Future battery concepts for back-up storage

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- Low power, high energy
- Low sticker price
- Mostly parked
- Used 'daily'
- Volume and Weight restricted
- 'Night' charging

- High power, high energy
- Low total cost
- Mostly unused
- Very high reliability
- Controlled environment
- Always charged

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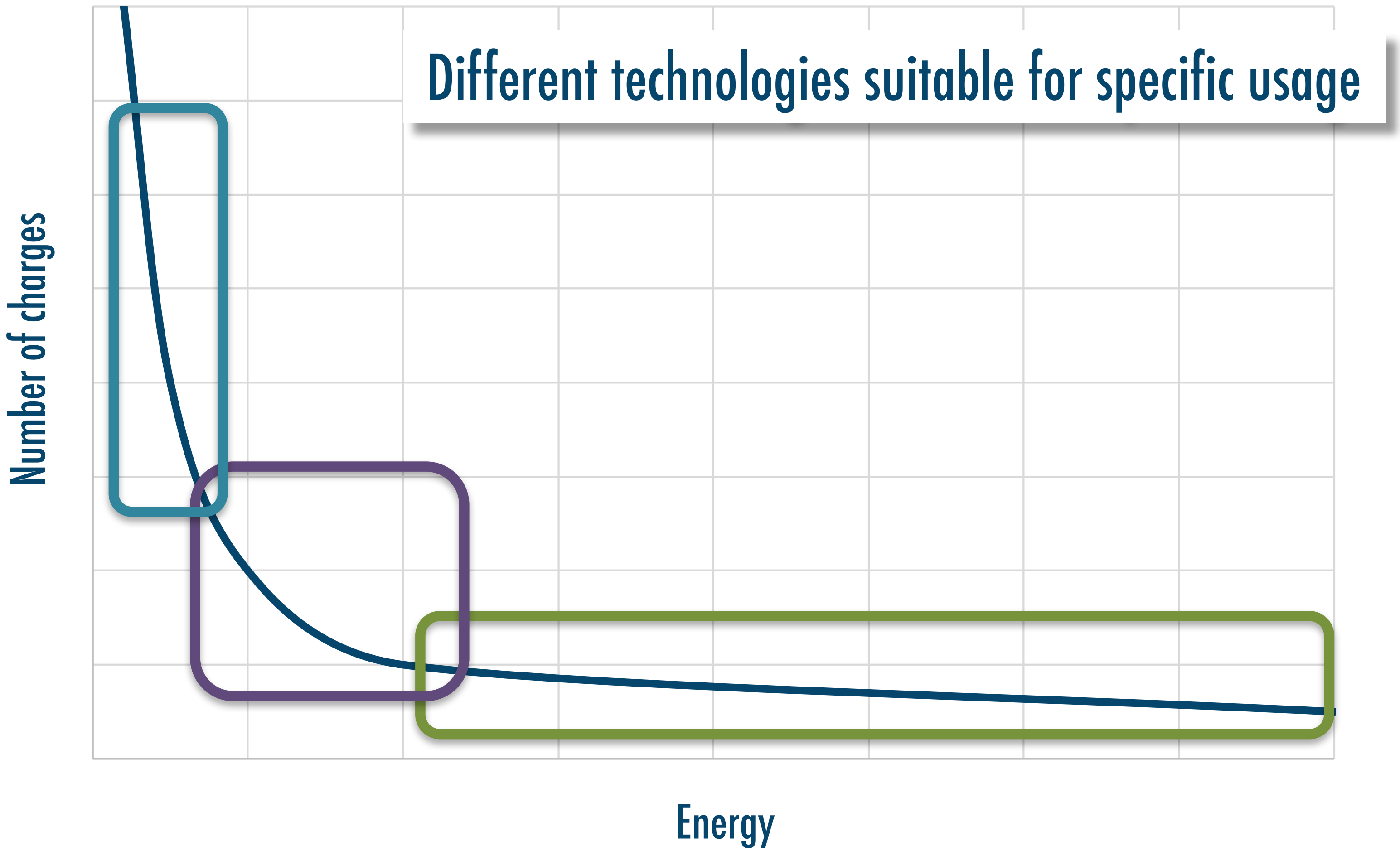
Charging



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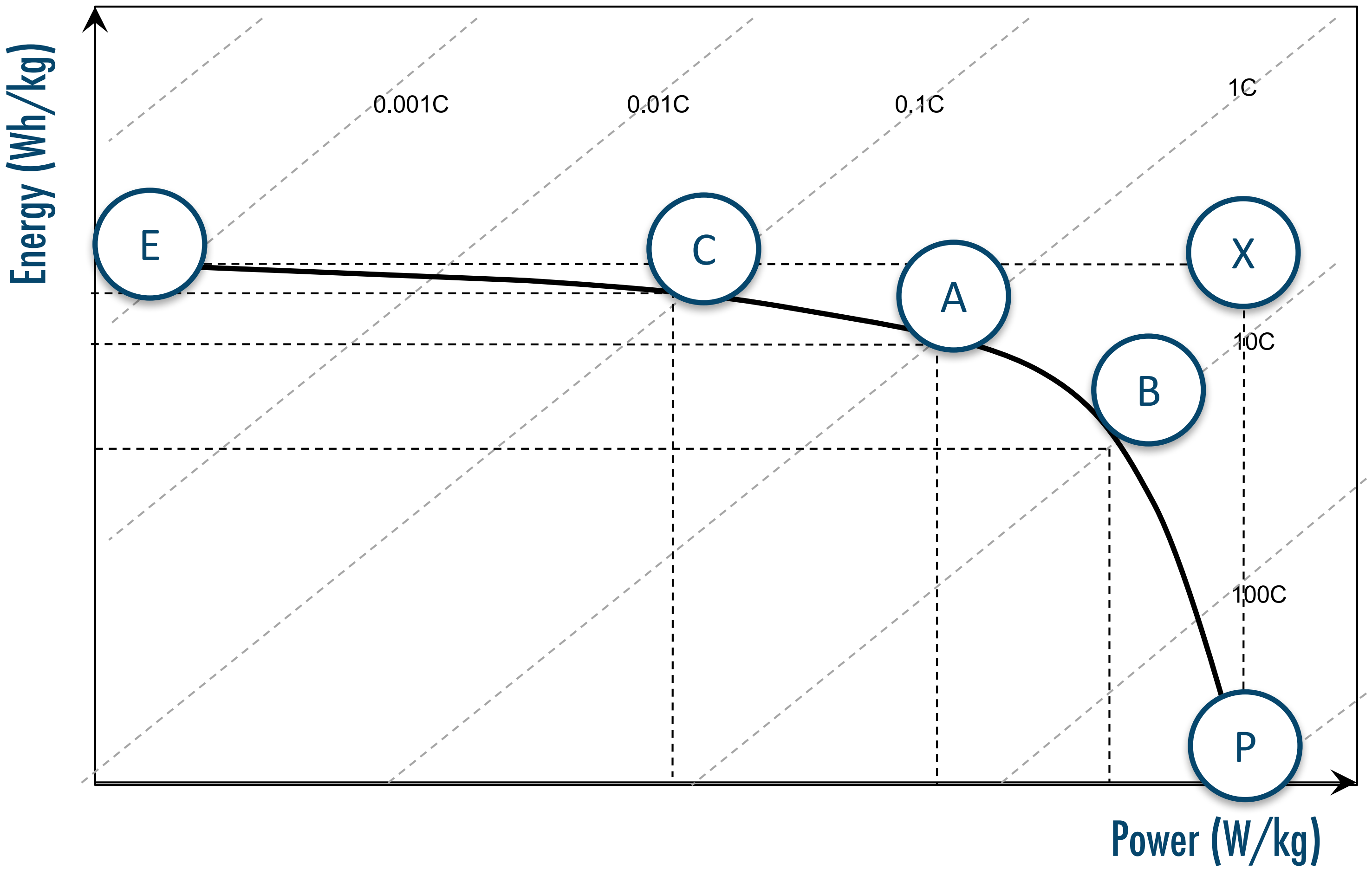
Energy vs. Power



