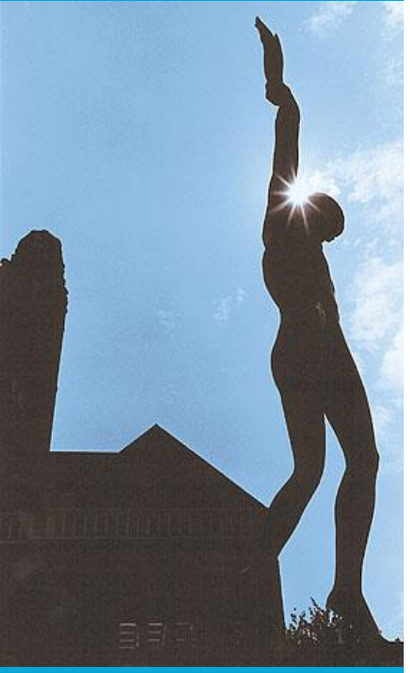

High energy density Li-ion cells for traction

EuroLiion

- Erik Kelder
  Delft University of Technology

CP-CP 265368

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Delft University of Technology

Joint EC & EGVIA workshop for advanced automotive batteries research - European projects' contributions to the key user requirements – 12 October 2016, Brussels

EGVI
European Green Vehicles Initiative

Project general overview

EC Call	**GC-SST.2010.7-9. TPT:** Collaborative project			
	Type of action	**Project budget**	**EU Funding**	**Project Start-End**
	Research & Innovation	€ 5.35 m	€ 3.95 m	1st February 2011 31st January 2015
Partners	See next slide			
Target & Deliverables	**Development of a new Li-ion cell for traction purposes with the following characteristics:** - Low costs: i.e. a maximum 150 €/kWh - An energy density of at least 200 Wh/kg - Meet or exceed safety standards			
Overall Approach	Combined timeline and approach – see next slide			

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The Team

ALISTORE-ERI (an institute evolved from an EC-FP6 Network of Excellence)

- Delft University of Technology - coordinator (NL)
- CNRS with two laboratories - Laboratoire de Réactivité et Chimie des Solides (FR), - Institut des Matériaux de Nantes (FR)
- Uppsala University (SE)
- Kemijski institute (National Institute of Chemistry) (SI)
- University of Cambridge University (UK)
- Warsaw University of Technology (PL).

Knowledge institutes:

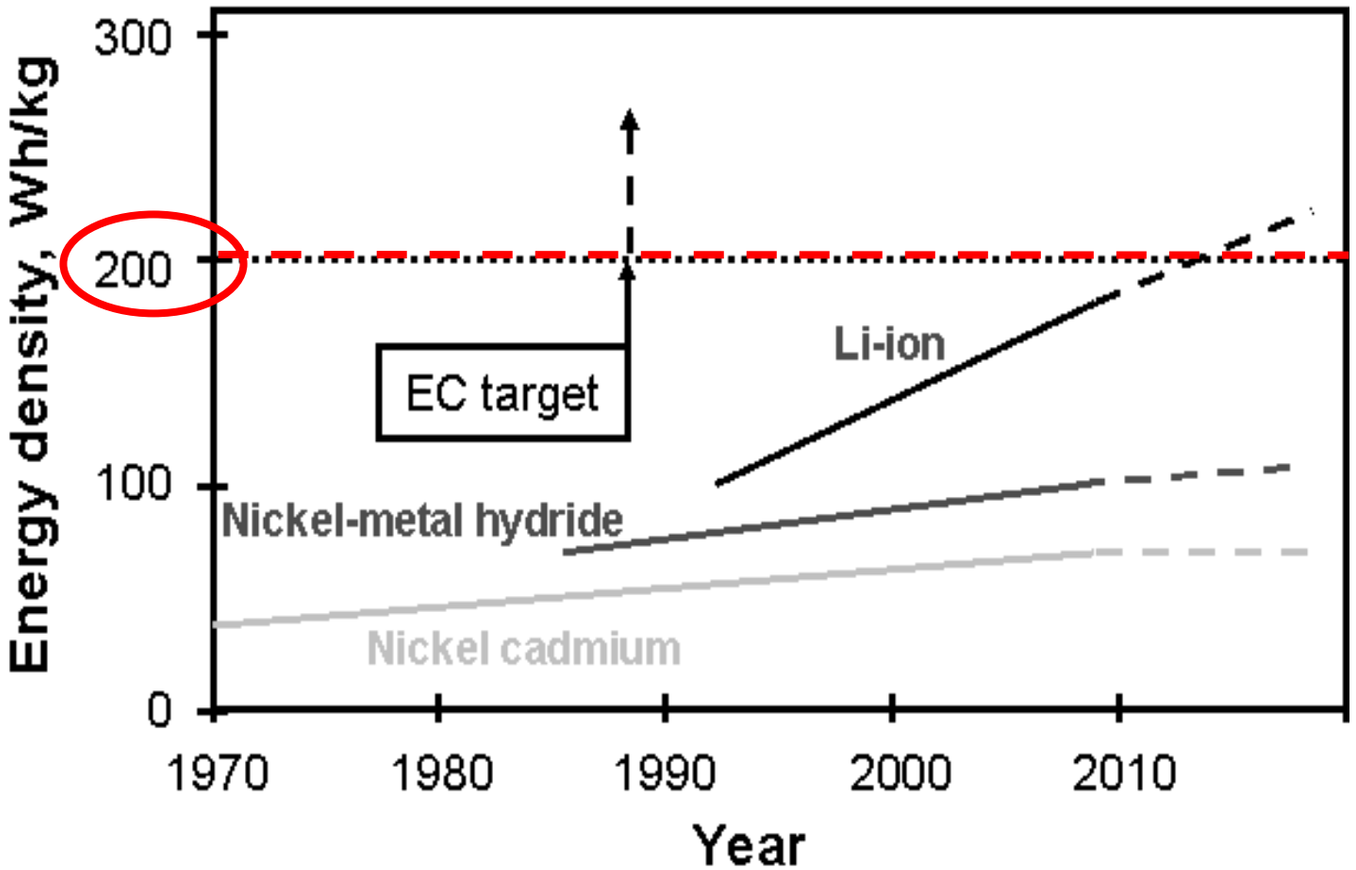
- CEA (also the battery producers as off 01-02-2014)
- ZSW
- AIT

