ALISE: Advanced Lithium Sulphur battery for xEV

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Outline

- **Li-ion (limited <300 Wh/kg) ⇒ Post Li-Ion (>400 Wh/kg)**

  LEITAT positioning as RTO

  EU policy

  Post lithium for higher energy density

- **User case ALISE (PHEV)** & Annex: ALION (Stationary)

  Material & Concept associated versus current state of the art

  Key Issue & Challenges

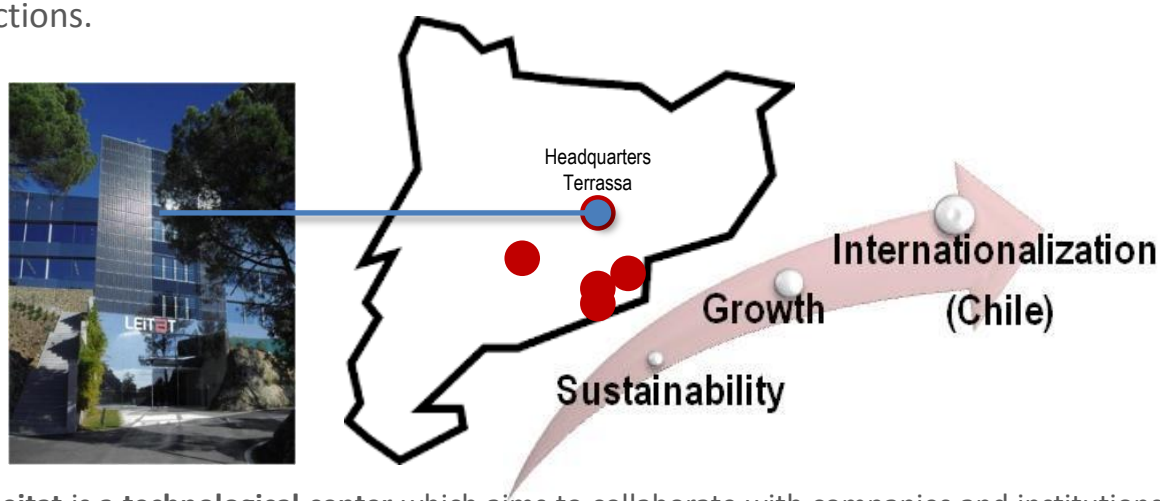
These projects have received funding from the European Union's Horizon 2020 research and innovation programme under grant agreements Nº 666157 and Nº 646286. These results reflect the author's view and the Commission is not responsible for any use that may be made of the information it contains.

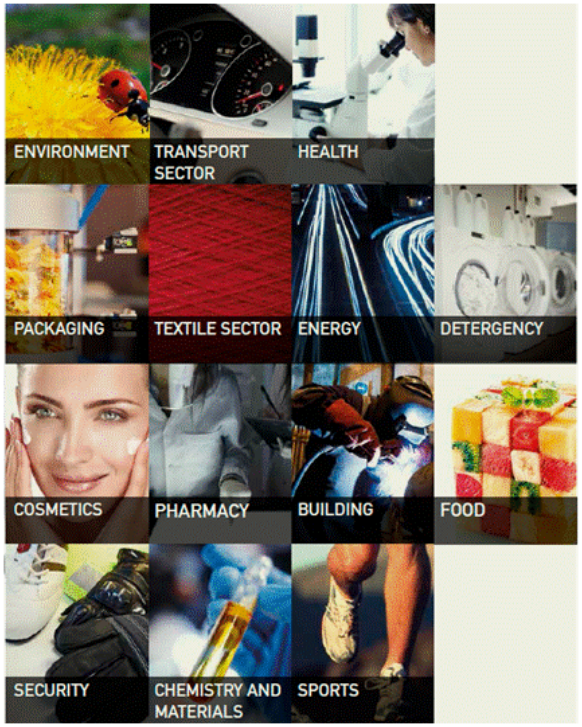
MISSION

Create and transfer **value** with research and technological projects.

VISION

Be an acknowledged **technological partner** for companies and administration; create a co-operative culture that enables sustainable growth and efficiency of actions.





- **Leitat** is a **technological center** which aims to collaborate with companies and institutions to create economic, social and sustainable value.
- Leitat is the trademark of Acondicionamiento Tarrasense, an Spanish **non-profit private institution** constituted in 1906.
- Leitat **performs R&D projects** in collaboration with companies and institutions both nationally and internationally

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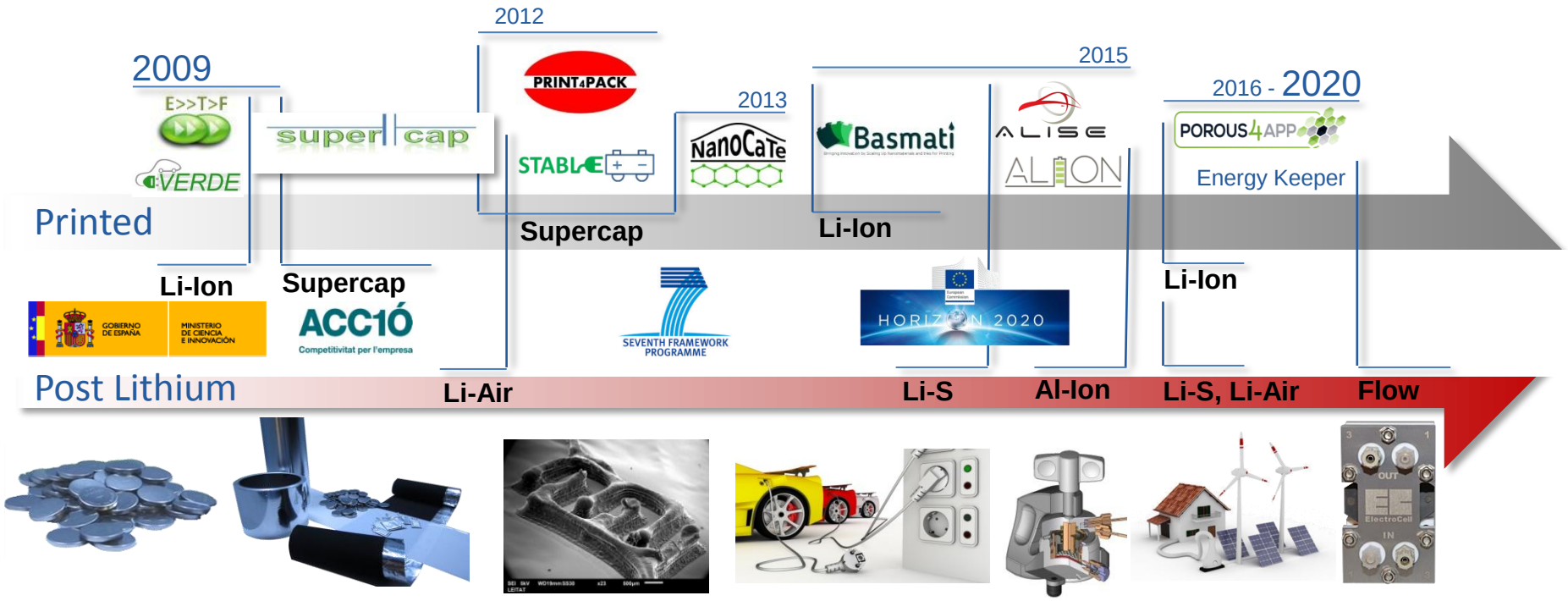
R&D LEITAT Energy Storage

- Post lithium ion for EV and stationary (>400Wh/kg, Al-Ion, LiO_2, LiS, Flow Batteries)
- Printed batteries for small electronics (Supercap, Li-ion, Al-Air and hybrids)



Li-Ion | Supercap | Printed | LiS, Li-Air | Al-Ion, Polymeric Flow RedOx

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Li-ion battery: Market and European Policy from 2008

- Number of Advanced Material Patents was well balanced in 2010 (30% US / 31% EU / 35% Asia)
- The Asian share of Li-ion battery production increased from 87% in 2010 to 94% in 2012
- EU recovering from crisis: new sources of economic growth needed
- Strengthen and revitalize the European Industrial base
- For competitiveness and to address Grand Challenges
- Leadership in enabling industrial technologies (LEIT) is crucial
- EU support six Key Enabling Technologies (KETs) in Horizon 2020 and other programs
  - Europe is a global leader in knowledge creation (publications and patenting)
  - Europe falls behind competitors in knowledge exploitation largely due to ‘valley of death’ problems
  - Asia leading in mass manufacturing of KETs based products, but competitive advantage is eroding as labour costs in China rise and robotics reduces the importance of labour in manufacturing

