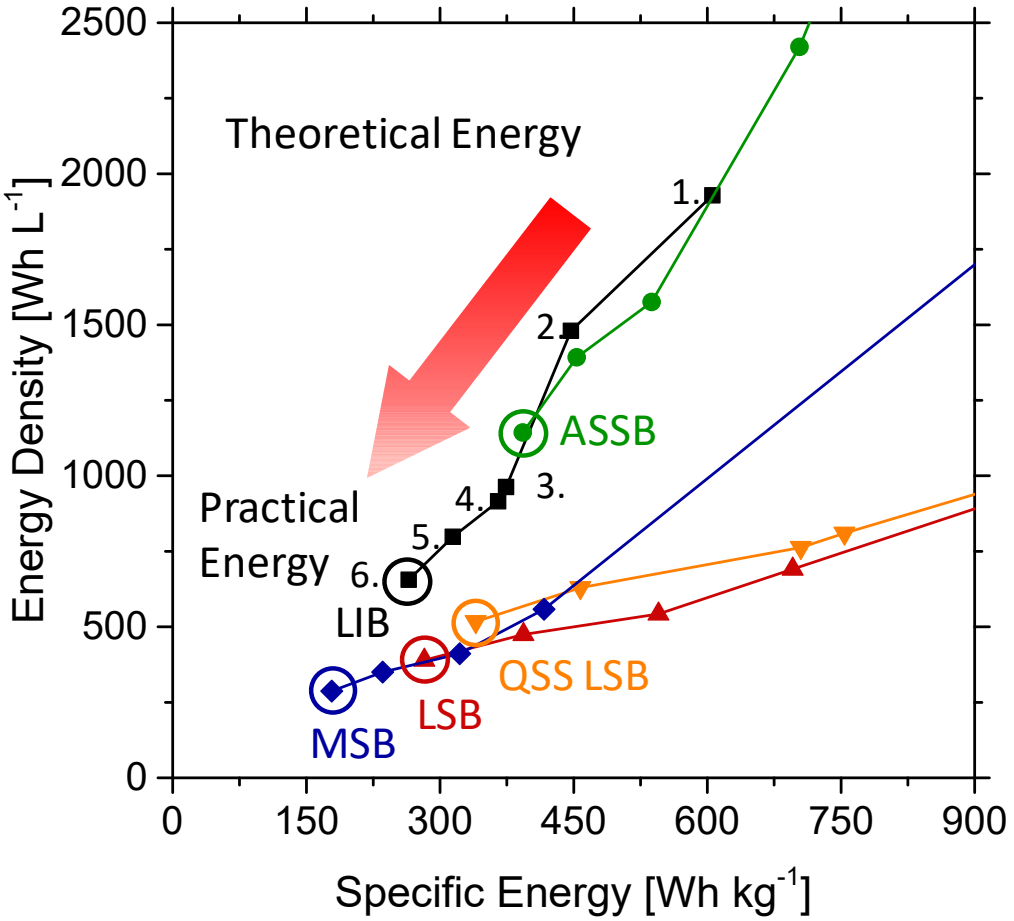
Summary



	Theoretical:	Practical:
All-Solid-State Battery:	2x E_{LIB}	1.5x E_{LIB}
Lithium/Sulfur Battery:	4x E_{LIB}	1.1x E_{LIB}
Mg/Sulfur Battery:	3x E_{LIB}	0.7-0.9x E_{LIB}

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Conclusions

Theoretical energy values transfer very differently into practical cells

- different practical mass utilization
- different amount of electrolyte
- different amount of other inactive materials
- different overvoltages

Theoretical energy values of Next Generation Battery Systems might be misleading!

But: It‘s not only about energy…

- Price
- Abundance of ressources (Ni, Co)
- Ecological aspects
- Conflict materials (Co)

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ACHiLiS (03XP0037A)
MgMeAnS (03XP0140)
BenchBatt (03XP0047A)

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