Car industries:

- VOLVO (SE)
- Renault (FR)
- Spijkstaal (NL) an SME

- high energy density – light and small
- high power density – many Watts
- cheap – may cost “nothing”
- safe – may not explode - please
- long life time (calendar and cycles)
- reliable
- recycleable

~400 € / kWh
10km / kWh
1kWh / 5kg



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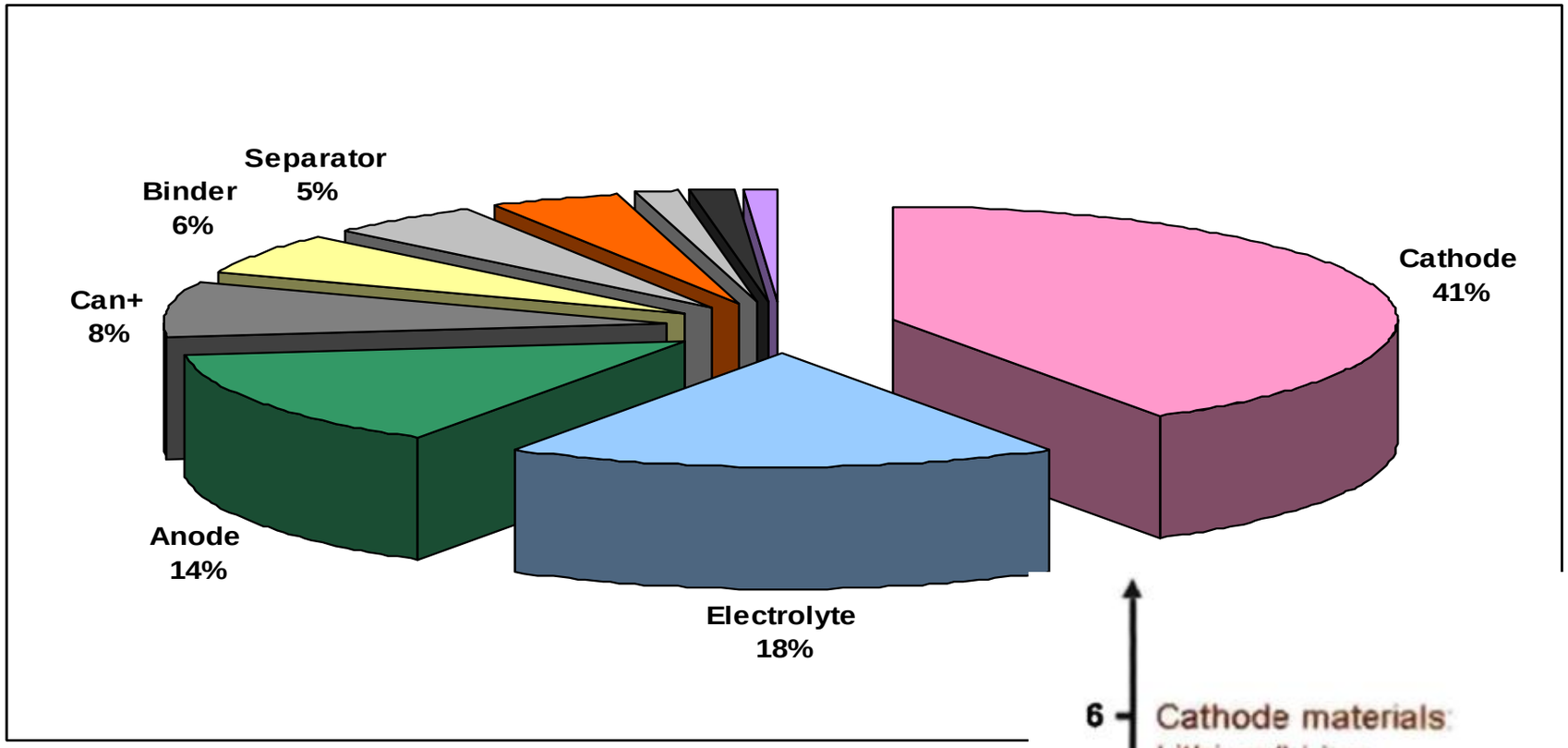
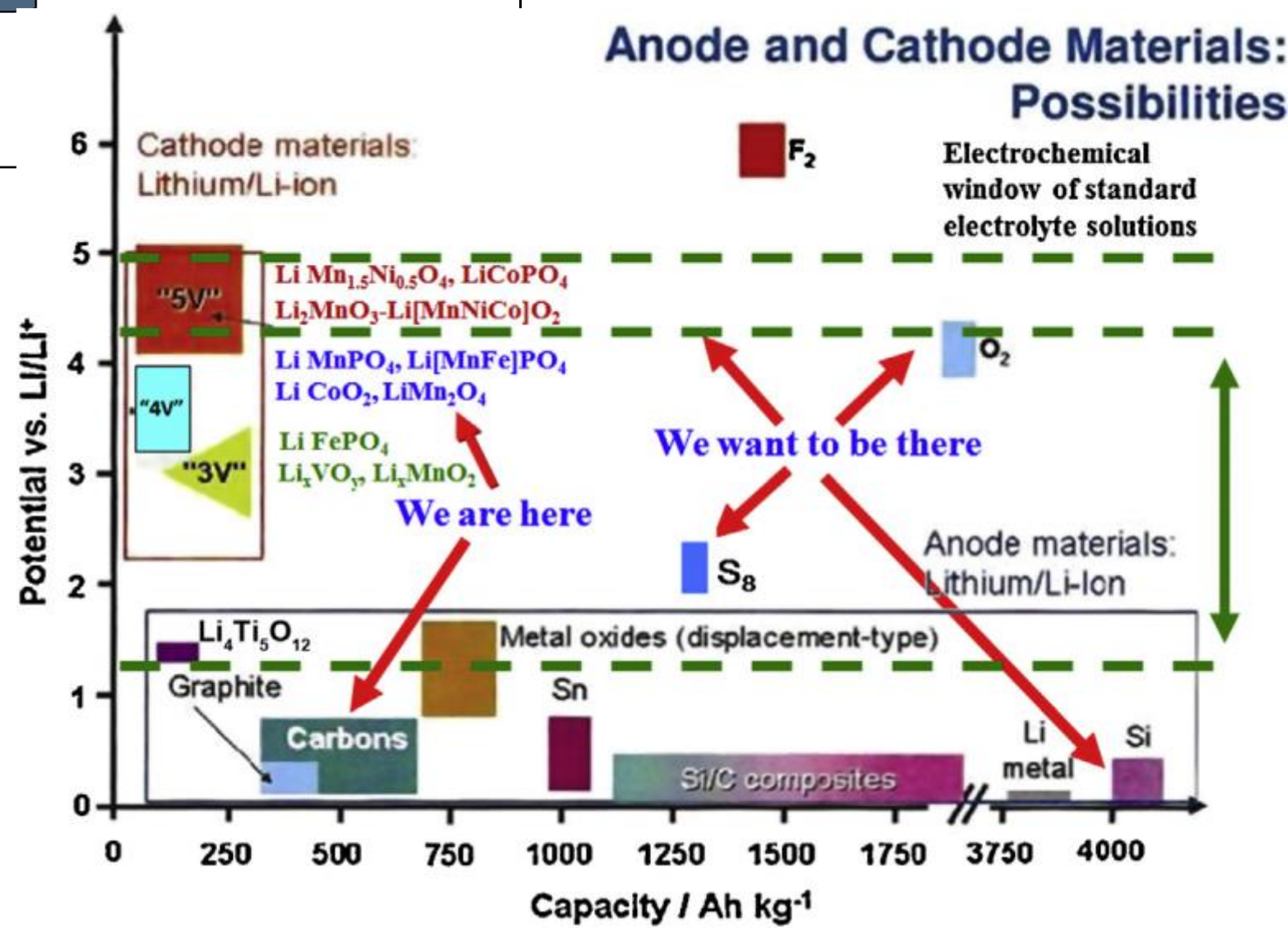
Where to look