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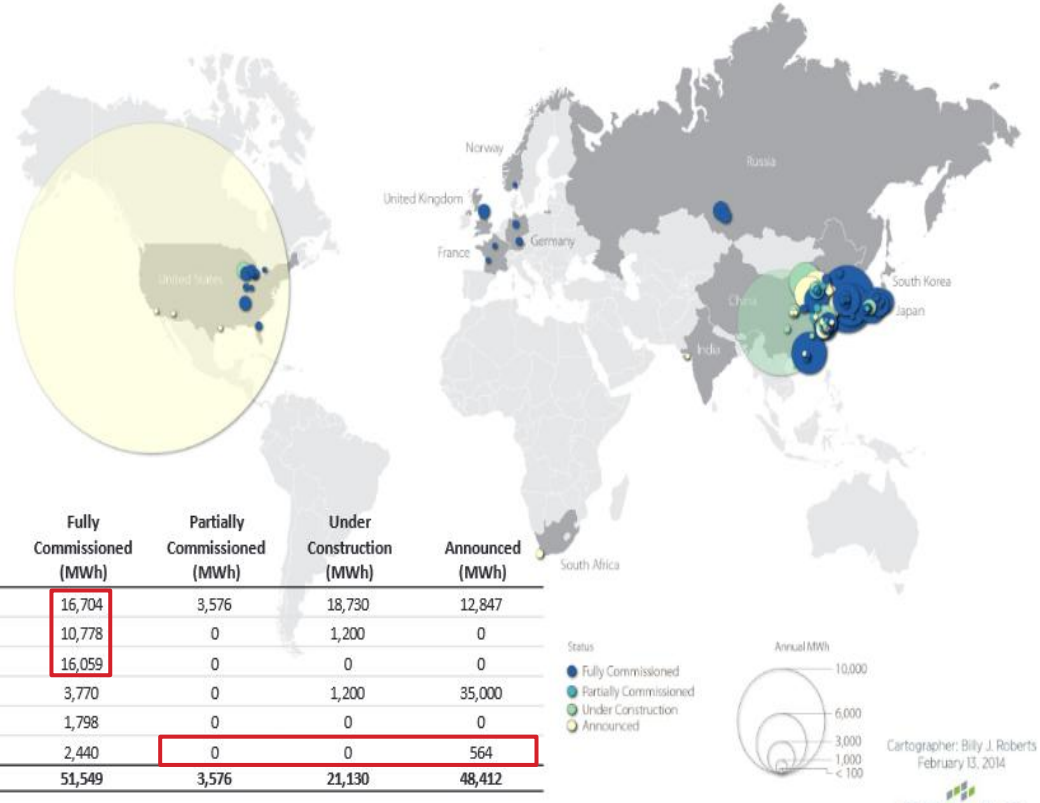
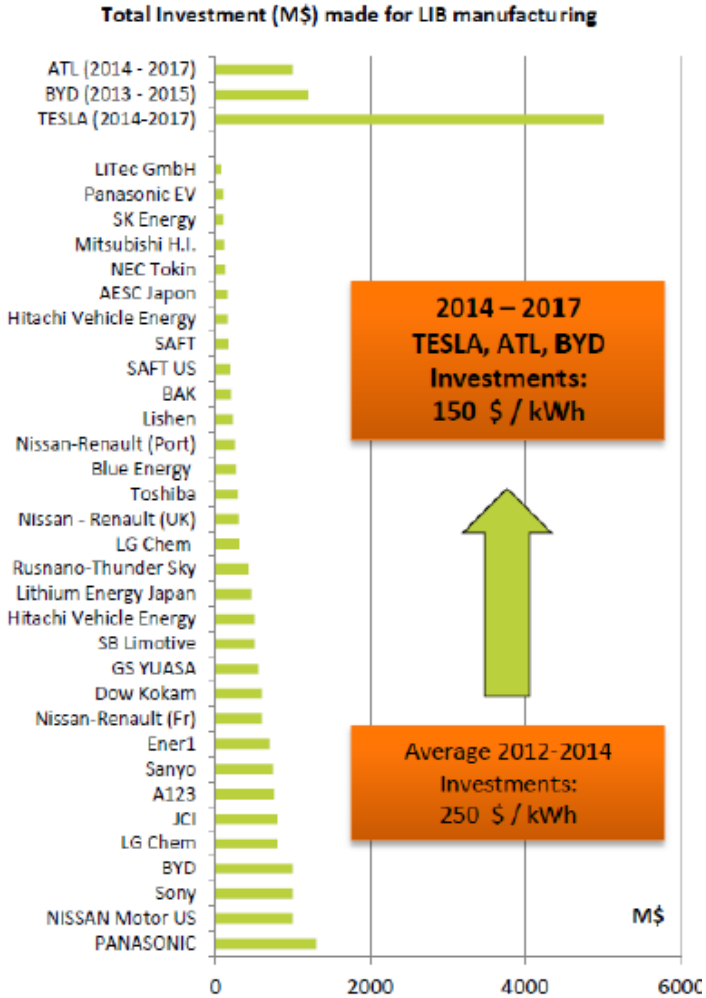
Global Li-ion battery manufacturing (2015)

- LIB Manufacturing is concentrated in Asia
- EU policy aims to develop new technologies beyond LIB



	Fully Commissioned (MWh)	Partially Commissioned (MWh)	Under Construction (MWh)	Announced (MWh)
China	16,704	3,576	18,730	12,847
Japan	10,778	0	1,200	0
Korea	16,059	0	0	0
U.S.	3,770	0	1,200	35,000
EU	1,798	0	0	0
Rest of World	2,440	0	0	564
TOTAL	**51,549**	**3,576**	**21,130**	**48,412**

Note: This map includes factories that are fully and partially commissioned, under construction, and announced. Capacity is not disclosed for all factories.
Source: Corporate reporting. Bloomberg New Energy Finance BNEF (2015).



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Major part of the value is ascribed to materials & manufacturing

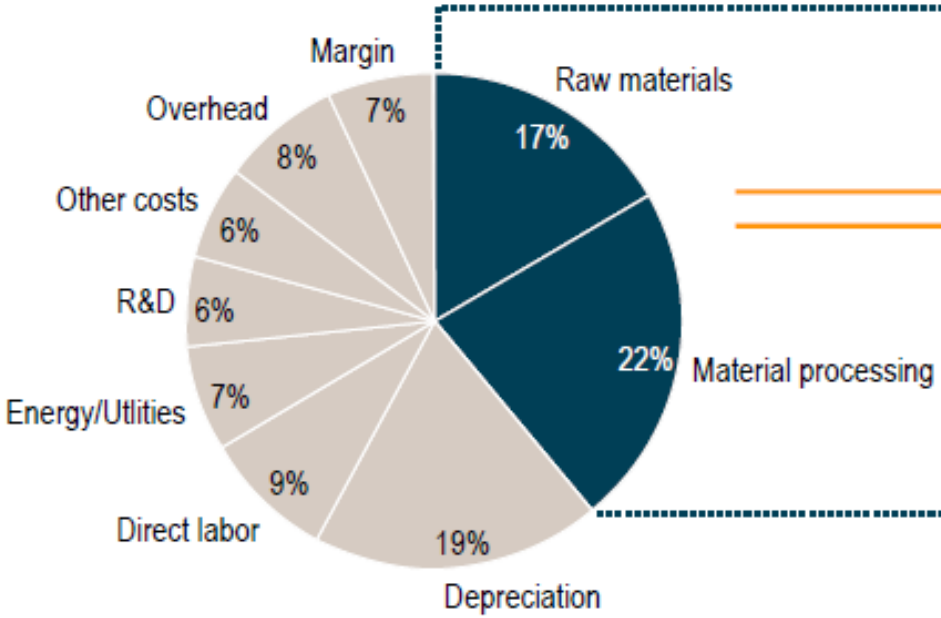
30% final battery systems cost

Roland Berger Strategy Consultants

Importance of different materials in cell battery cost structure

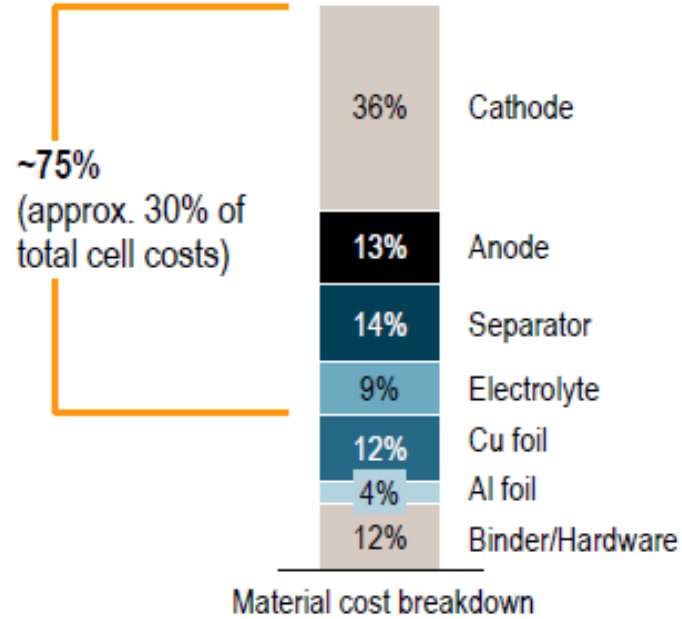
Battery cell cost breakdown, 2010[1)]