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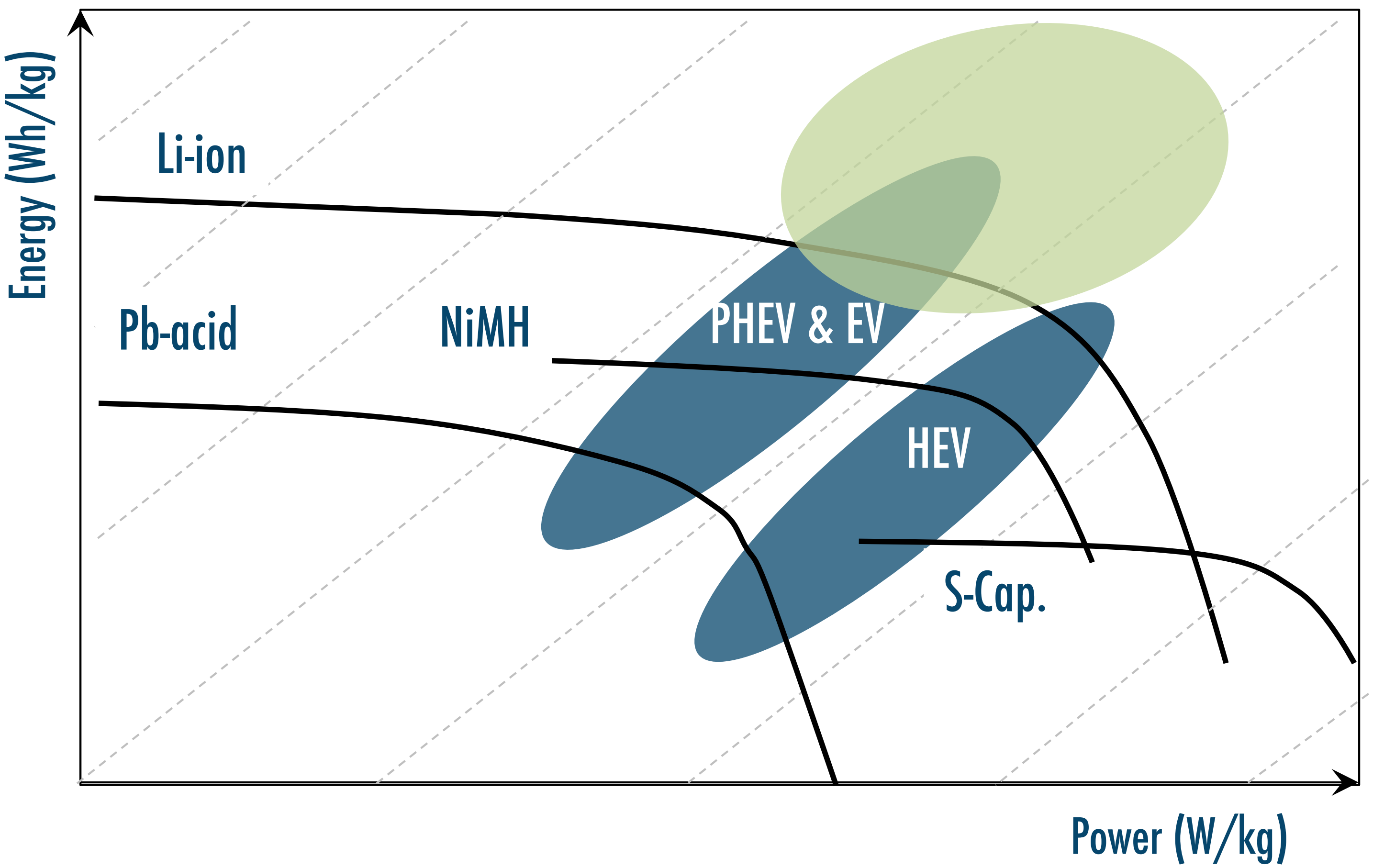
Energy and power needs



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Challenges for Pb-acid batteries

- Self-discharge
  - Both electrodes aim for $PbSO_4$
  - Depends on cell design, chemical additives and temperature
- Sulphation
  - $PbSO_4$ crystals grow during cycling or storage to block the surface
  - Increase of resistance and decrease of capacity
  - Temperature and concentration dependent
- Stratification
  - Concentration gradients in the electrolyte
  - Electrolysis of electrolyte → H_2 and O_2 gases can be formed
  - Voltage dependent
- Shedding or Exfoliation of electrodes
  - Depends on cell design, charging conditions