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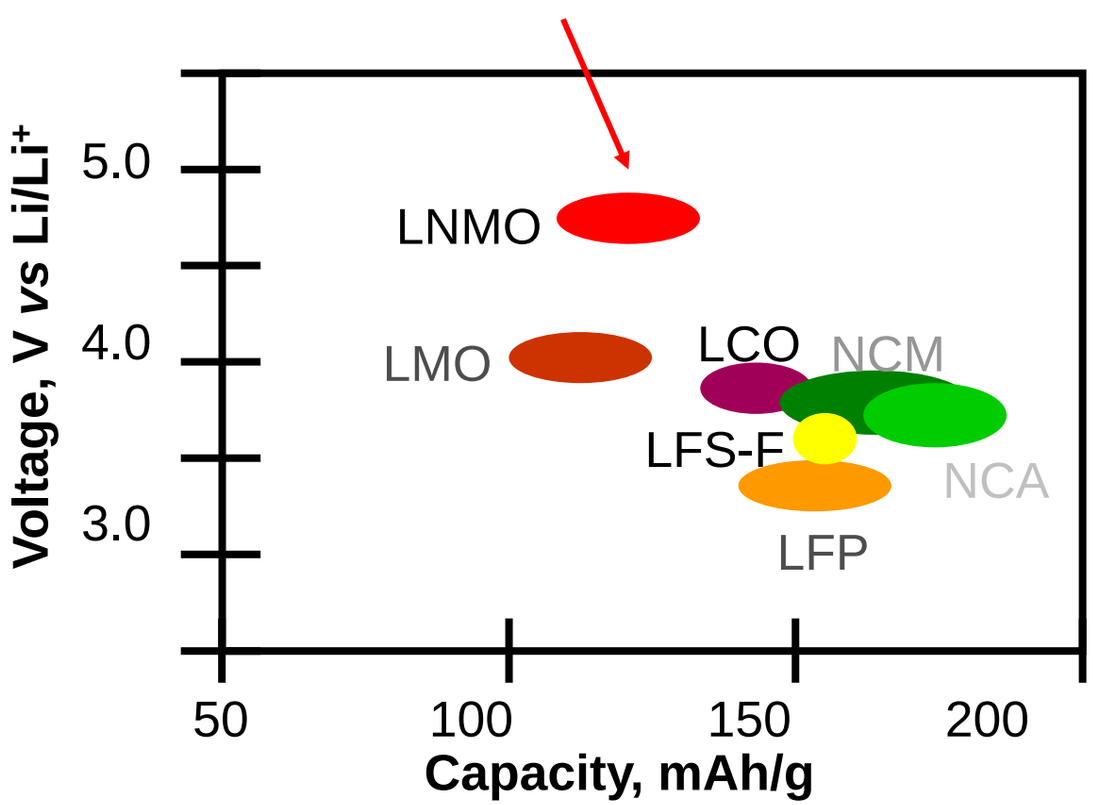
Where can we break in