Total cost: approx. USD 500/kWh



Material cost split, 2010[1)]

~USD 195/kWh



1) Approximate values for ternary mixture (NMC), depend on the chemistry and quality, excl. module/pack components (connectors, housing, BMS, cooling module)

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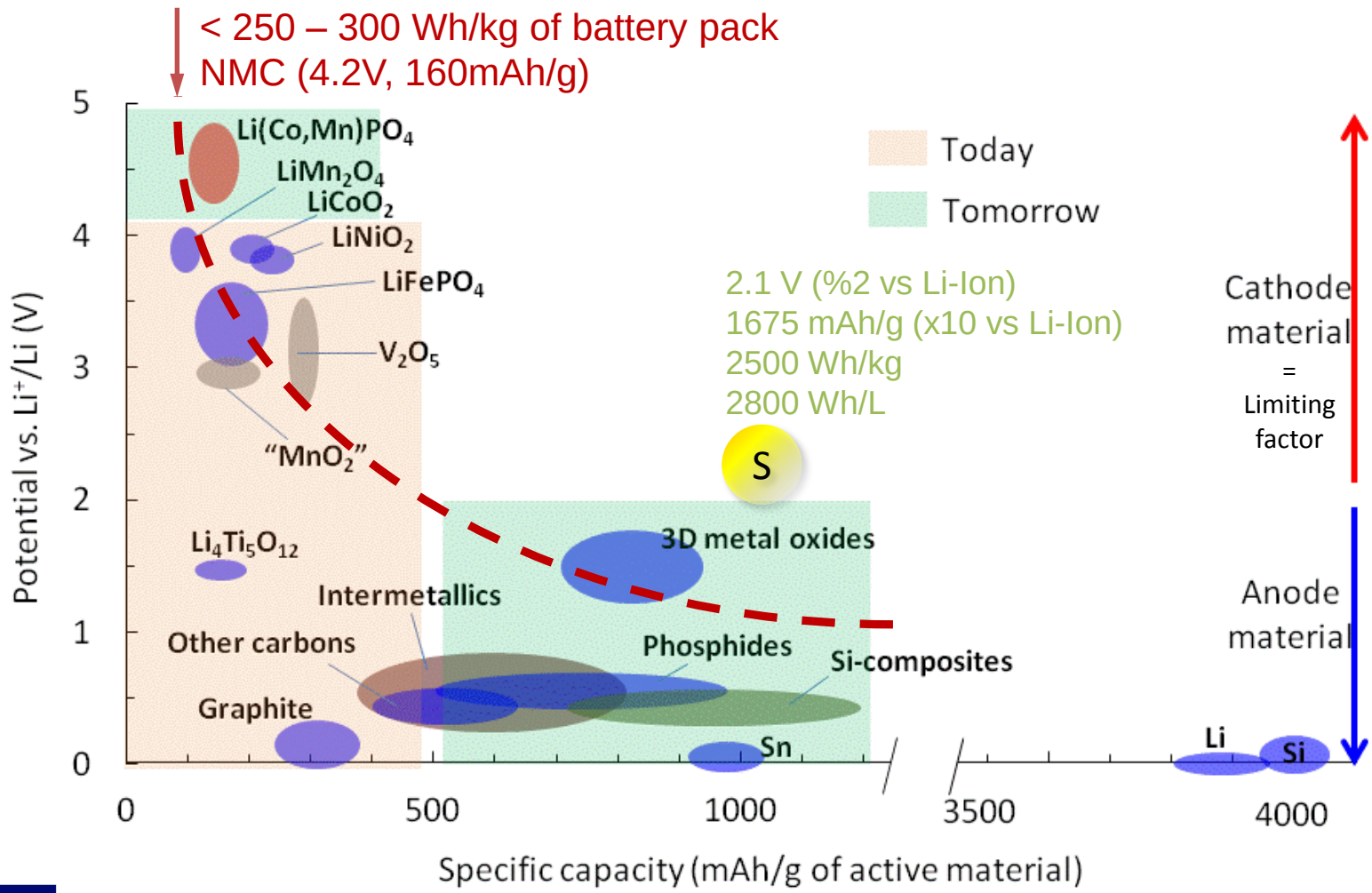
Li-ion battery is reaching its performance limit



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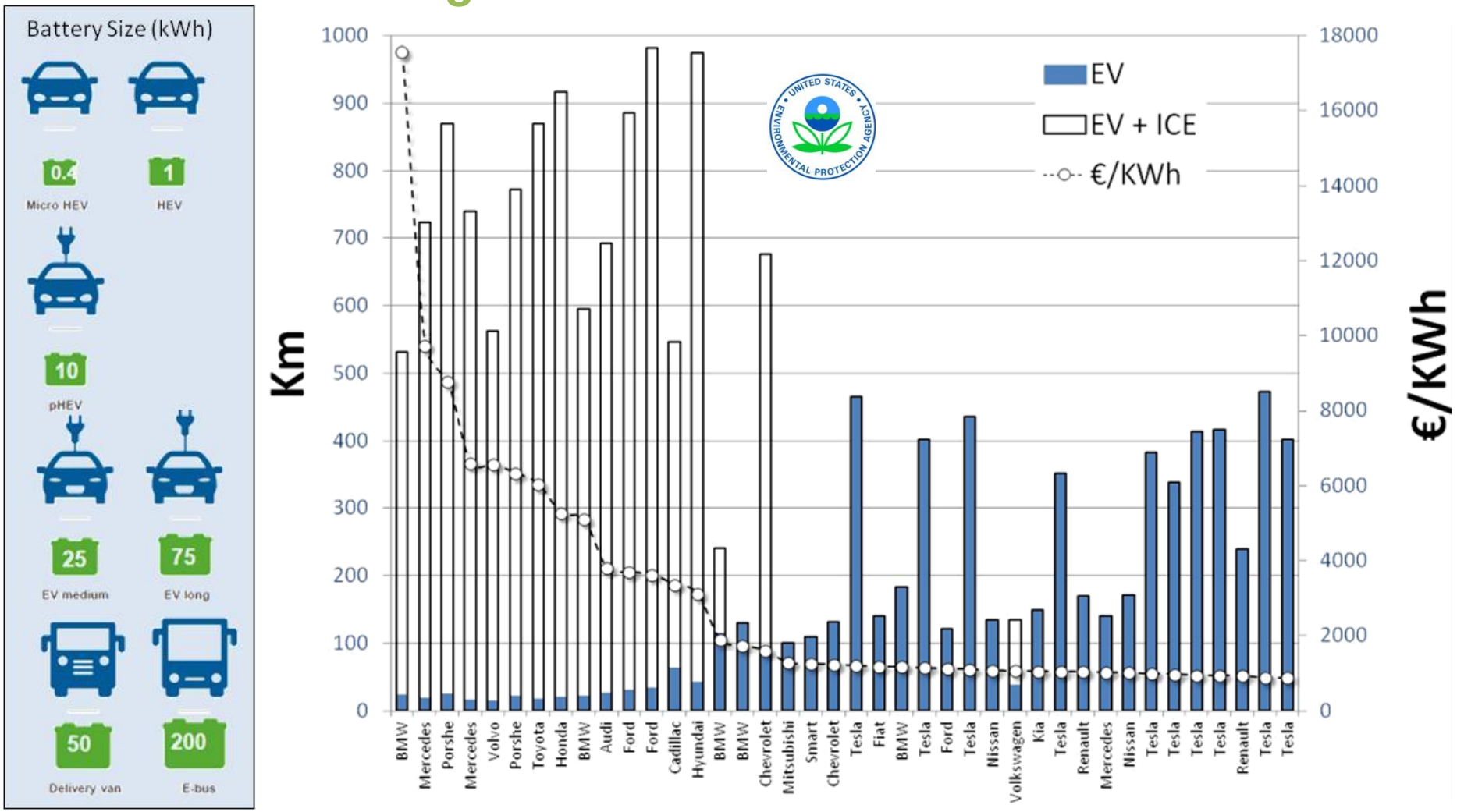
EV Panorama: Range versus €/KWh