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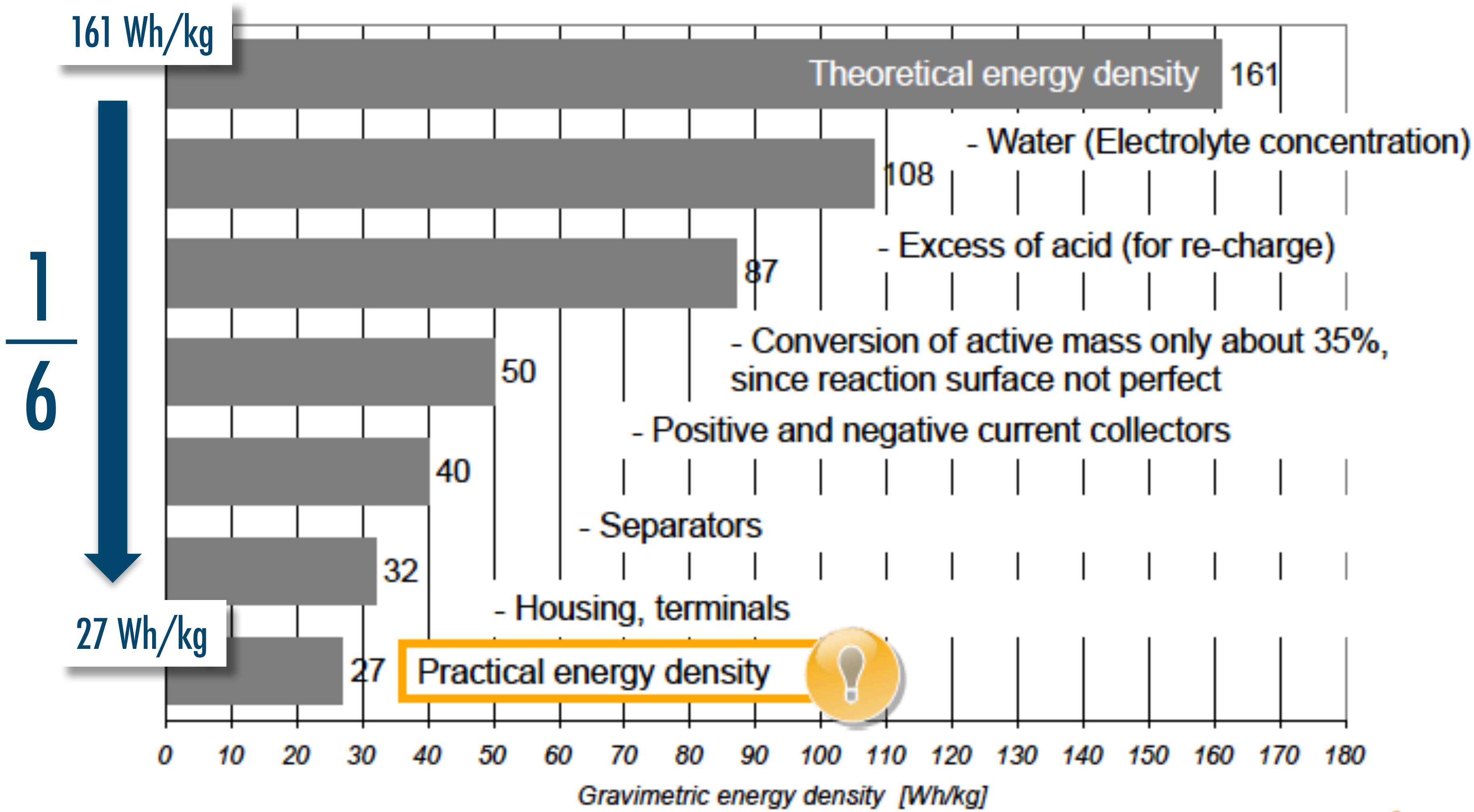
Pb-acid vs. Li-ion batteries

- More or less ONE chemistry
- Moderate voltage
- Heavy and large
- Robust
- Low cost
- Low energy density
- Maintenance needed
- Low charge acceptance
- Limited cycle life
- Many suppliers of high quality

- MANY chemistry variations
- High voltage
- Light and small
- Supervision needed
- Expensive
- High energy density
- No maintenance
- Variable charge acceptance
- Long cycle life
- Few suppliers of high quality

Energy density of Pb-acid batteries



Source: Prof. Dr.-Ing. Kai Peter Birke, Universität Stuttgart, 2016.

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Energy density of Li-ion batteries

500 Wh/kg

↓

250 Wh/kg

↓

125 Wh/kg

Practical driving range a factor 4 of theoretical

→ How to minimise inactive material with same safety level?

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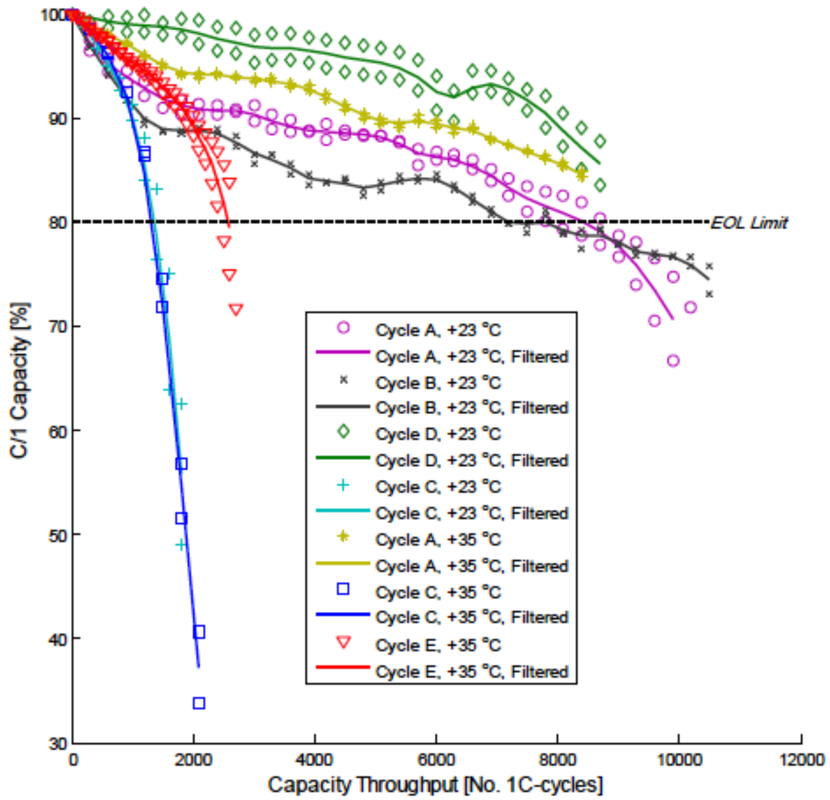
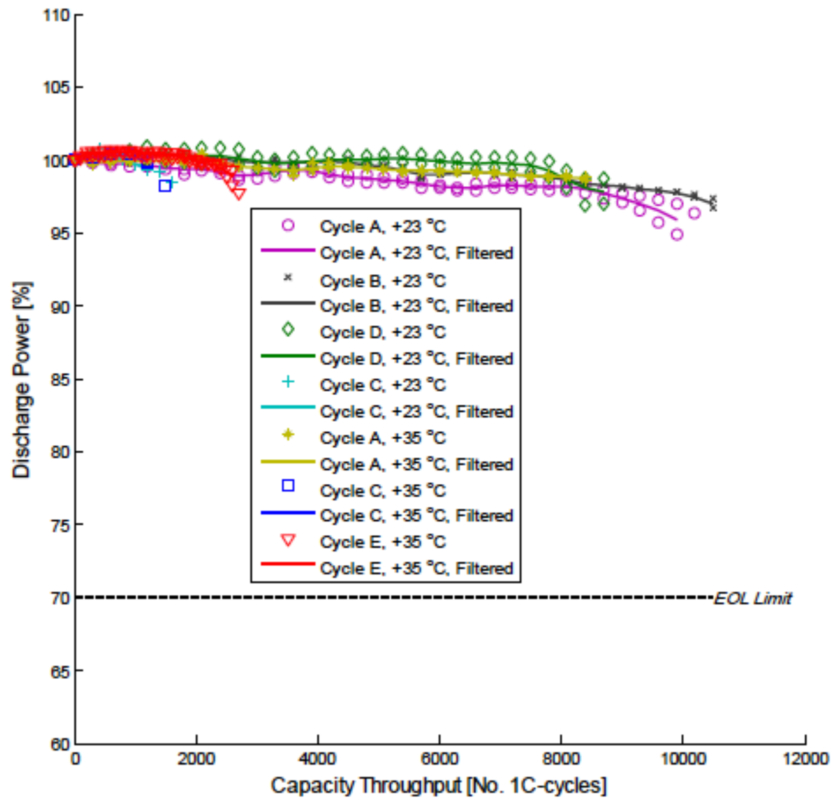
Capacity vs. Power