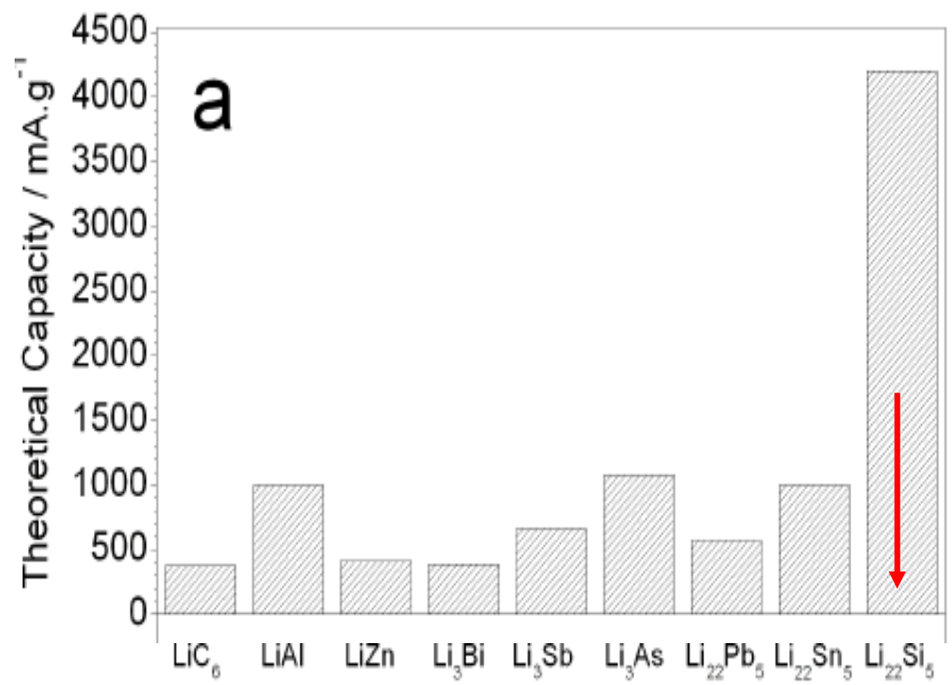
Capacity, energy density in Wh/kg : VAh/kg

1-increase in potential → V
2-increase in electron strorage → Ah/kg
3-reduction of inactive components
4-change of chemistry

•**Cathode material:**
+ $LiNi_{0.5}Mn_{1.5}O_4$ spinel

•**Anode material:**
+ Silicon





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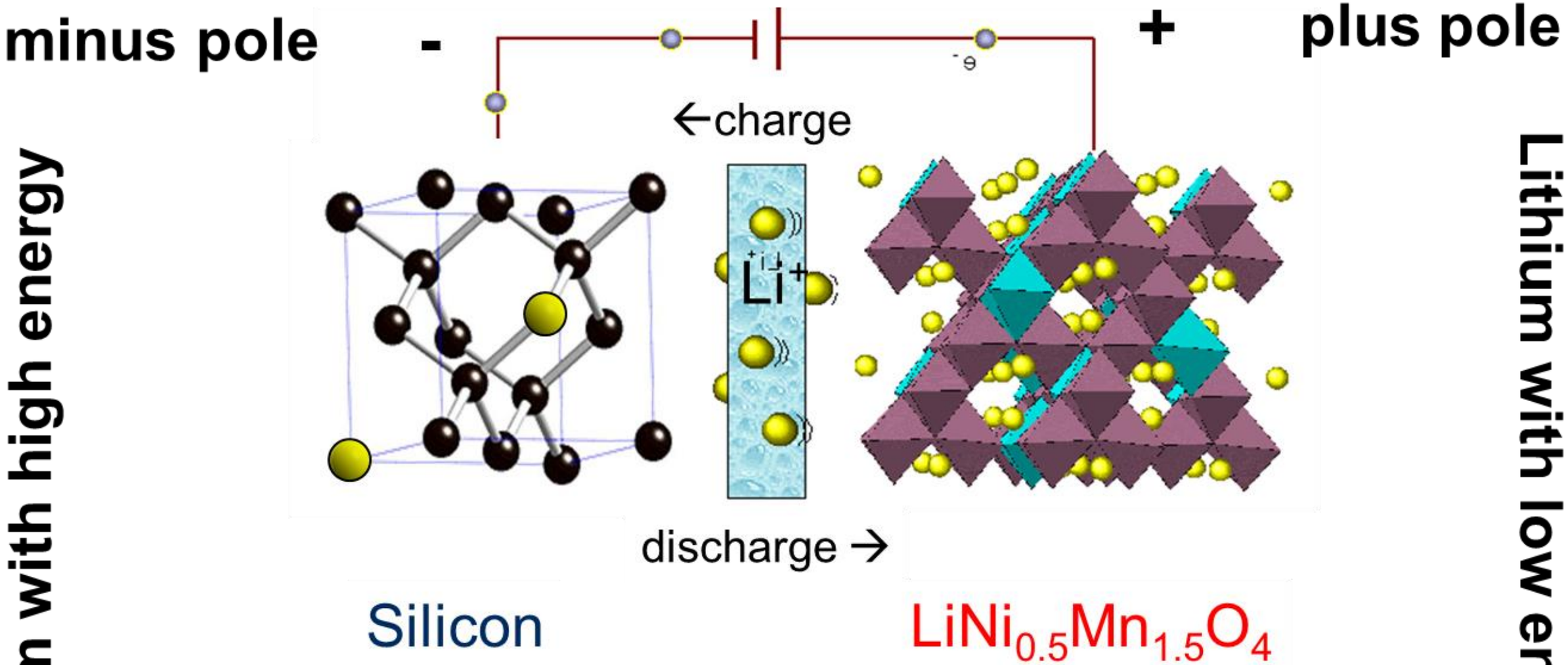
The Li-ion battery chemistry



$LiNi_{0.5}Mn_{1.5}O_4 \rightarrow Li^+ + e^- + LiNi_{0.5}Mn_{1.5}O_4$ $(Ni^{2+} \rightarrow Ni^{4+} + 2e^-)$

