



UiO:Energy Forum
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The value chain of batteries: from material production to recycling initiatives

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IFE's vision:
Internationally leading research institute

Turnover:

1

MRD



Annual publications:

120



1948: IFA



1980: IFE

Employees:

600



14.000



Annual visitors

Advanced laboratories:

24



Nationalities: 32

Researchers: 218

PhDs: 105

Centres for renewable
energy:

2



International projects:

> 30%



Better batteries
- what are the
challenges?



Battery value chain – where are we?





Battery activities at IFE



Silicon- based nanoparticle production

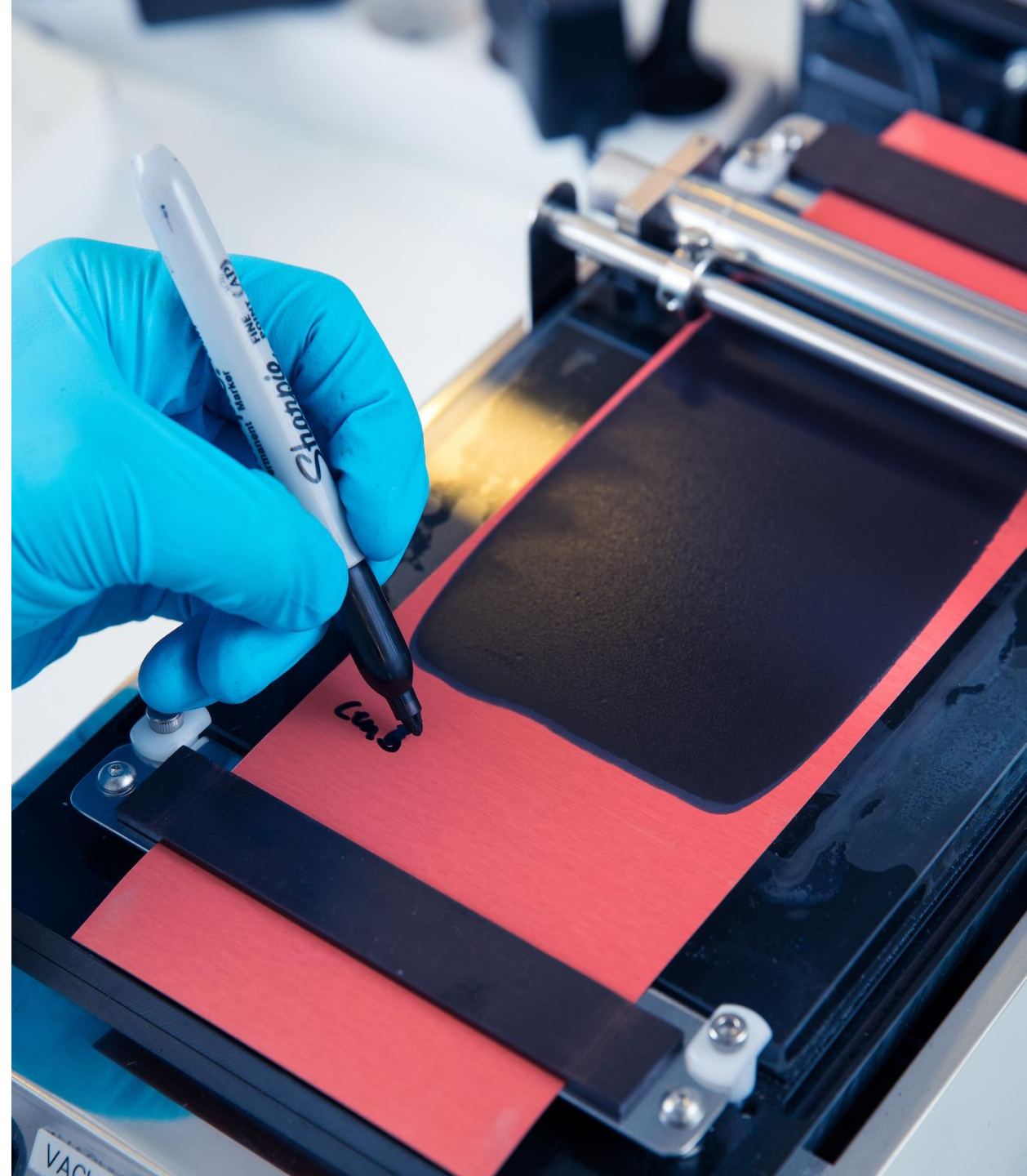
- Producing silicon based energy materials
- Free space reactors
- Gas-phase silane polymerization
 - Understanding the chemistry of silane
 - Production control
 - Flexibility in composition
 - Up-scaling