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What affects the durability?

- Temperature
  - Variations, min and max
  - Technology and Design dependent
- Voltage level
  - Charge sustaining actions
- Currents, charge and discharge
  - Fast charging
  - Temperature
- Cycling, shelf-life, age
- Maintenance
  - Capacity check-ups, etc.

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Safety arrangements

- Cell and module supervision and balancing
  - Voltage, temperature
- Management unit
  - Voltage, current, temperature, history, control, communication

- Thermal management
- Disconnect units, fuses, overcharge protections, ...

- Placement, ventilation
- Standards...

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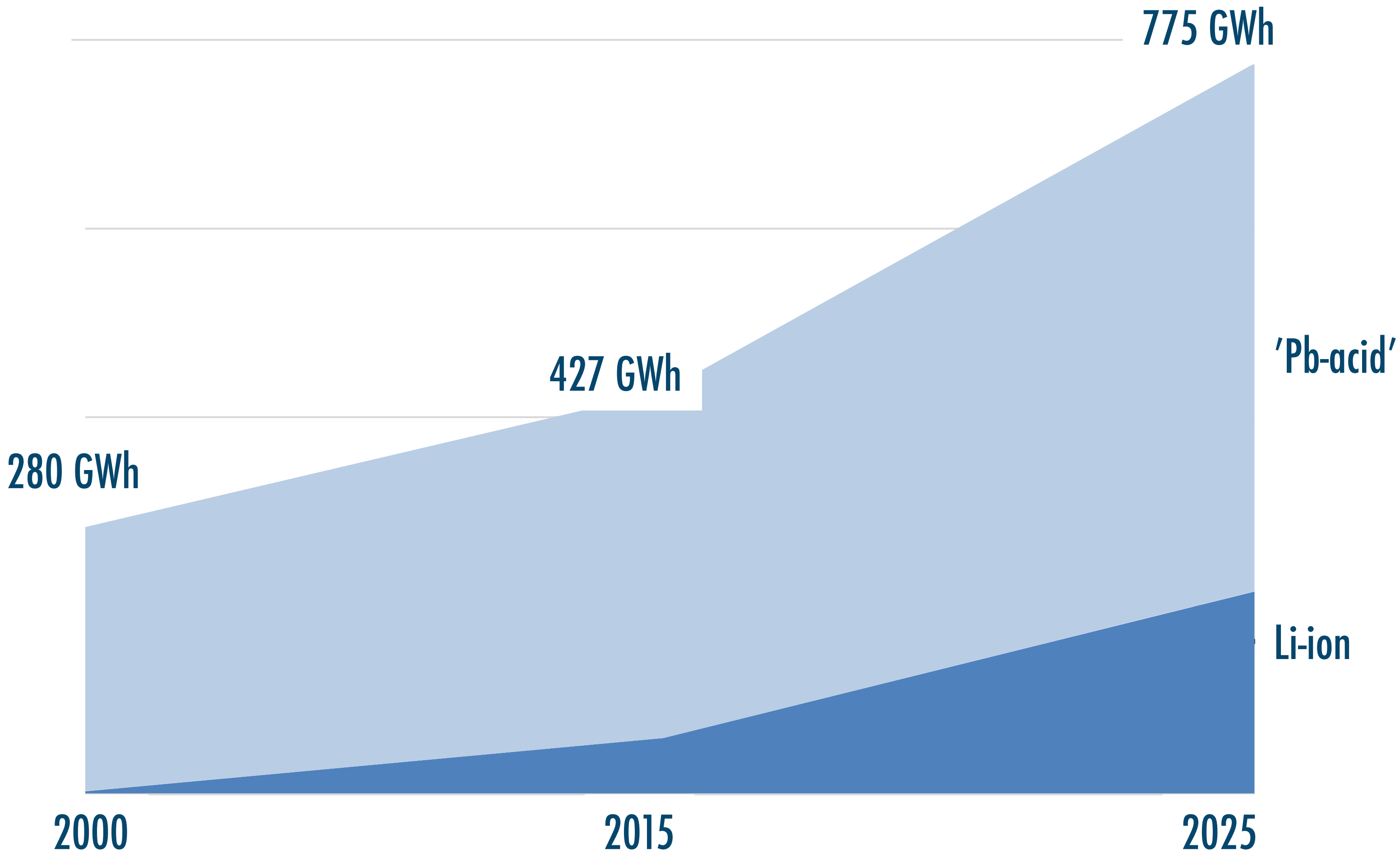
Malfunction of Li-ion cells

- Chemistry dependent
  - HF
  - Voltage levels (hign and low)
- Temperature (high and low)

- Cell protection devices
  - Current interput device (CID)
  - Positive temperature coefficient (PTC)
- Quality of Cell production