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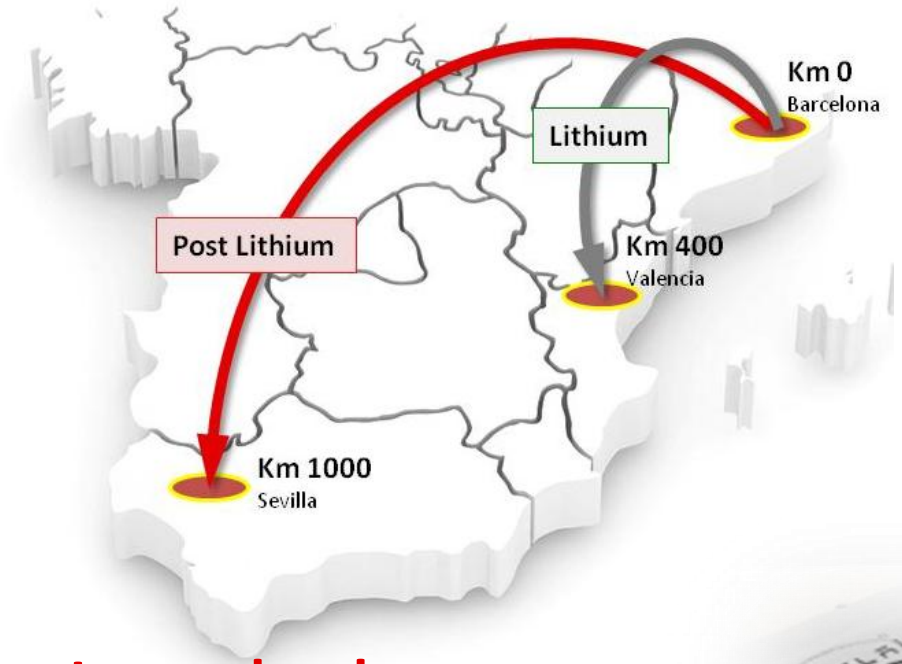
Post Lithium leads to Higher Specific Energy = Higher Range



We bet on

Post Li-Ion technology

for

Tomorrow

LiS – LiO_2 –Al-Ion

> 400Wh/Kg

Lithium Ion technology

Today

Panasonic 233Wh/Kg
Kokam 186Wh/Kg
Samsung 160Wh/kg
A123 Systems 118Wh/kg

Driving Range 500 Km

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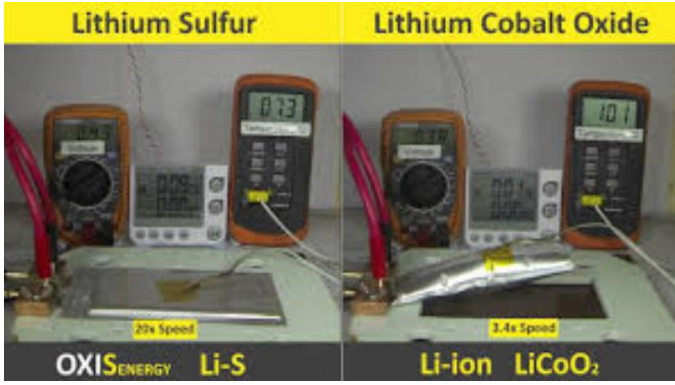
EV target



- Safety (Hazard level 4)
- Volumetric energy density 600-700 Wh/L
- Fast charge (30 minutes)
- Cells´ quantity availability (hundred GWh/years)
- Reasonable cost (<200 €/kWh)
- Recycling (Co free)

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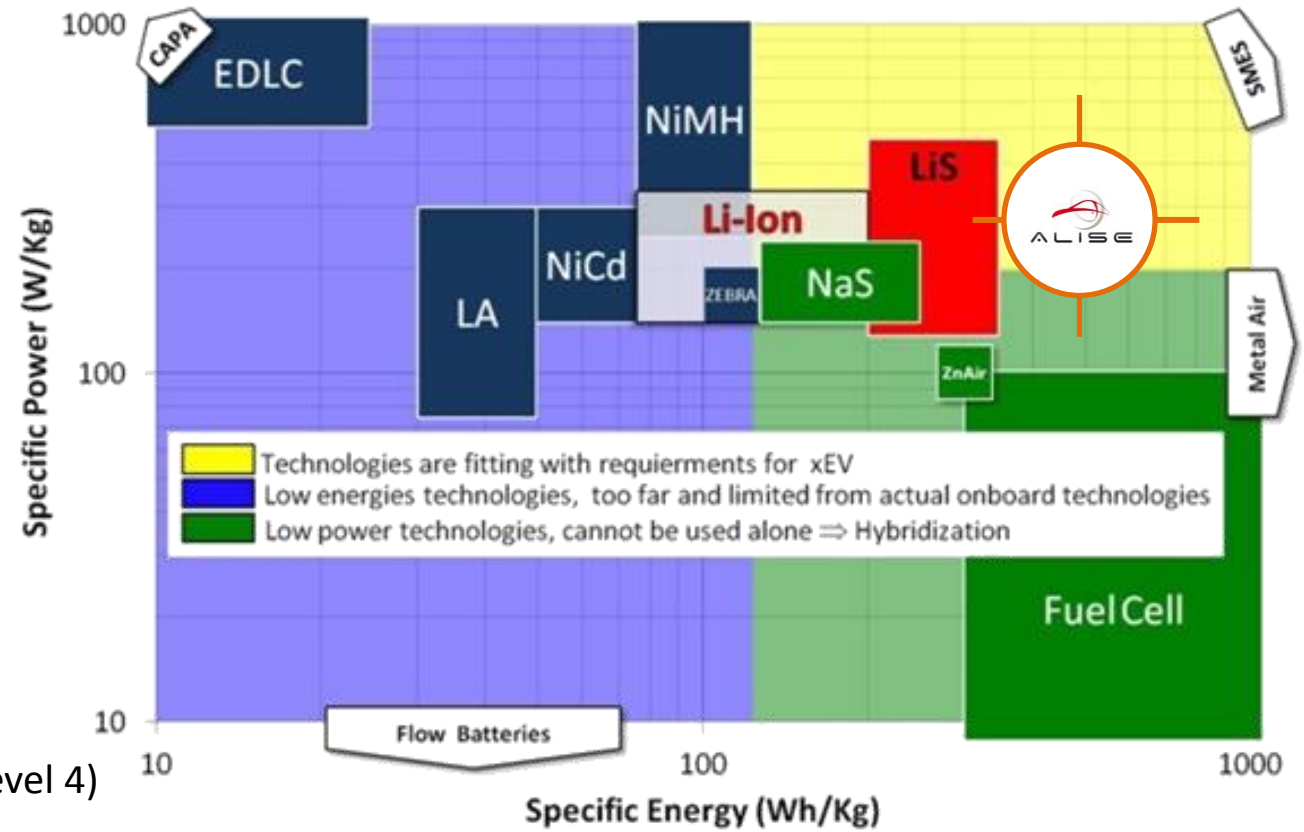
H2020-NMP-GV-2014
Grant agreement n° 666157.
EU contribution: 6,899,233 €
Duration : June 2015 – May 2019
Coordinator: LEITAT
http://www.aliseproject.com/

KPIs´ ALISE

- 500 Wh/kg
- 250 W/kg (C/2)
- ≤ 300 €/kWh
- 2000 cycles
- 80 wt.% S
- 80% S utilization
- Safe technology (Hazard Level 4)
- 17 KWh, 100Km