$Si + 4.4Li^+ + 4.4e^- \rightarrow Li_{4.4}Si$ $(Li^+ + e^- \rightarrow Li)$

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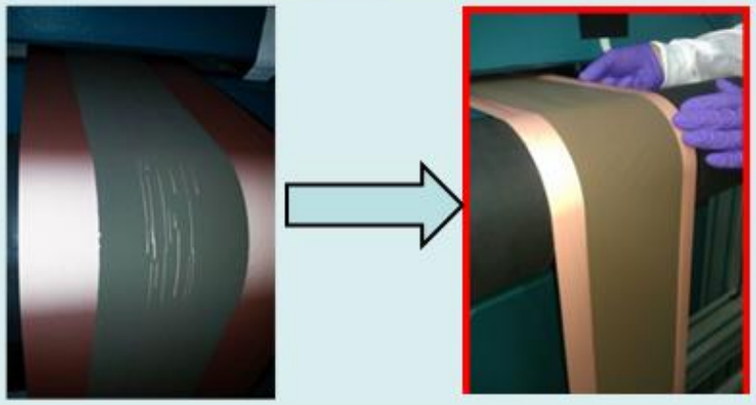
Research outcome (1)

- Laser-assisted chemical vapour pyrolysis of silane into silicon in order to form homogeneously distributed nano-silicon powder for high capacity anodes. Finally due to the difficulty in the electrode processing commercial material was selected to go ahead with
- Although not selected, the methods allows kg/h production via the gas phase
- TRL level (initial and approached): 3 → 6



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Research outcome (2)

- A non-fluorine containing salt was made available in order to reduce the overall fluorine amount in a Li-ion battery
- Although not selected, the methods allows kg production for other (LPF) cells
- TRL level (initial and approached): 2 → 6

Electrolyte	salt: c / mol·kg^{-1}	σ / mS·cm^{-1}	t_+ / t-	σ_{Li+} / mS·cm^{-1}
LiTDI in EC:2EMC	0.3	4.18	0.544	2.27
LiTDI in EC:2EMC	0.7	4.87	0.518	2.52
LiTDI in EC:DMC:EMC	0.4	4.69	0.455	2.13
LiTDI in EC:DMC:EMC	0.7	5.47	0.434	2.37

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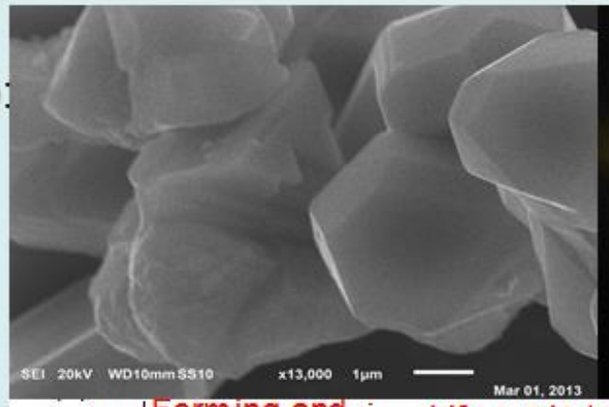
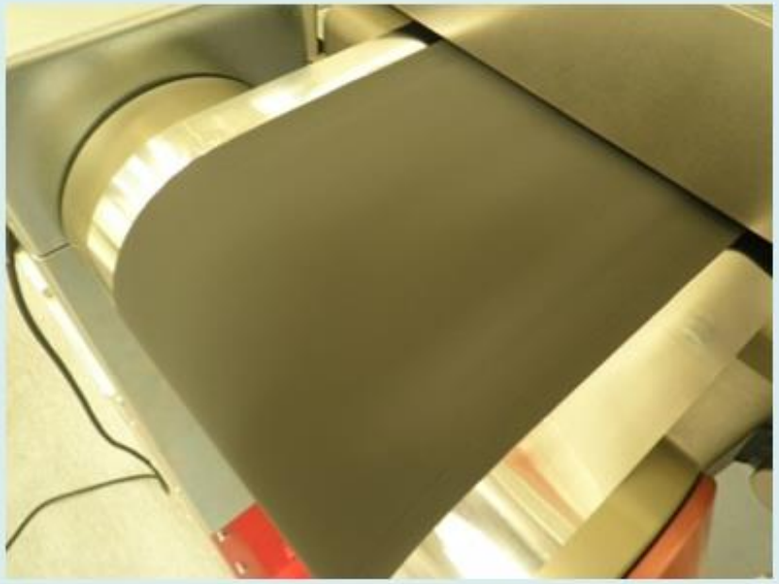
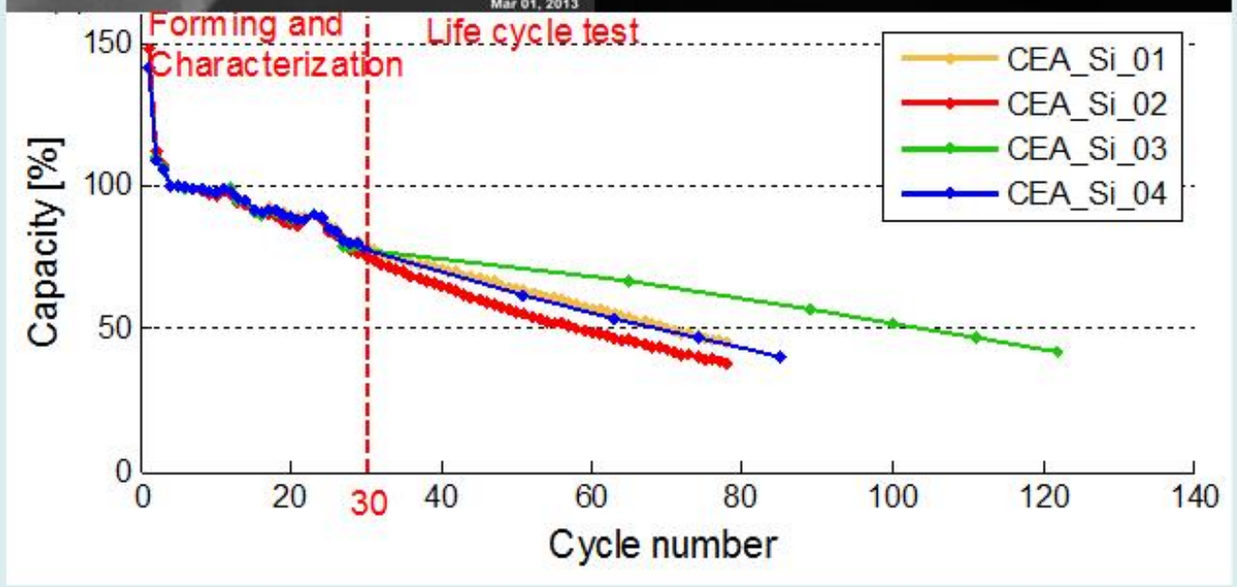
Research outcome (3)