Battery market

– rechargable batteries



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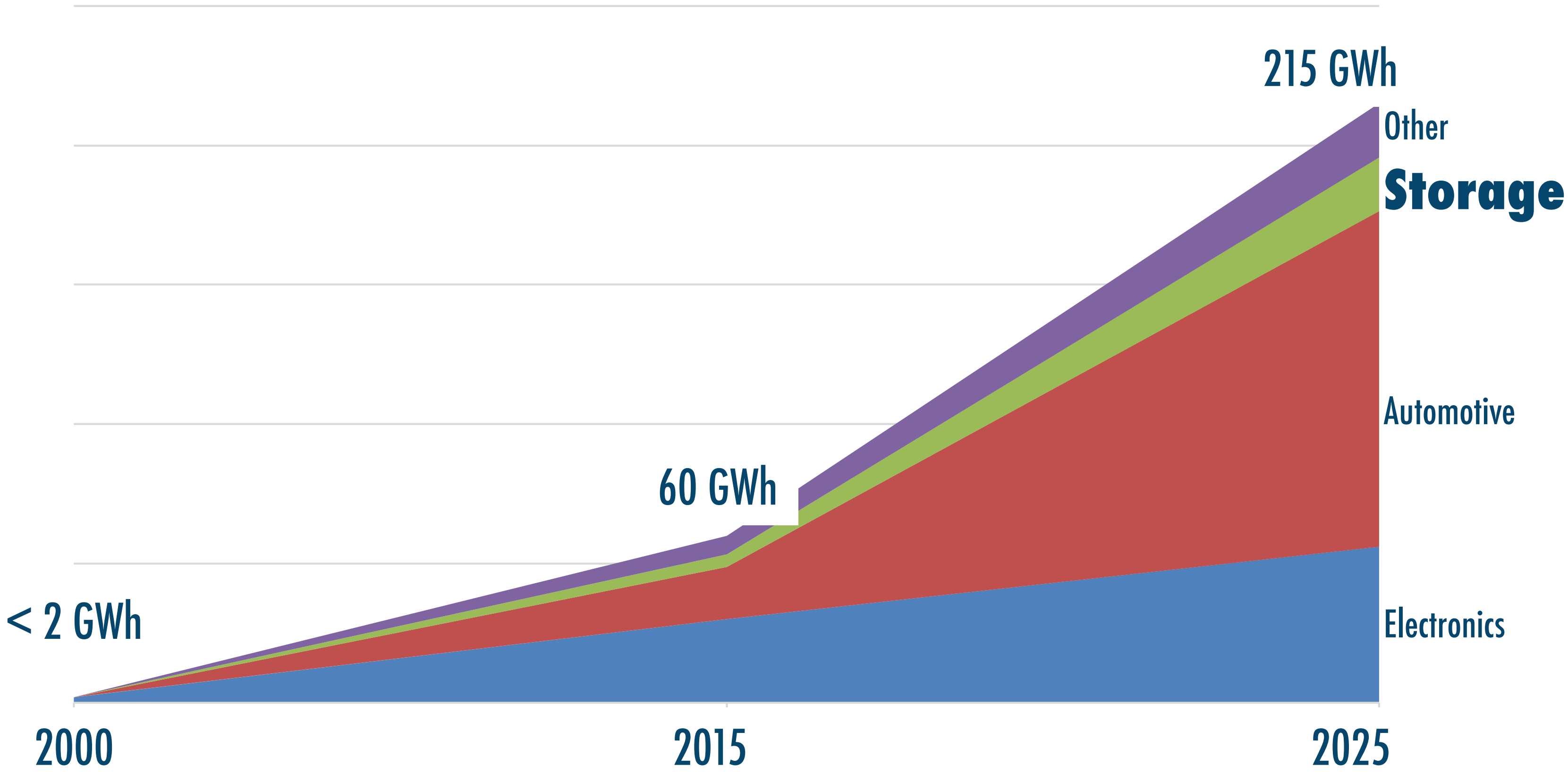
Source: Avicenne, 2016

Li-ion battery market



Source: Avicenne, 2016

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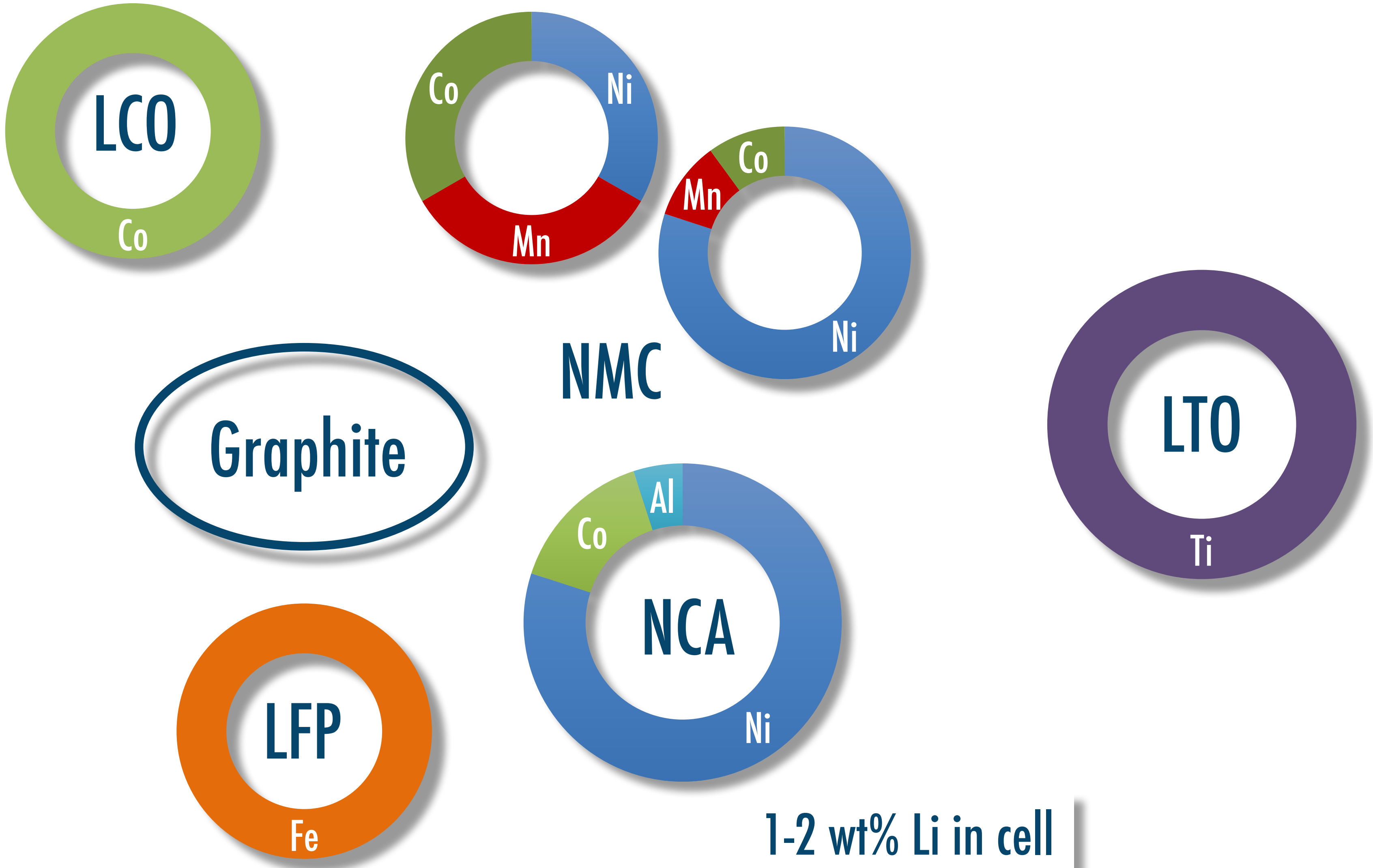
Li-ion cells