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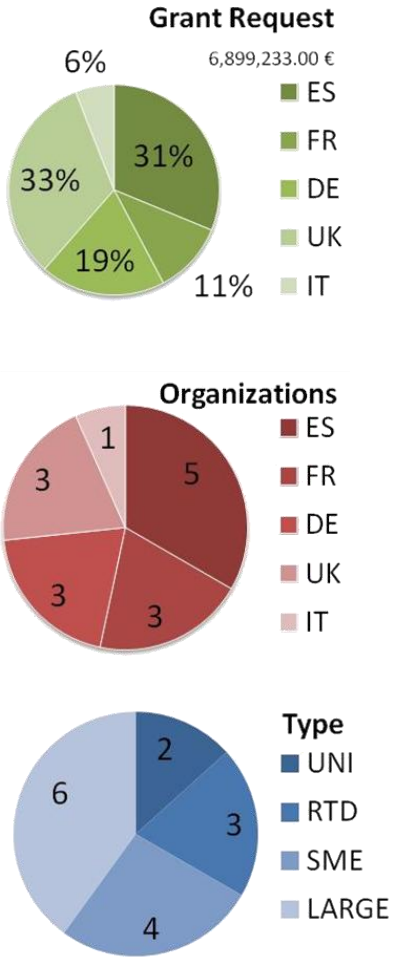
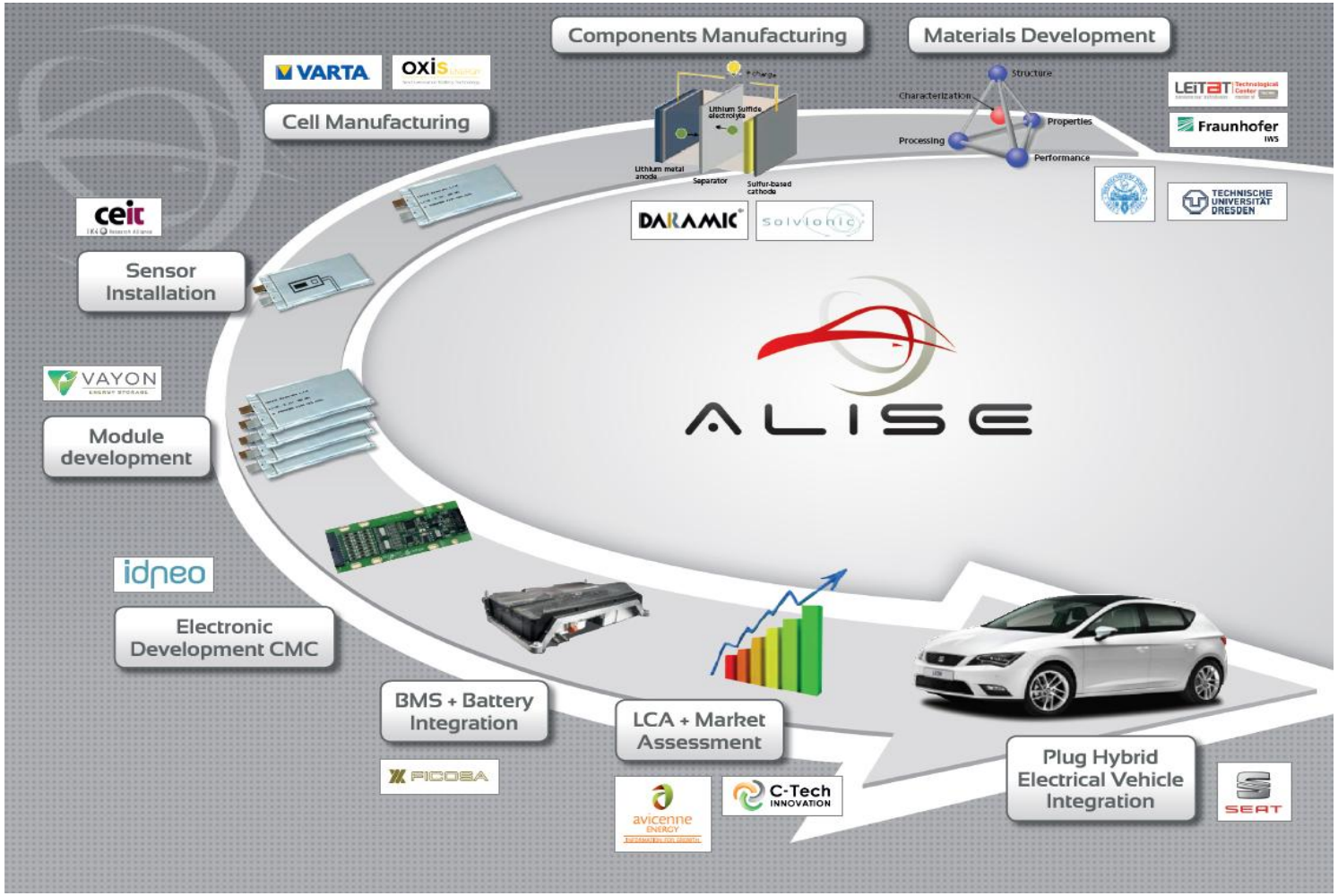
ALISE LiS EU Value chain





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Highlight ALISE contribution

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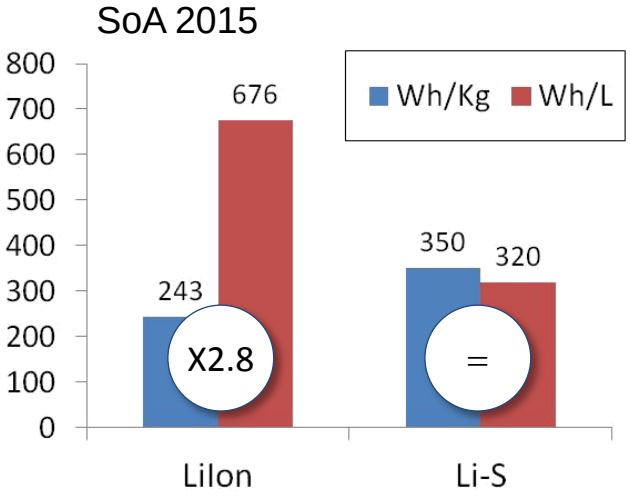
ALISE Time line



Today labscale (ALISE)
10Ah pouch cell
400 Wh/kg,
300 W/Kg @ 1C
2.1 V
100 cycles

2nd cell Generation
Target 500 Wh/kg

June 2015 → June 2016 → Sept. 2016 → Feb 2017 → Nov 2018 → May 2019

KOM

Milestone reached
S content >70wt%,
Specific capacity
2.5mAh/cm²
1200mAh/g of S

1st cell Generation
Target 400 Wh/kg

112 €/KWh @ cell level
186 €/KWh @ pack level

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LiS Challenges for EV & related to material/electrochemistry

- Wh/L is too low (today 300Wh/L → possible 600 Wh/L)
- Electrolyte weight percentage is too high
- S as Active material is not electrically conductor
- Polysulfide shuttle
- Lithium anode is limiting the cycle life (SoA 50-100 cycles)
- LiS algorithmic unknown (SoH, SoC, chemical aging)

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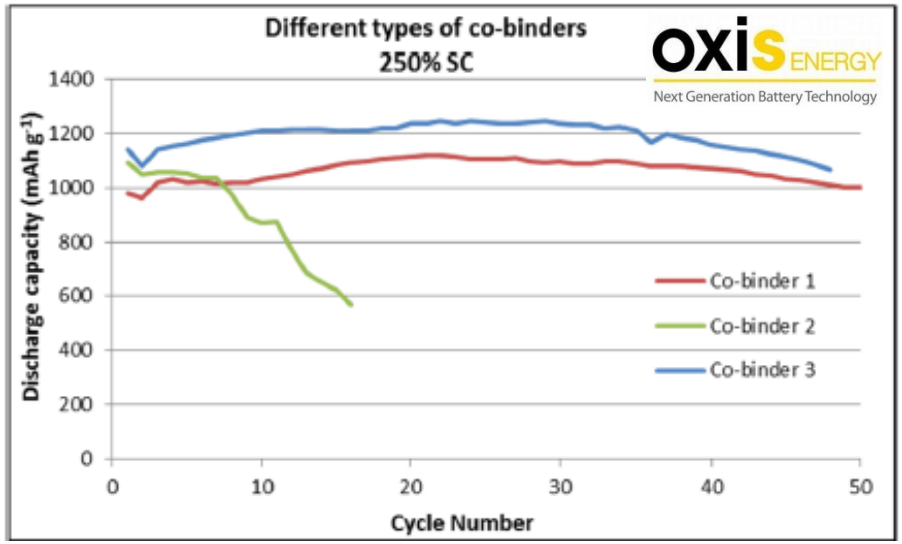
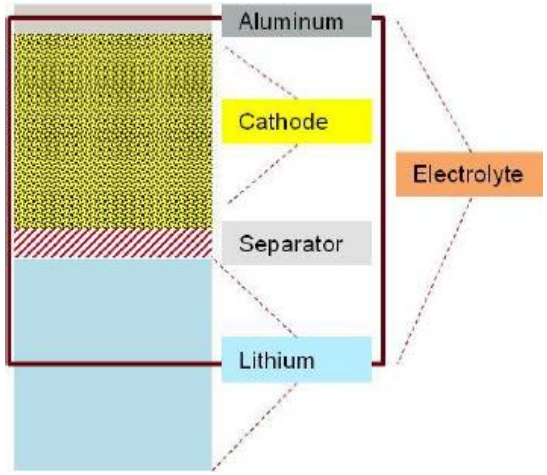
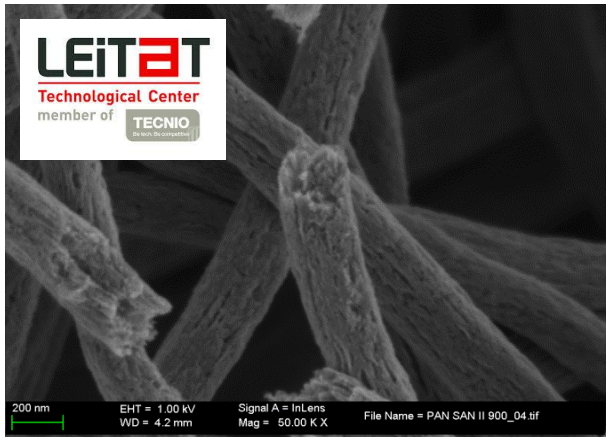
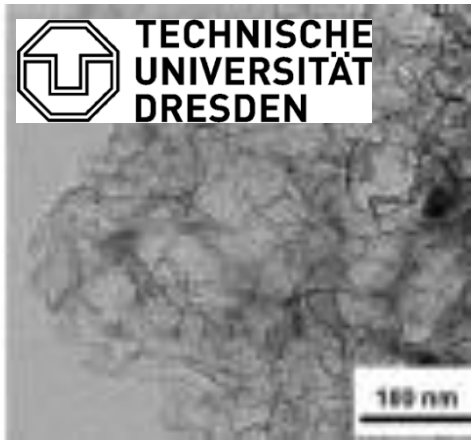
LiS Challenges: Highlight on cathode