Battery development laboratory

How to optimize the battery

- Testing different material sources
- Preparing electrodes
- Research on all components in anode (binder, carbon)
- As well as other battery components such as electrolyte, cathode
- Electrochemical testing of cells
 - Largest lab scale facility in Norway



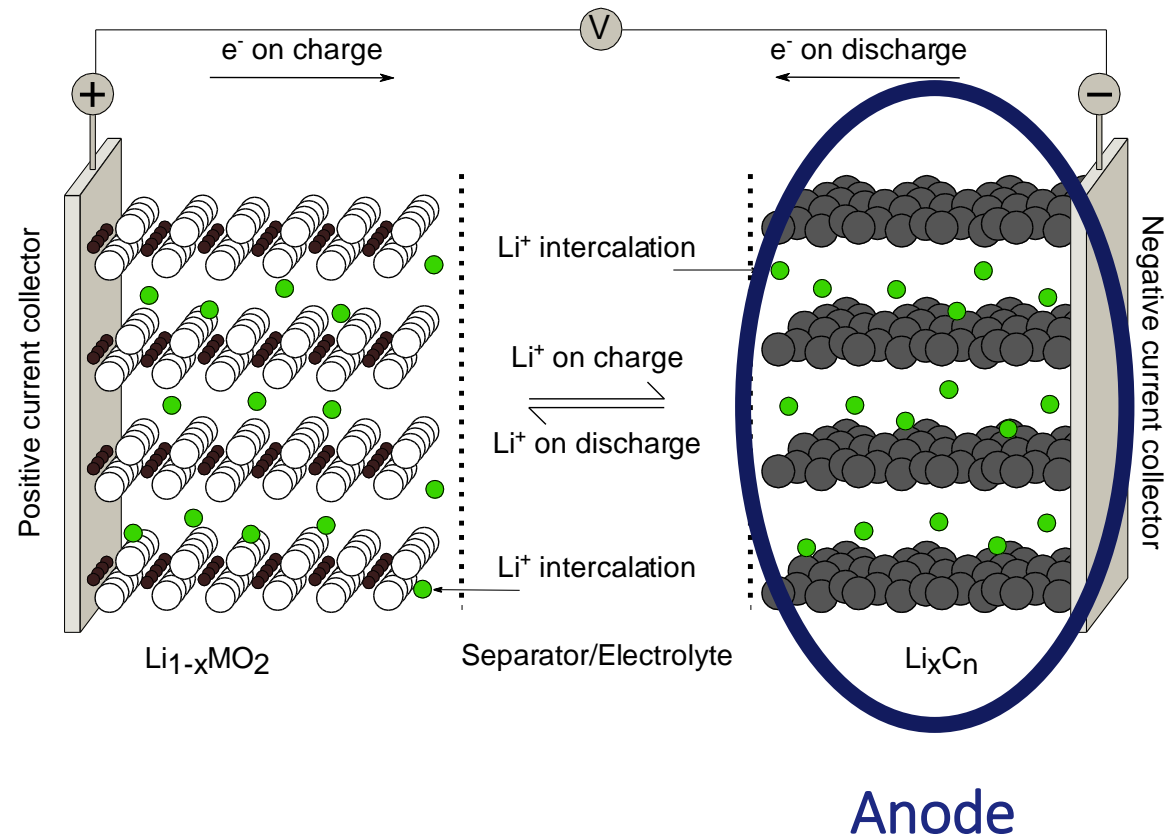
Commercial battery testing

Battery research for end-users

- Strong cooperation with norwegian maritime industry
- Predicting life time of commercial battery cells and packs
- Evaluation of battery ageing through experiments and modelling