1-2 wt% Li in cell

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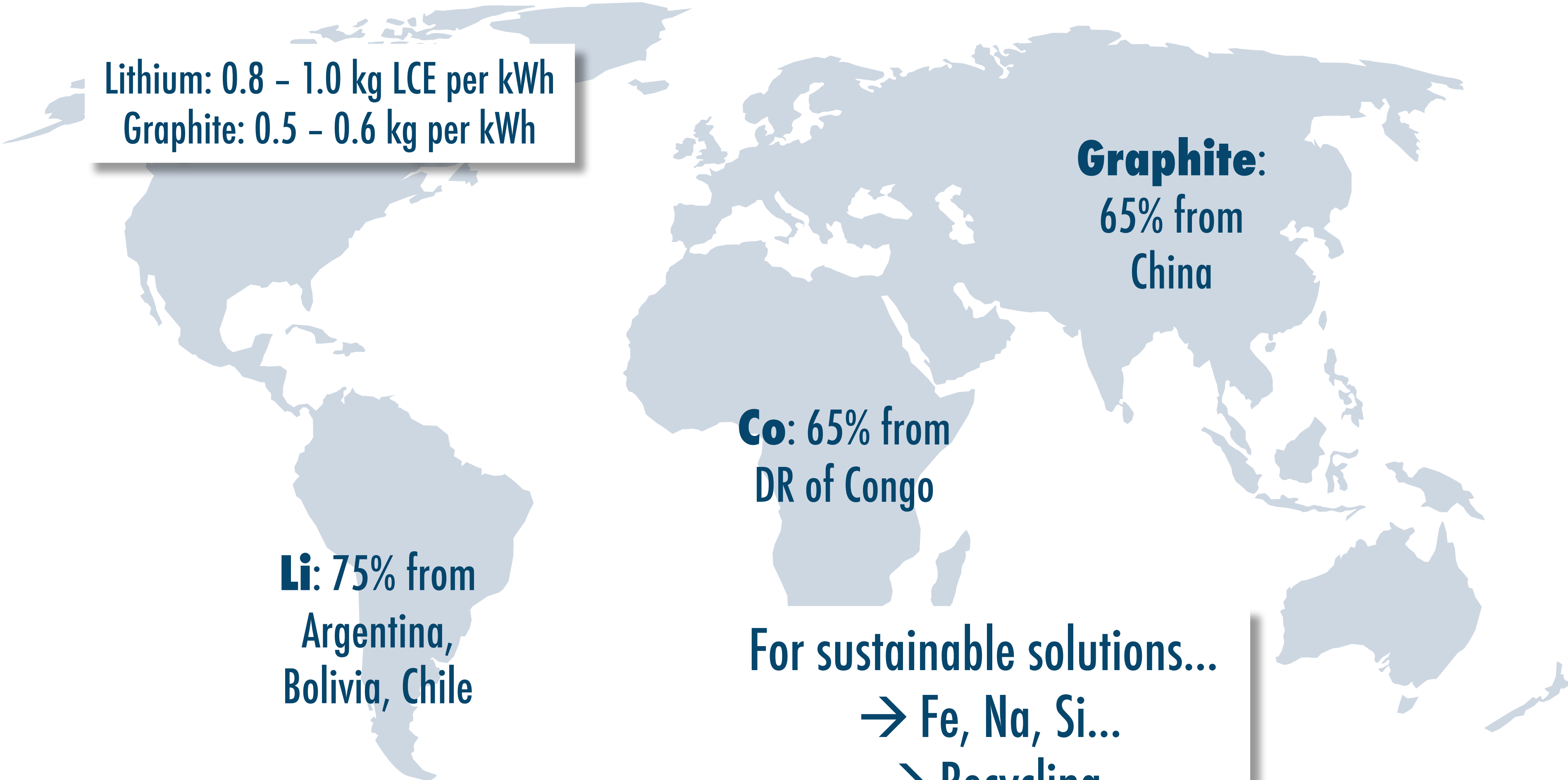
Material resources



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Challenges for recycling

- Complex materials with low concentration of valuable materials
- Energy intense processes
  - Must work for a large variety of cells and chemistries
- Material functionality lost
  - Li often found in slag
- 'Design for recycling'
- Legal issues, directives and regulations
  - Battery directive within EU, WEEE, etc.