↓ Electrolyte volume = Wh/L↑







TARGET

- Areal capacity: > 2.5 mAh/cm^2
- Target electrolyte / sulfur weight ratio < 3:1
- S contents > 70%
- Specific capacities > 1.200 mAh/g (for C400)
- For C500 a content of 80% sulfur in the cathode and 1300mAh/g is targeted.

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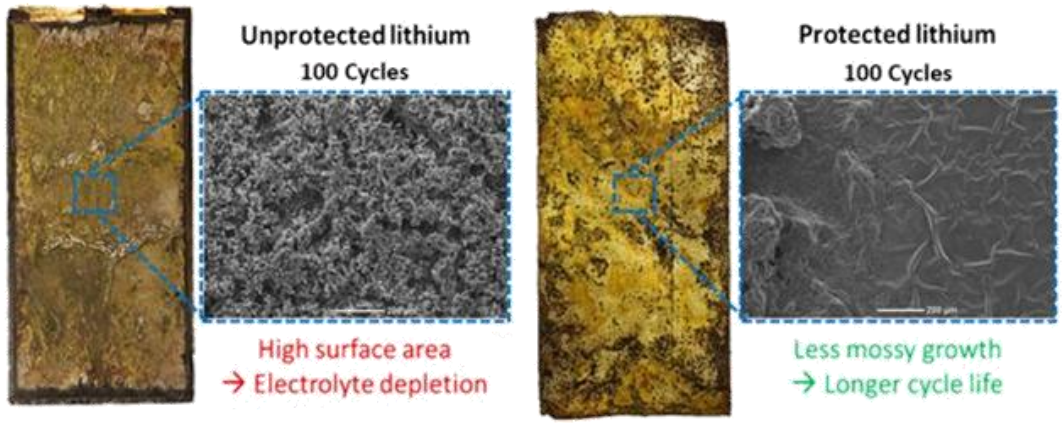
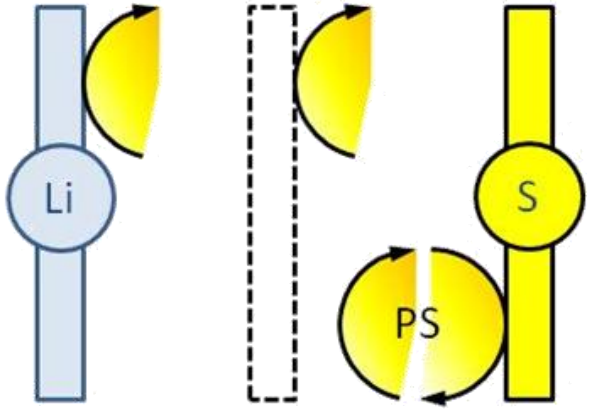
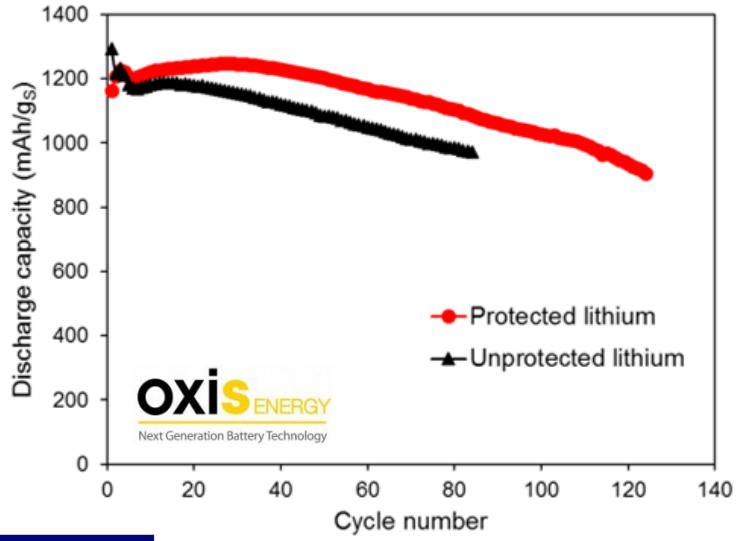
LiS Challenges: Highlight on anode / PS







CONCEPT

- To keep PS at the neighborhood of the cathode
- To avoid PS crossing membrane separator
- To protect metallic Lithium
- To develop lithium alternative

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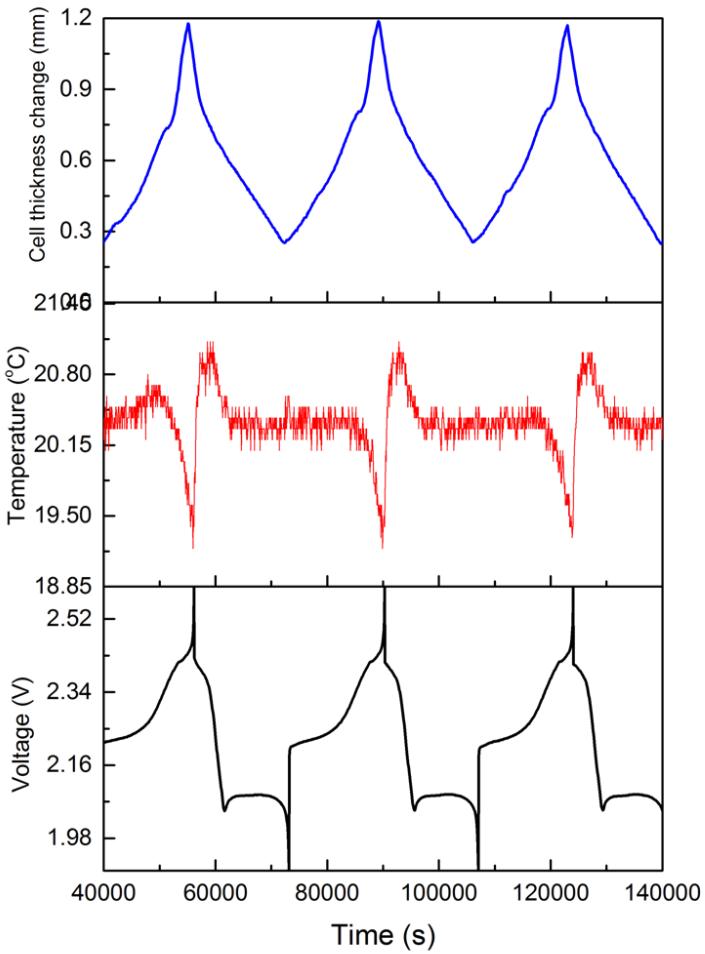
LiS Challenges: Highlight on SoC monitoring

CONCEPT

- To track V vs Q (mAh/g) is not possible
- Coulomb counting is not enough (chemical aging)
- To track SOC vs deformation is possible
- To track SOC vs T is possible
- To track SOC vs ESR is possible