- LNMO was selected as high voltage cathode material so as to increase the capacity of Li-ion batteries. Alternative cathode materials did not show adequate production quantities.
- The production methods of LNMO has been transfered to a commercial supplier (Euro Support, Uden, NL)
- TRL level (initial and approached): 4 → 7

- Modelling
- Safety tests (see other presentation):
  - overcharge
  - short circuit
  - thermal stability
  - Internal short circuit







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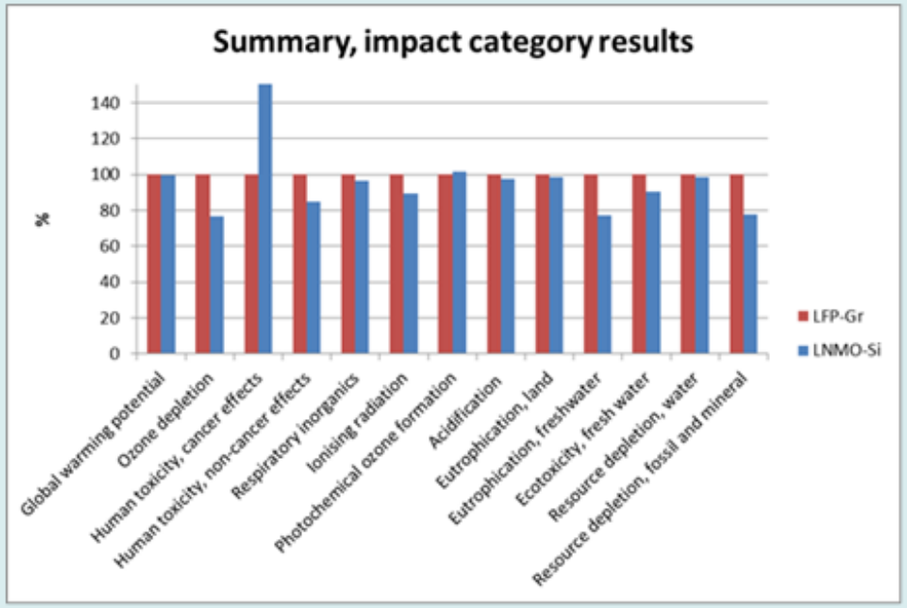
Research outcome (4)

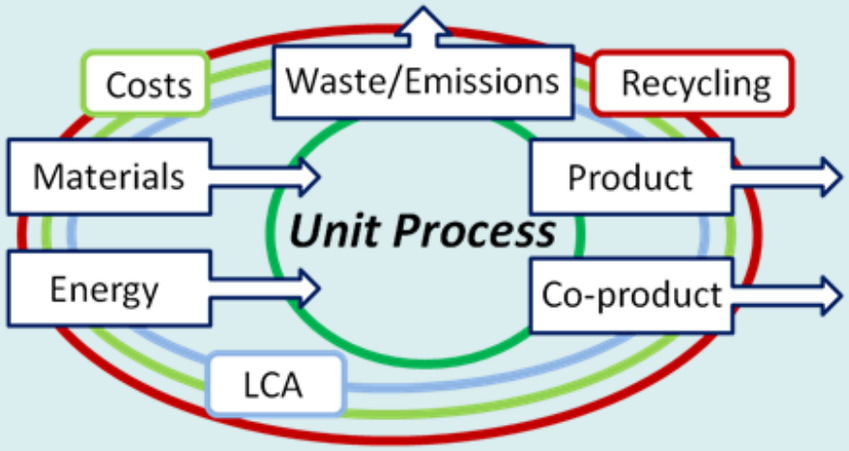
4) Indirect battery issues

- *what determines introduction of the new Li-ion battery based on the EuroLiion proposal*
  - Milestone 2.1: Report on Recycling methods and impact
  - Milestone 2.2: Report on LCA
  - Milestone 2.3: Report on costs analysis

- Recycling and Eco-design.
- Life Cycle Analysis
- Costs analysis
- TRL level (initial and approached): N/A

- LCA





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Battery tests (1)

Cell Data Outline

- Generation I cell
- 18650 shape
- Pilot line assembly
- Cathode material LFP
- Anode material Silicon 66% and 10,1% graphene, rest binder and additives
- Anode material capacity 1800 mAh/g for 200 cycles
- Electrolyte LiPF6