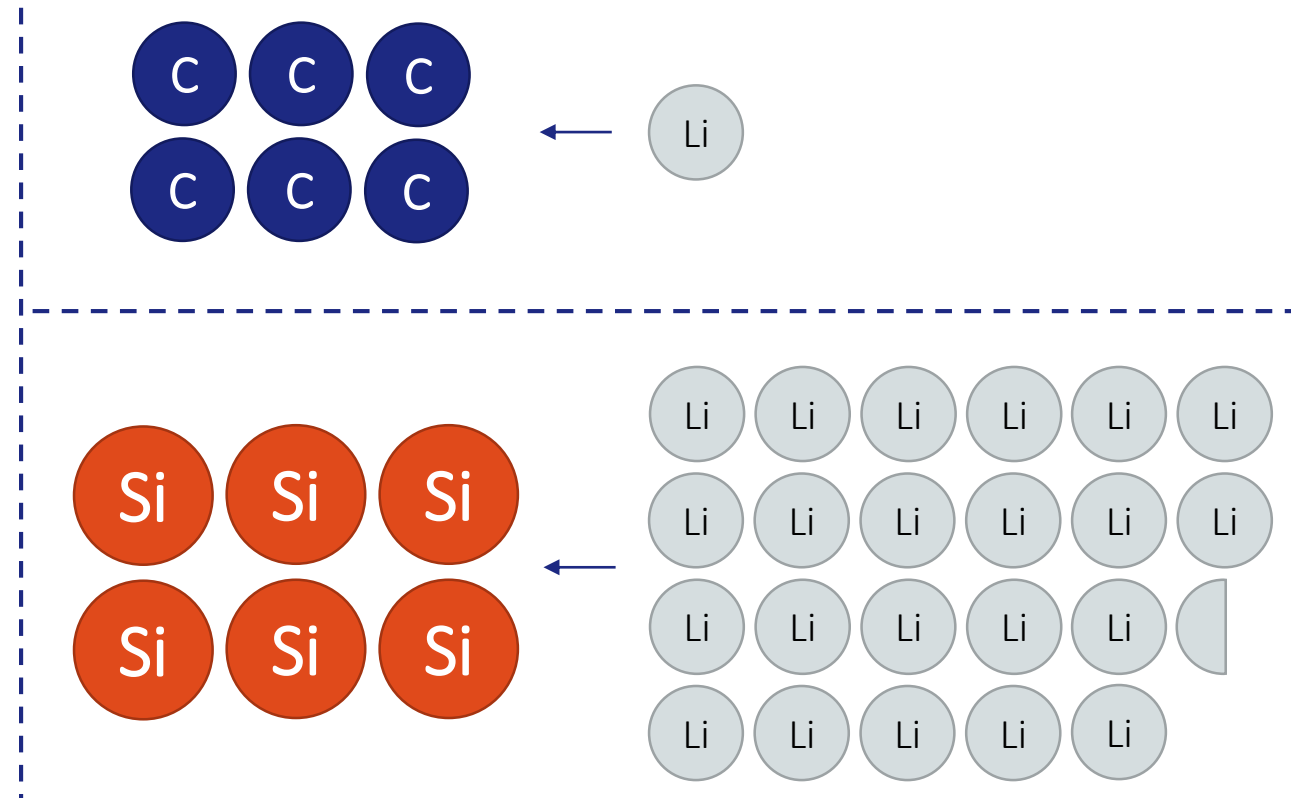
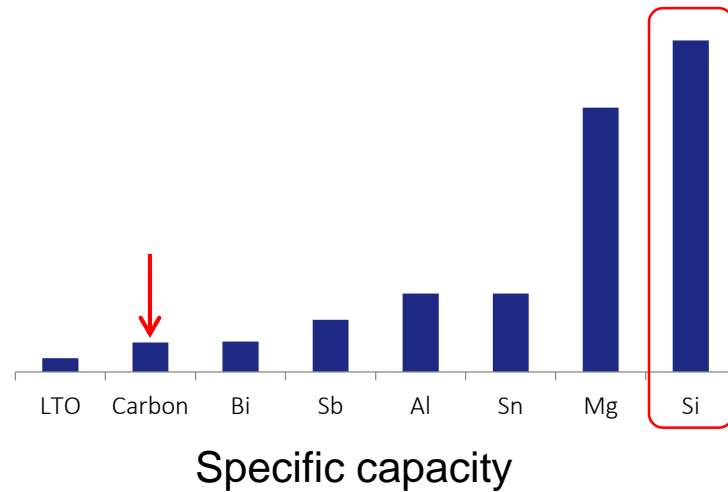
How does the battery work?