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Conclusion: Post lithium versus actual technologies

- **Interesting potential:**
  - Higher Li-Ion Wh/kg (Today) at same Li-Ion W/kg (Tomorrow), €/kWh (Tomorrow), cycles (Tomorrow)
  - EV target: 600-700 Wh/L, fast charge, <200€/Wh, safety, cells´ quantity availability, recycling
  - Sectors: EV (full, bus, heavy truck...) , Aeronautic, Maritime, Drone (infrastructure controlled), Medical....
- **Non industrial mature technology** Cell mass production is missing in EU
- **Time to market** EU & secondary storage system**:**

  [Implemented] Lead Acid, Ni-Cd >>> Na (high T), Li-Ion, supercap
  >> [Low Production] LiS, Flow batteries
  > [Research Stages] Zn Air (II), Na-S, Solid State >> LiO_2
  >>> [Laboratory scale] Al-Ion, Ca-Ion...
- **Research stages are needed:**
  - Electrochemistry, material, cell, modeling, electronic, module, pack

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Next Event @ Barcelona (Spain)

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Many Thanks

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ALION project

High Specific Energy Aluminum Ion Rechargeable Decentralized Electricity Generation Sources

H2020-NMP13-2014
Grant agreement n° 646286.
EU contribution: 7,223,552 €
Duration : June 2015 – May 2019
Coordinator: LEITAT
http://www.alionproject.eu/

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Stationary applications

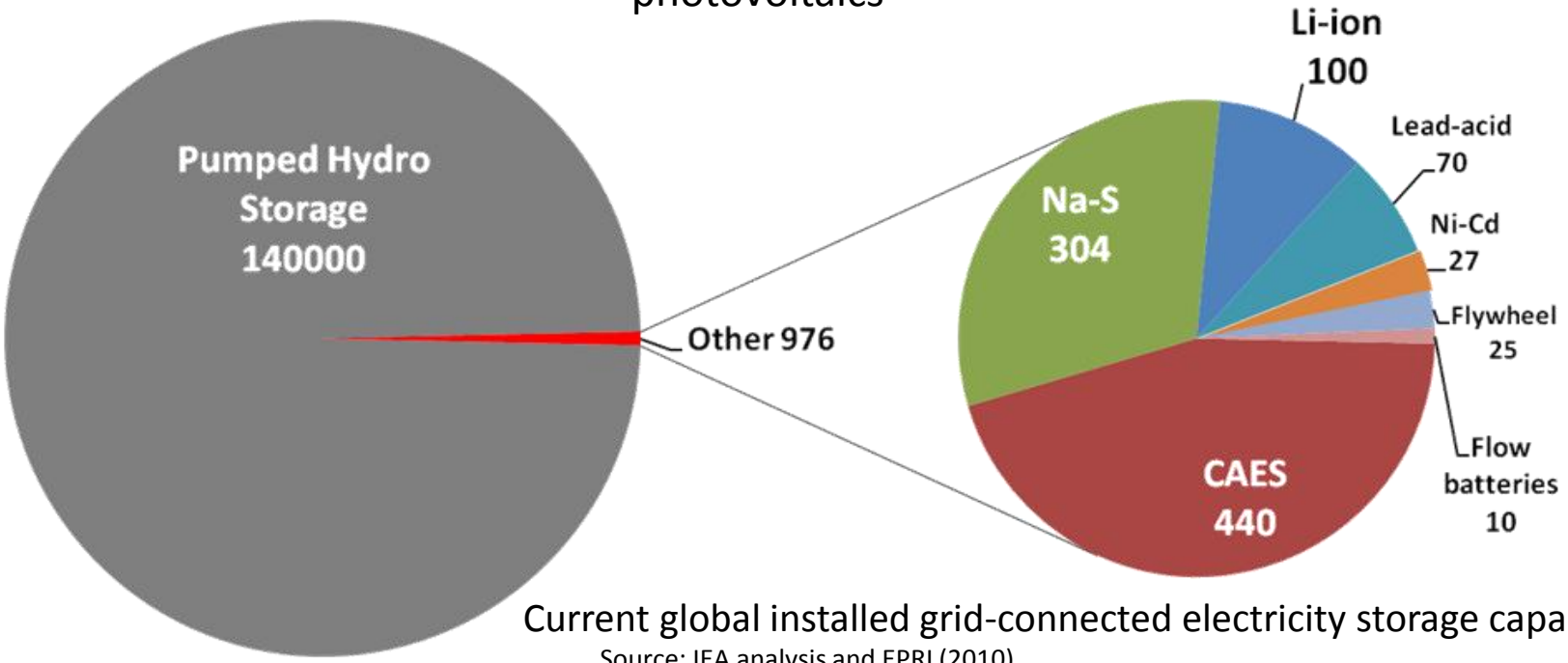
Buildings & Plants

Oil & Gas

Off-grid photovoltaics

Transport infrastructures

Utilities



Current global installed grid-connected electricity storage capacity (MW)

Source: IEA analysis and EPRI (2010)

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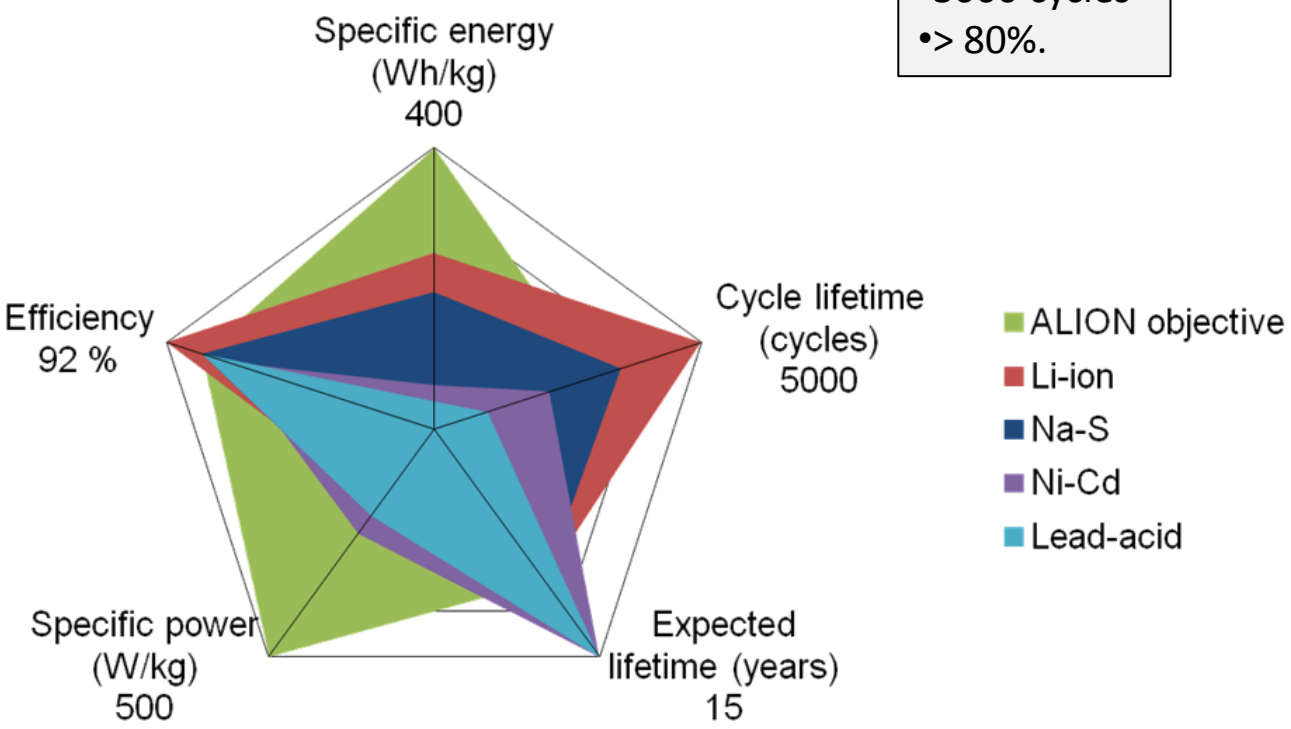
Stationary batteries

Golden Valley Electric Association (Alaska) 40 MW

Laurel Mountain West Virginia (US) 32 MW

Rokkasho-Futamata Wind farm (Japan) 34 MW - 238 MWh

KPIs´ ALION
- 400 Wh/kg
- 48 V
- 3000 cycles
- > 80%.