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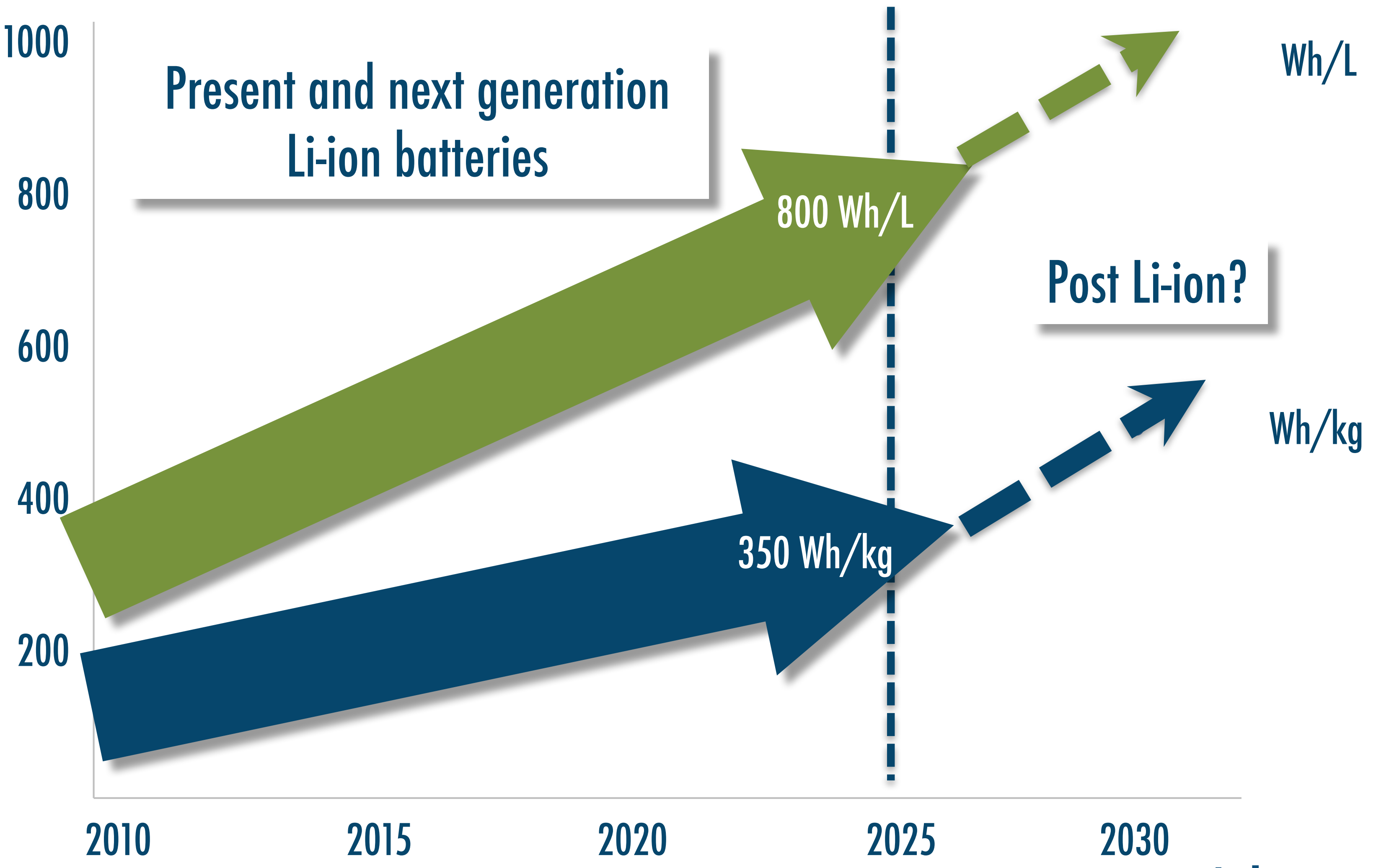
'Emerging' battery concepts for storage

- Next generation Li-ion batteries
- Na-ion batteries
- Al-batteries
- Zn-air
- UltraBattery®
  – Pb-acid + Super Cap in same cell
- NiCd
- Redox-flow…

Cell development



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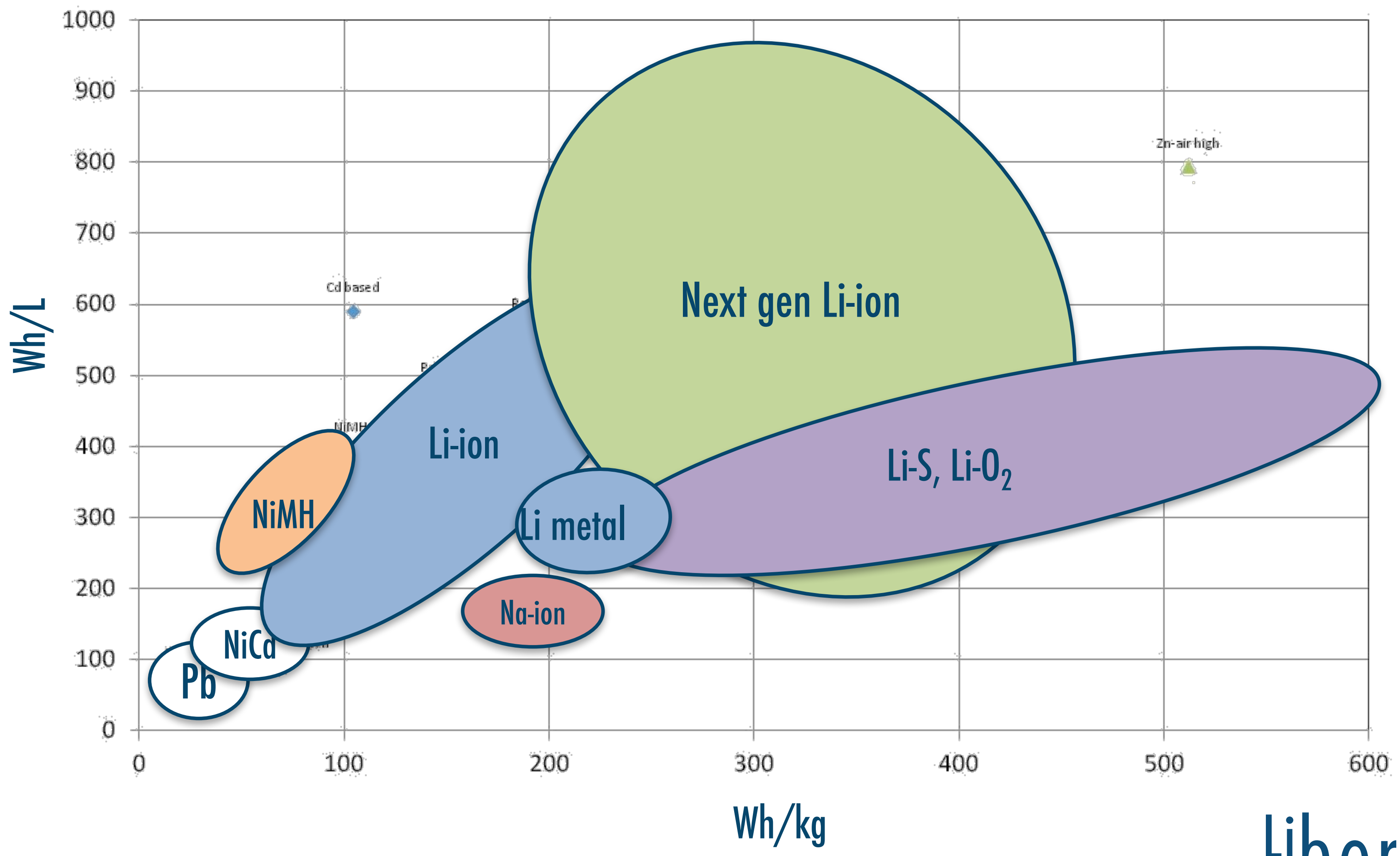
Weight & Volume