Silicon anodes

Main motivation:

- Graphite: LiC_6 \rightarrow 372 mAh/g
- Silicon: $\text{Li}_{3.75}\text{Si}$ \rightarrow 3579 mAh/g



Silicon market

“It’s a race among the battery makers to get more and more silicon in”

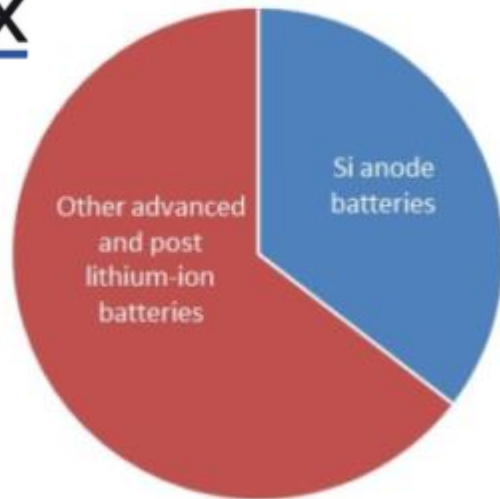
- Jeff Dahn, 3M and Tesla



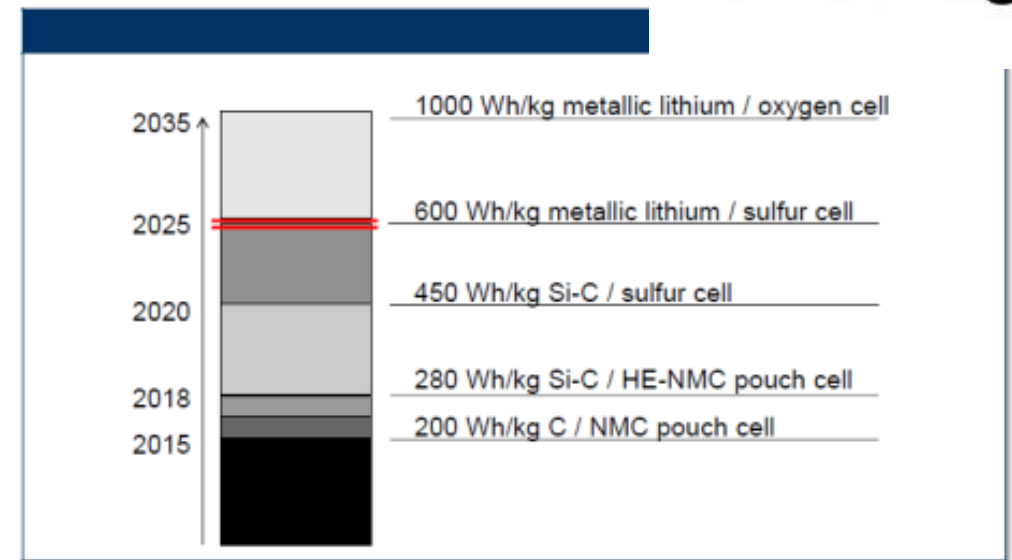
Volkswagen

Advanced and Post Lithium-ion Battery Market Split in 2026

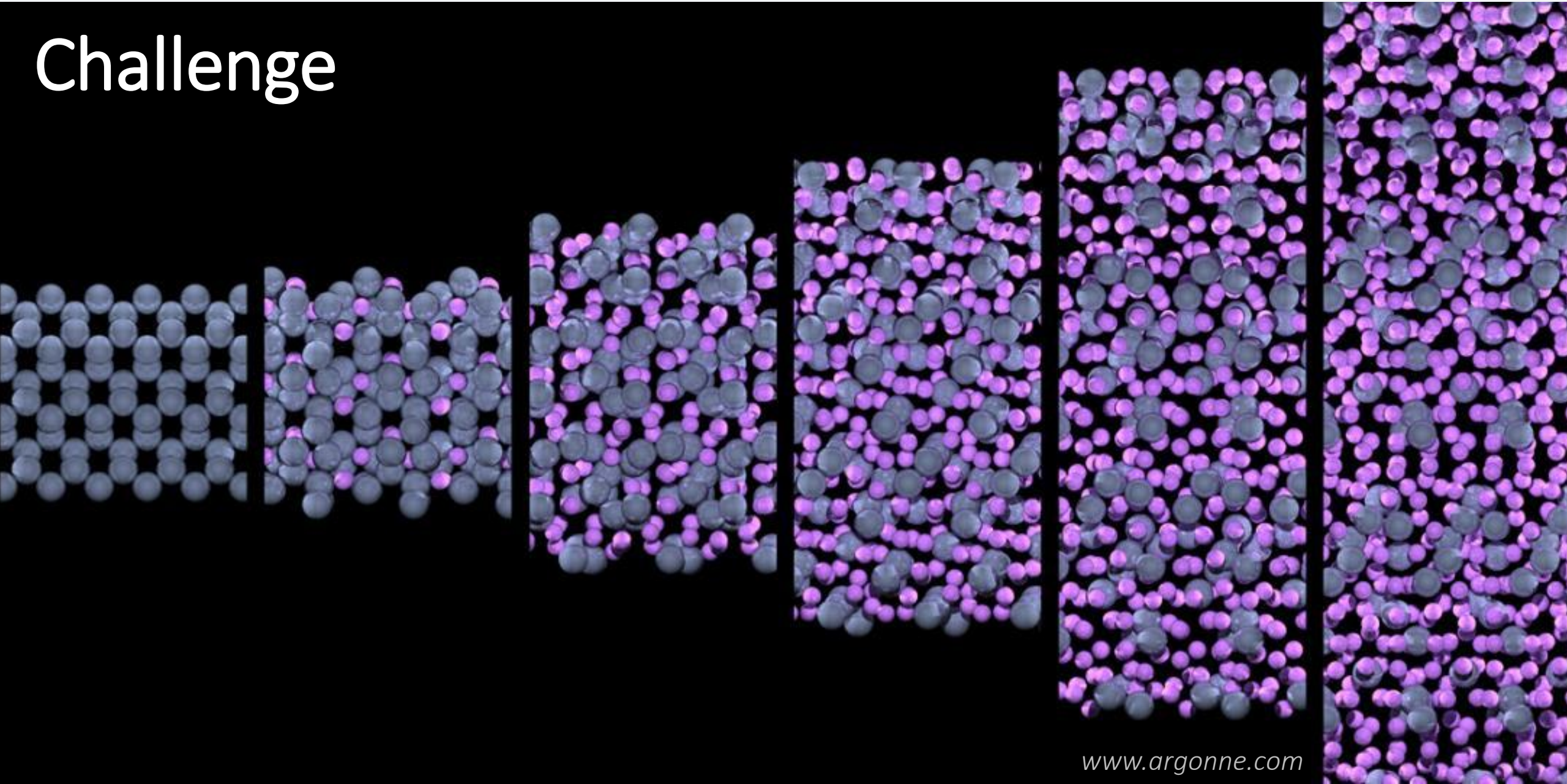
IDTechEx



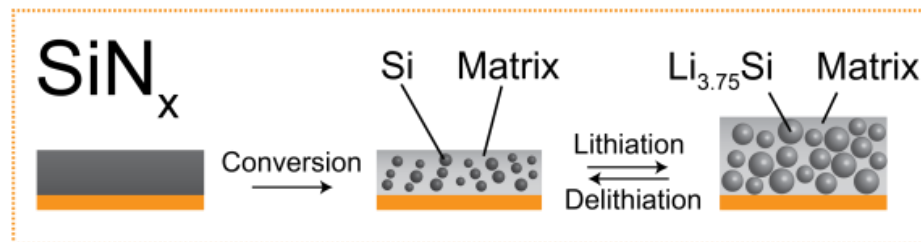
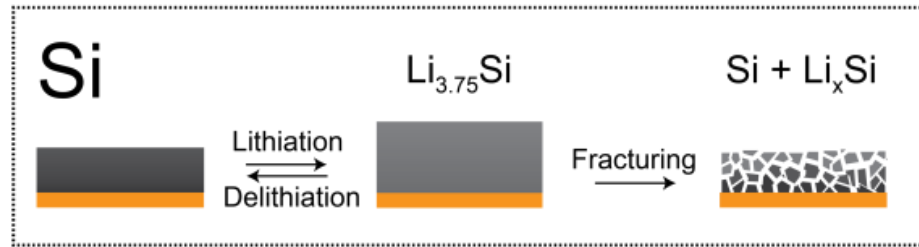
Technology steps of battery cells