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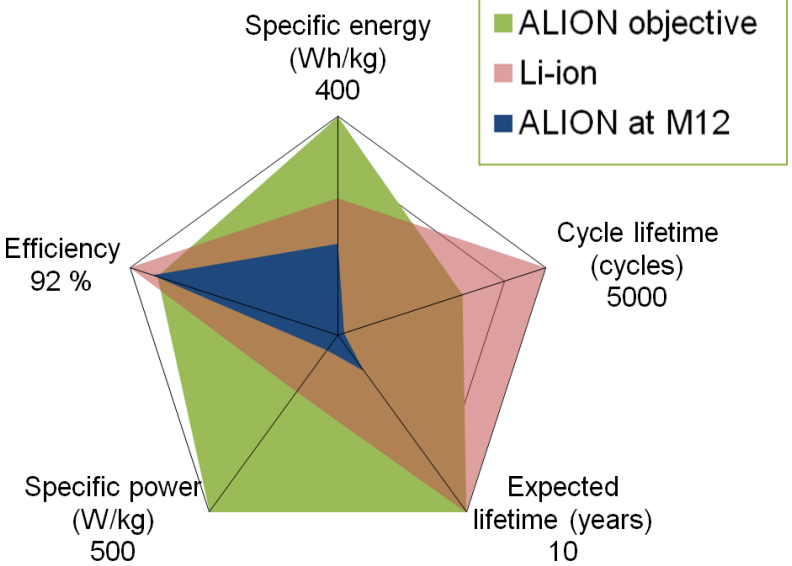
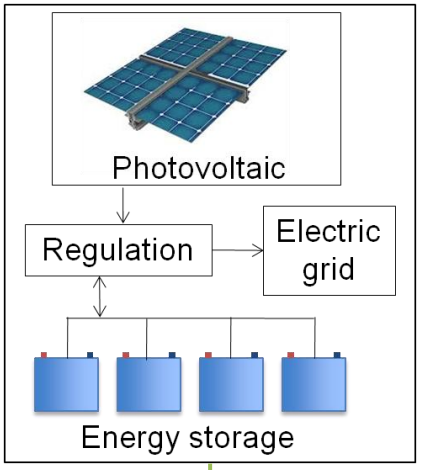
ALION Timeline



Today labscale (ALION)
Swagelok
160 Wh/kg,
50 W/Kg @ 1C
2 V
50 cycles
90% columbic efficiency

SoA 2015 labscale (1)
0.3x6 cm² Pouch cell
40 Wh/kg,
3000 W/Kg @ 60C
2.25 – 1.5 V
7500 cycles
90% columbic efficiency

Integration in microgrid



June 2015 → Sept. 2016 → September 2017 → May 2019

Start

Cell
400 Wh/kg
200 cycles

(1) An ultrafast rechargeable aluminium-ion battery, Nature 520, 324-328 (16 April 2015)

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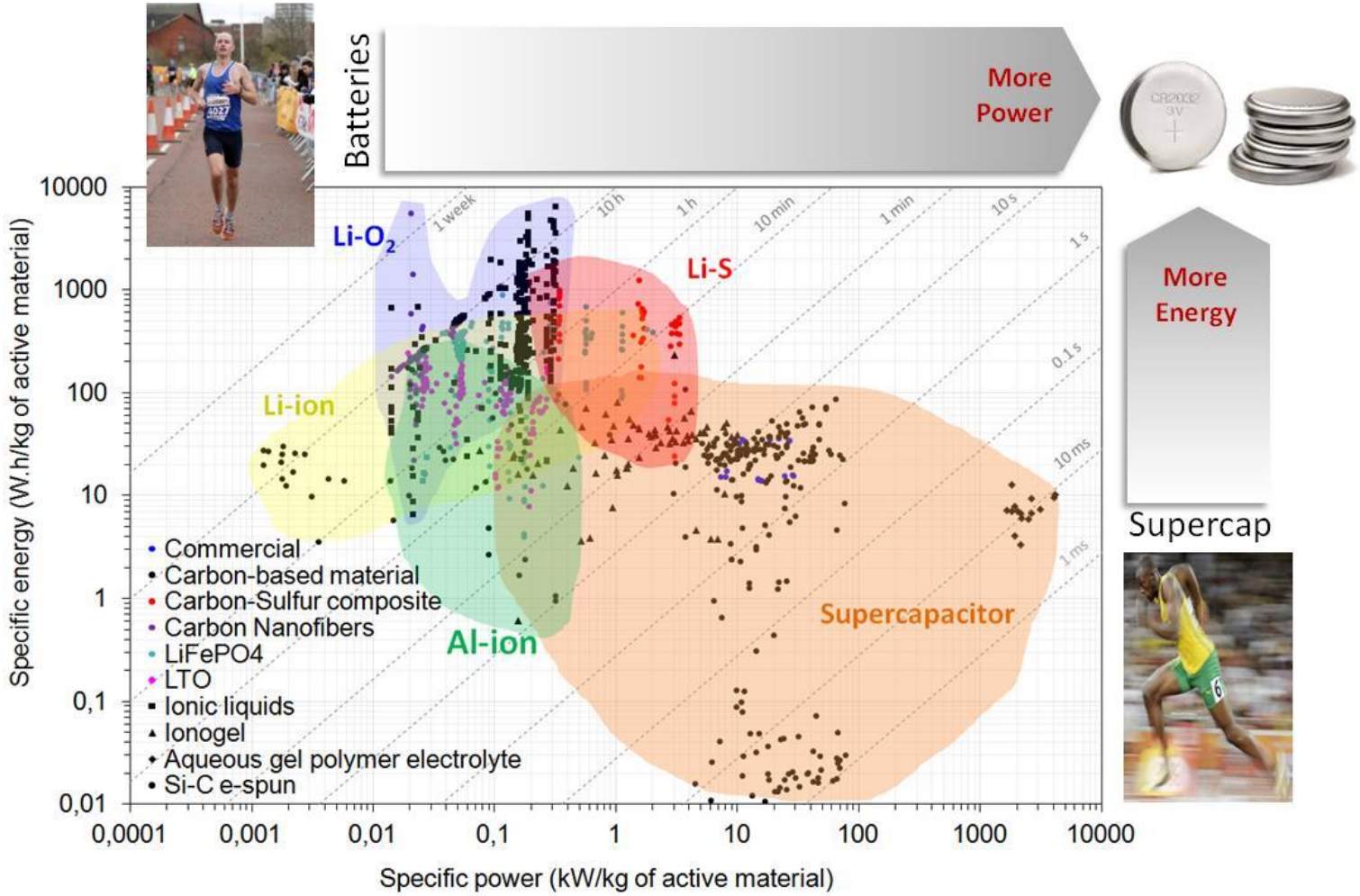
LEITAT lab samples



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Significant Achieved Milestones and Technology Roadmap

OXIS Energy Delivers On Cycles, Gravimetric and Volumetric Energy

2012

Capacity:
1.7 Ah

Type of cells:
- Coin and small pouch

Gravimetric energy:
- 200 Wh/kg

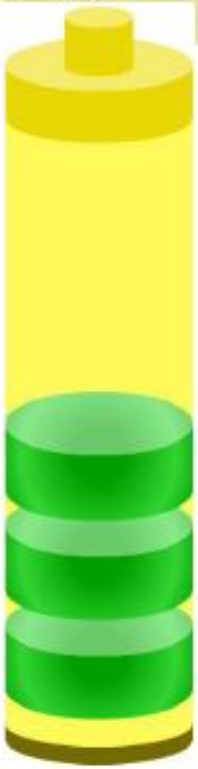
Volumetric energy:
- 300 Wh/l

# of cycles[2]:
- 100 – 300

Manufacturing:
- Hand made

2016

Capacity:
39 Ah



Type of cells:
- **Large pouch**

Gravimetric energy[1]:
- **220 – 350Wh/kg**

Volumetric energy[1]:
- **230 – 400 Wh/l**

# of cycles[1]:
- **120 – 1,400**

Manufacturing:
- **Automated line**
- **Volume**

2019/2020

Capacity:
>50 Ah

Type of cells:
- **Large pouch**

Gravimetric energy[1]:
- **280 – 500 Wh/kg**

Volumetric energy[1]:
- **280 – 550 Wh/l**

# of cycles[1]:
- **1,500 – 2,500**

Manufacturing:
- **Automated line**
- **Mass production**

OXIS Energy has consistently delivered on its technology roadmap, be it on gravimetric energy, volumetric energy and number of cycles. This makes OXIS the leading supplier of lithium sulfur battery technology.

(1) Figures given relate to the range covered by both OXIS's Long Life and Ultra Light Li-S technologies
(2) At 100% or 80% DoD
Source: OXIS Energy

OXIS ENERGY
Next Generation Battery Technology