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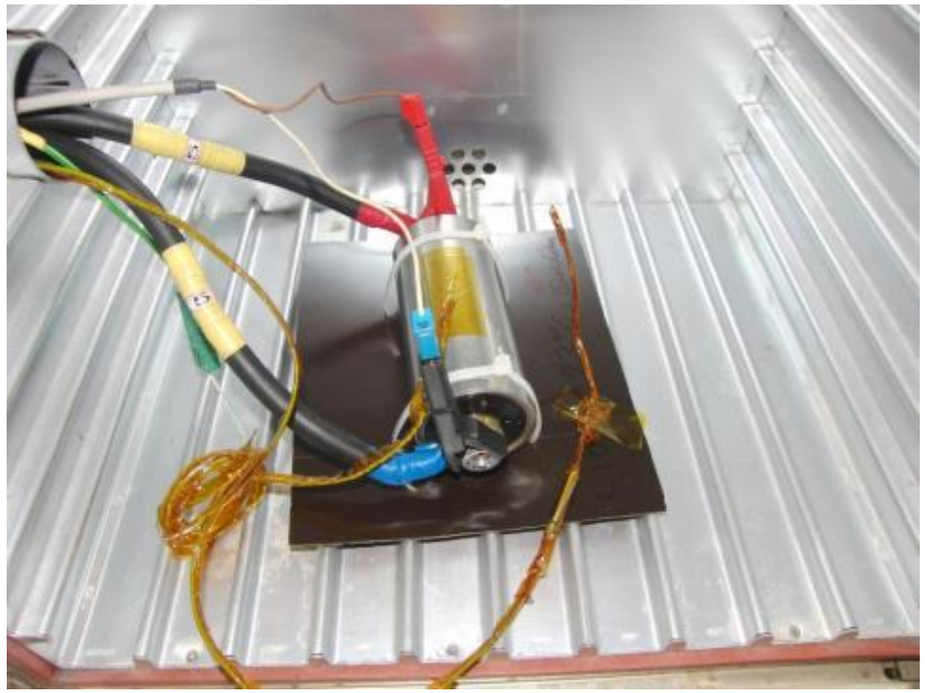
Battery tests (2)

Operational Values

- Mass = 38.5 g
- Energy = 4 Wh
- Energy density = 105 Wh/kg
- Nom. voltage = 2. 9 V
- Max. voltage = 3.6 V
- Mini. voltage = 2.0 V
- Max. discharge current = 2. 8A



Test Sequence

- Forming (6 to 8 cycles)
- Full performance test at different temperatures (sequence 23, 0 and 45° C; including OCV, HPPC, multiple C and impedance spectroscopy
- Life cycle and calendar life tests

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Safety tests (3)

Results and Discussion

- The cells show an initial capacity of 1850mAh which is a specific capacity of 48Ah/kg and after forming 1350mAh which leads to 35Ah/kg.
- After formation the loss of capacity gets reduced to ~0.012% per cycle.
- Cells in this case show better performance at 23° C than at 45° C for both capacity and impedance. This is belived to be a result of test procedure sequence and loss of performance due to cycling.
- Temperature and SOC window have significant impact on cycle life also for this chemistry. Cycle life for 23° C (best test case) and 60% SOC is 50% longer than 45° C and 100% SOC.

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Safety tests (1) – *overcharge test*

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Safety tests (2) – *short circuit test*

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Safety tests (3) – *nail penetration test*

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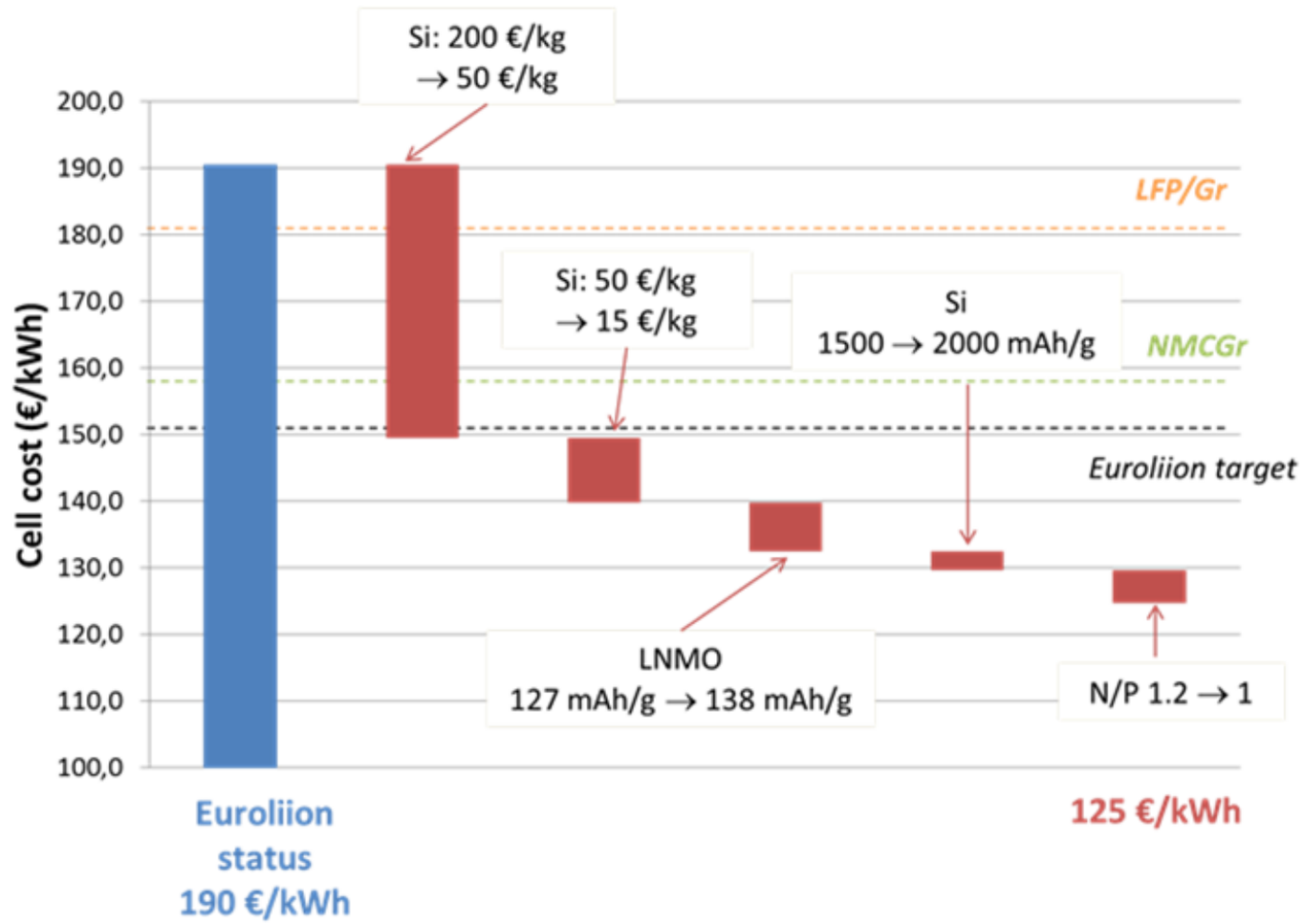
Conclusions