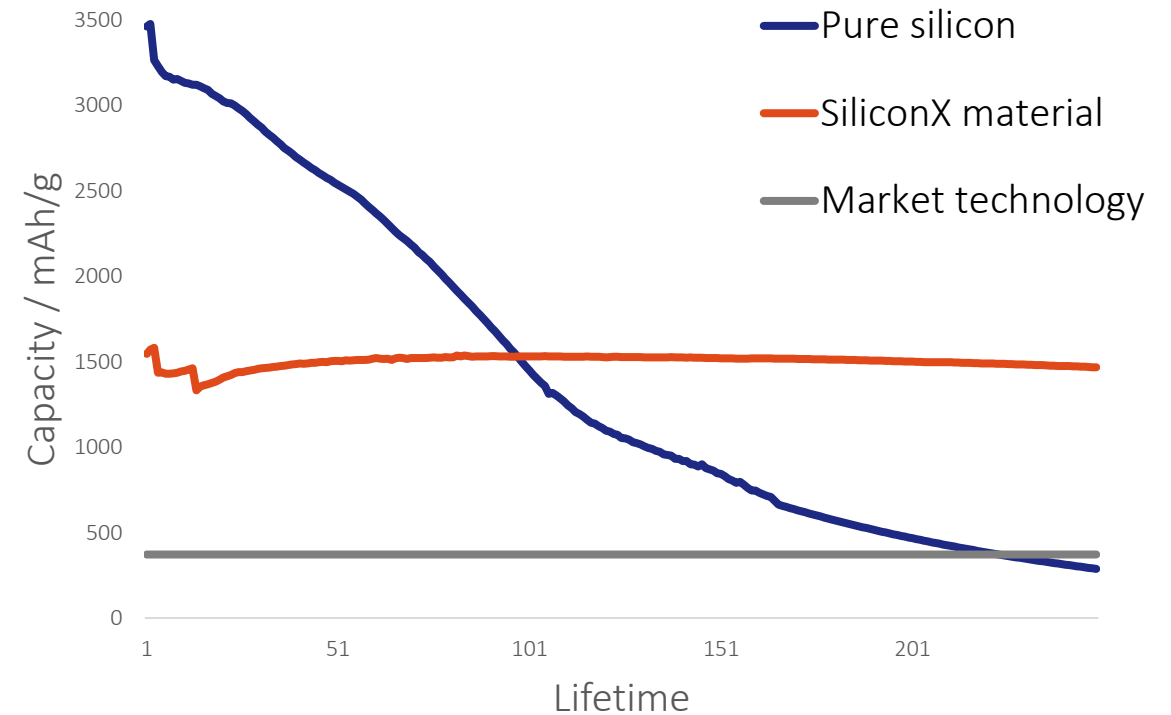
Challenge



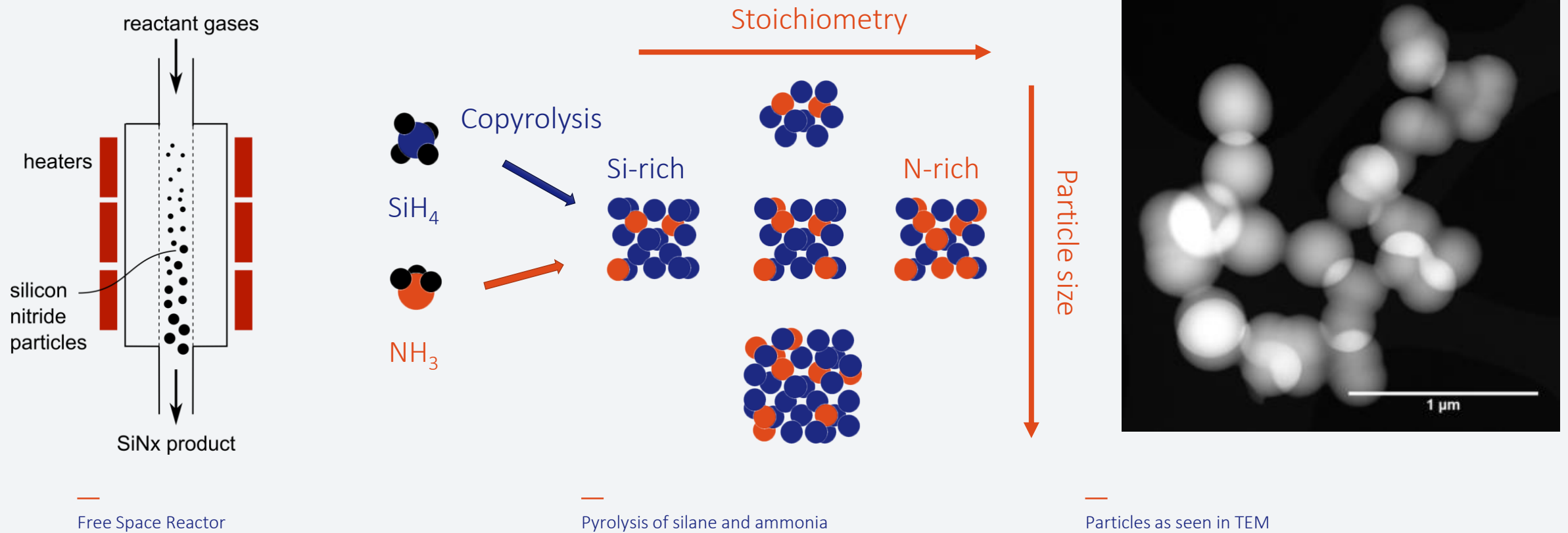
SiliconX



- Using silicon nitride material produced at IFE
- Improvement of both capacity and lifetime
- Patent granted