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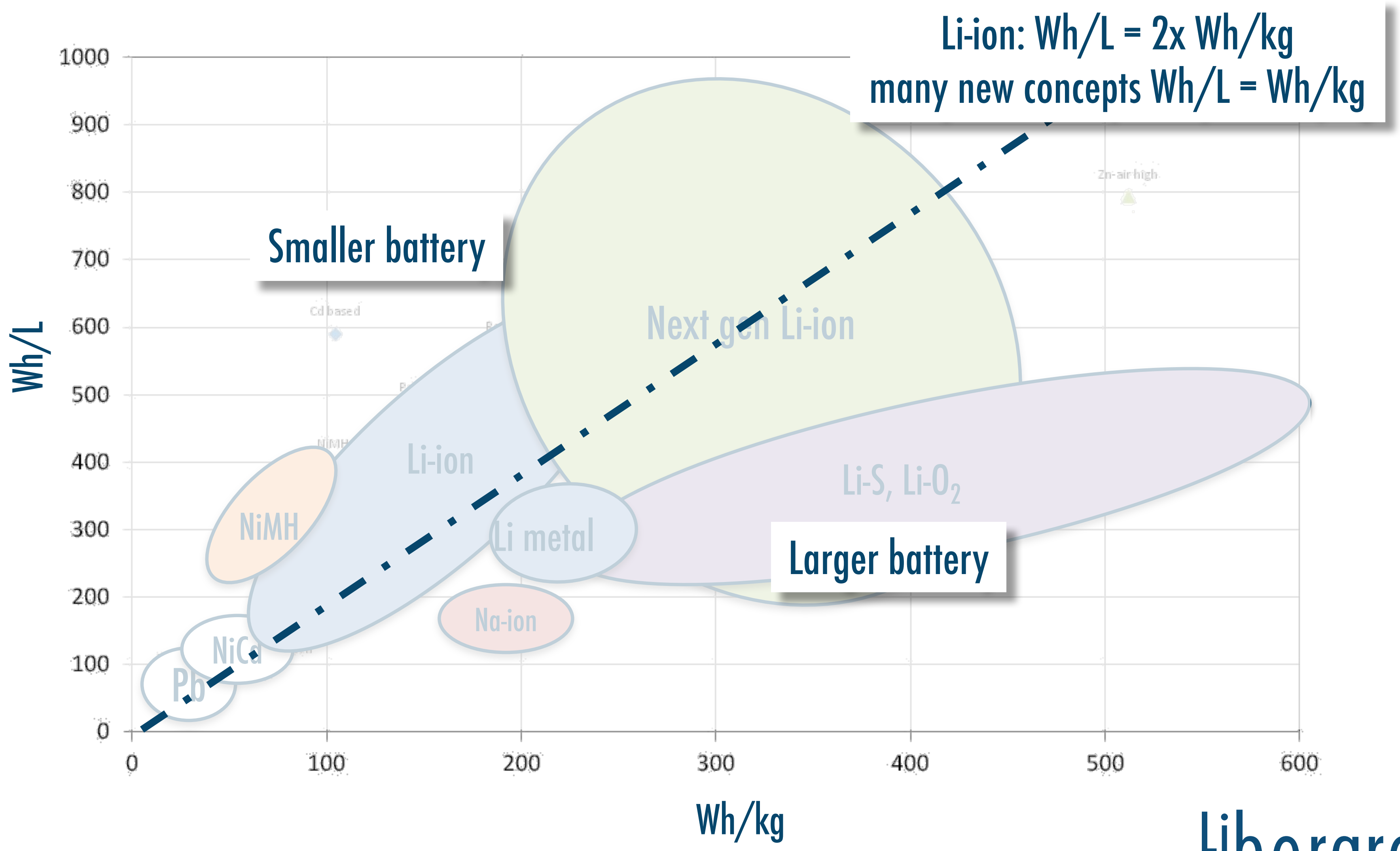

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	N.G. Li-ion	Na-ion	Al	Zn-air	UltraB	NiCd
Energy & Power*	+++	++	+++	0	-/+	0
Weight & Volume*	+++	+++	+++	0	+	0
Durability*	+	+	?	?	+	+
Sustainability	Co	V	?			Cd
Safety	Electrolyte	Storage at 0 V possible!	?	Handling	Same as trad. Pb-acid	No main safety issue, Cd health and envi. issues
Maintenance*	++	++	++	0/-	+	+
Cost of ownership*	+	++	?	0	+	0
Risks	Supply of Co	Few and new suppliers	Research	Mechanical issues	One supplier	Legislation
Time to Market	< 5 yrs	< 5 yrs	> 15 yrs	5-10 yrs	5-10 yrs	On the market

* = compared to Pb-acid of today

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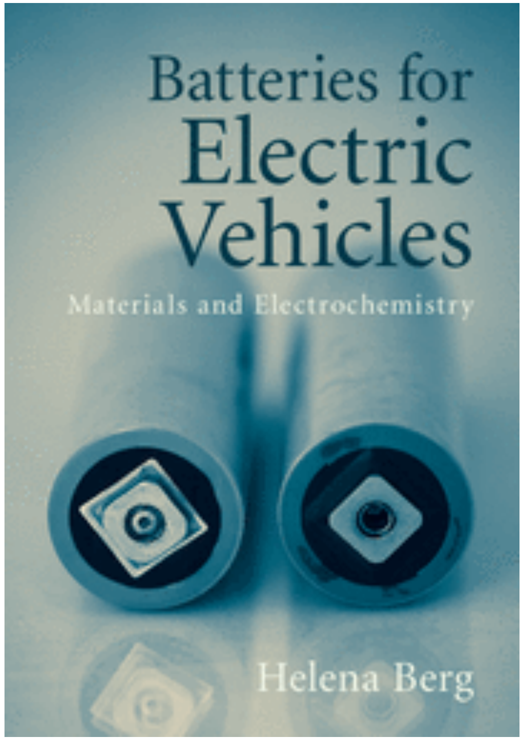
Summary

- Pb-acid batteries are reliable and inexpensive
  – Requires maintenance
- Potential future concepts based on Li-ion or Na-ion are most promising for longer back-up times
- Many more concepts available mainly for portable and automotive applications

Further reading...



28-29 november 2017
Battery course in Göteborg
Link soon at libergreen.com

http://www.cambridge.org/se/academic/subjects/engineering/energy-technology/batteries-electric-vehicles-materials-and-electrochemistry?format=HB#4kHg9CLWpjXUEDhc.97

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