	Current	EuroLiion
Anode (capacity, mAh/g)	Carbonaceous (250-350)	Silicon (1000-1500)
Cathode (capacity, mAh/g)	NMC, NCA, LFP (150)	LNMO (120)
Cell capacity(Wh/kg)	150	200
Costs (€/kg)	See Figure	See Figure



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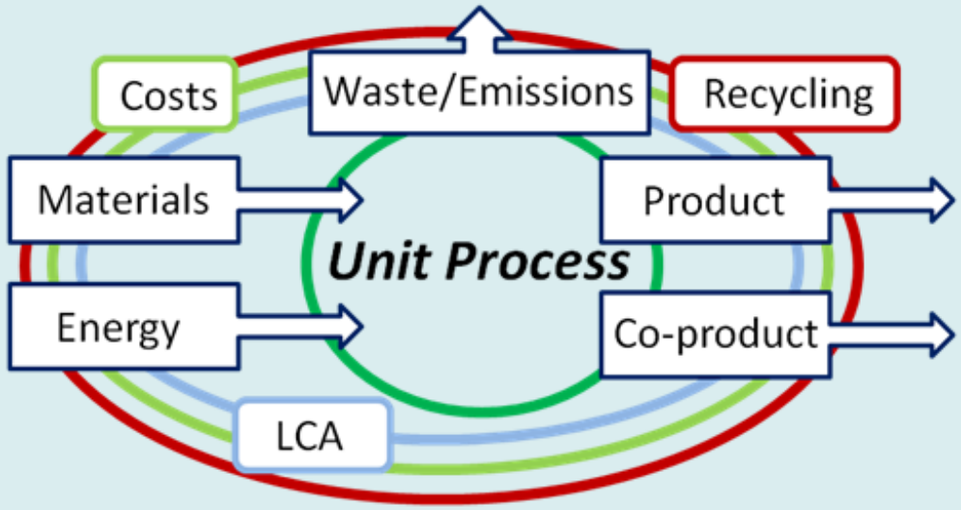
Keep in mind

- Recycling

	pyrometallurgical	hydrometallurgical	physical
temperature	High	low	low
Materials	Co, Ni, Cu, (Li and Al to slag)	Metals or salts, Li_2CO_3 or LiOH	Cathode, anode, electrolyte, metals
Feed required	None	Separation desirable	Single chemistry required
Comments	New chemistries yield reduced product value	New chemistries yield reduced product value	Recovers potentially high-value materials; Could implement on home scrap

- Costs
- LCA
- Optimisation/stabilisation of the cell units



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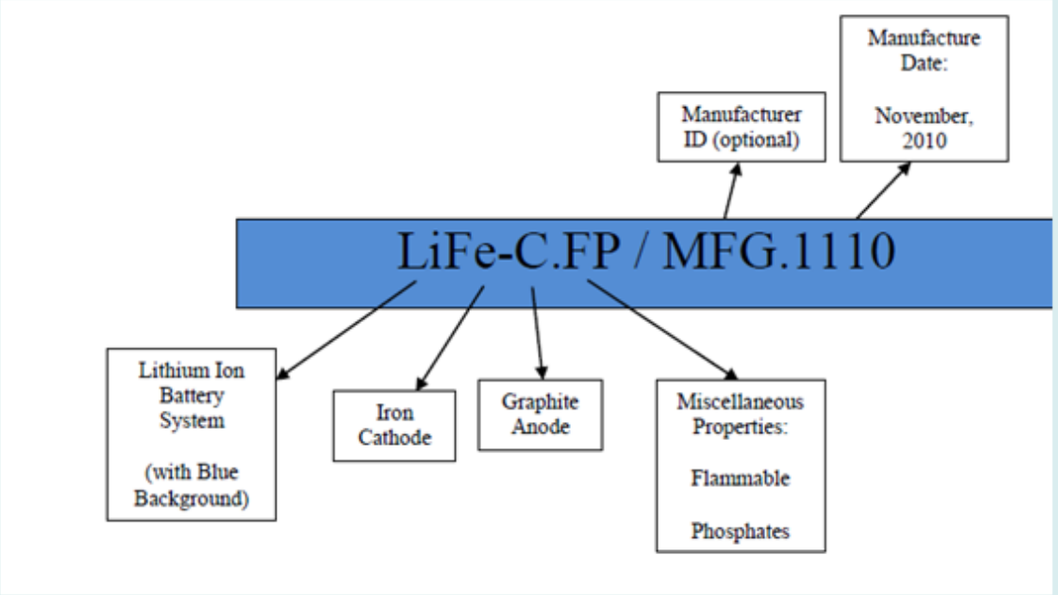
And next

Public support

Needs

- Infrastructure: *where do we „refill“?*
- Standardization: *safety (e.g. labelling)*
- Frame for regulations: *transport of cells*



New Research direction

Needs

- Adaptation of Roadmaps needs: *not sure*
- Definition of new research direction (topics, new synergies, …- *once we would like to significantly increase the capacity, novel chemistries are required such as Li-air and/or Li-sulfur: not going into detail on safety at the moment.*

  Rechargeable Zink, Magnesium, Calcium?

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