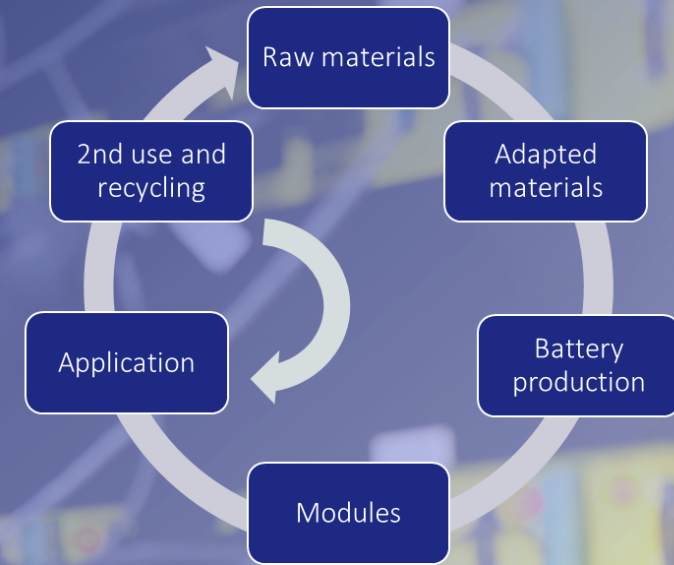


Production of SiliconX at IFE





Commercial battery testing



Life time testing of commercial cells

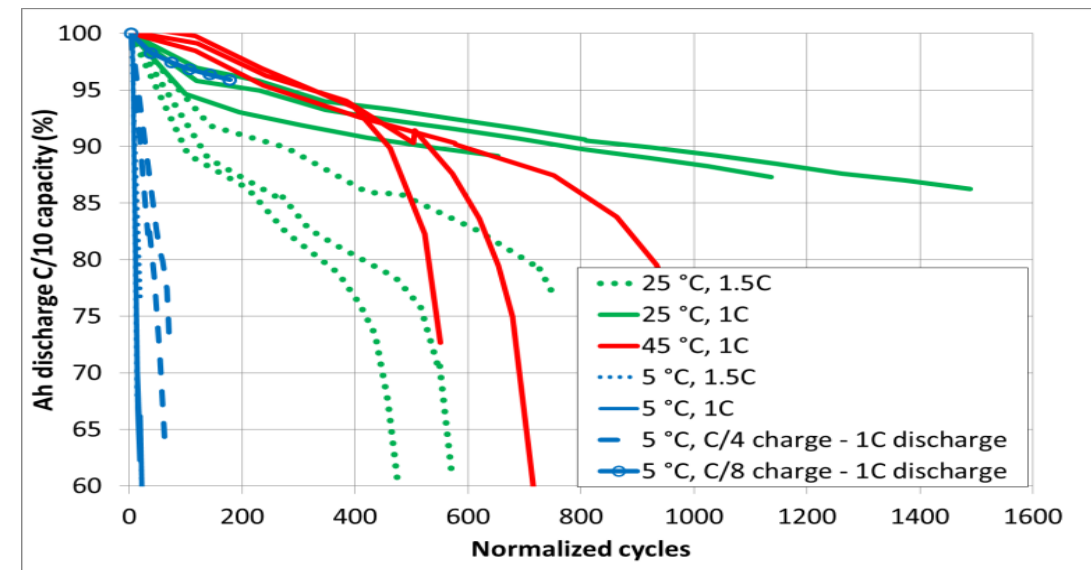
- The BattMarine project

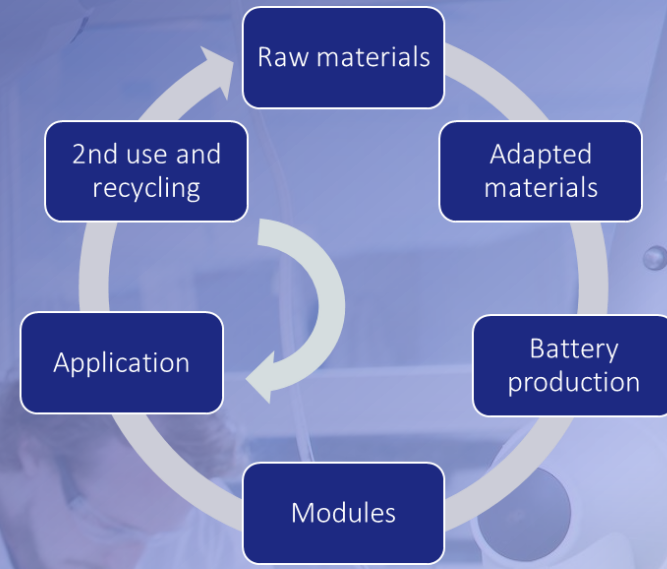
- Cooperation with partners from the maritime industry
 - Fast growing sector in Norway
 - Hybrid solutions are necessary
- Safety and life time evaluation of large Li-ion cells and packs
- Develop new measurement techniques
- Risk reduction – physical and economical



Li-ion battery ageing

- Calendar life – loss of capacity during storage
 - Factors:
 - Temperature
 - State-of-charge
- Cycle life – loss of capacity due to cycling
 - Factors:
 - Temperature
 - Current – charge and discharge
 - SoC
 - Maximum
 - Minimum
 - Cycling window
 - Mechanical pressure





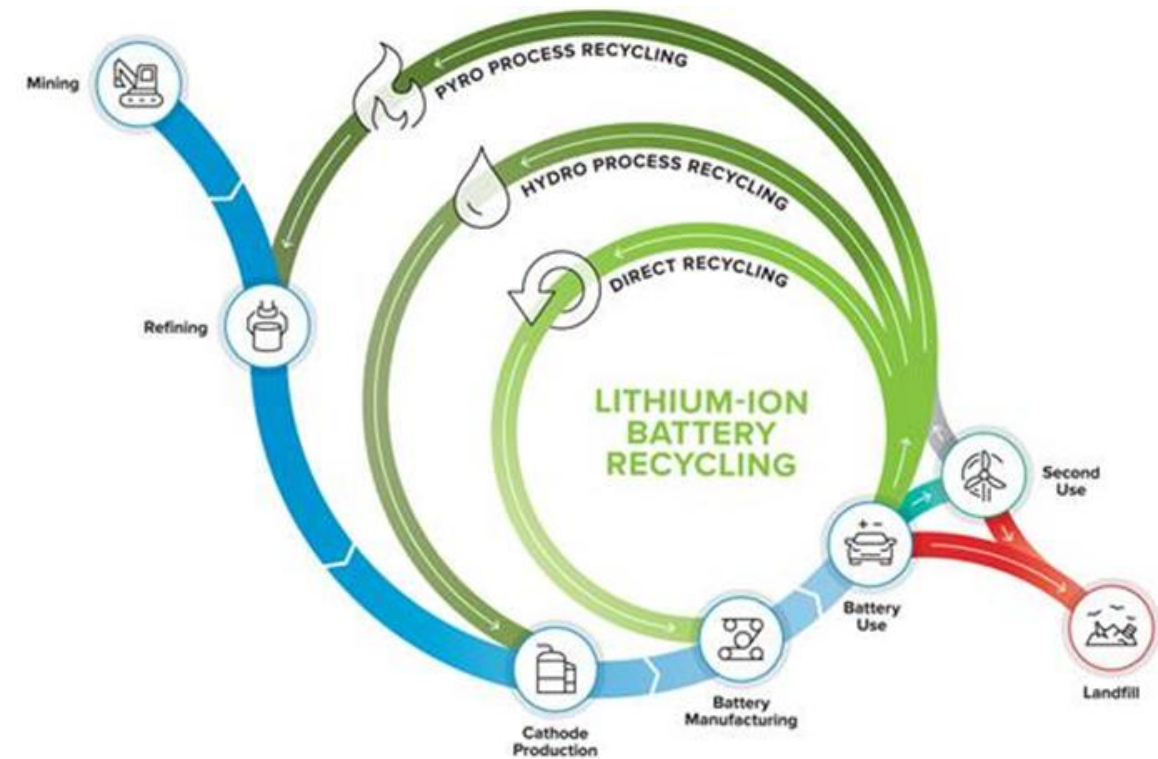
Recycling and reuse



Recycling and reuse

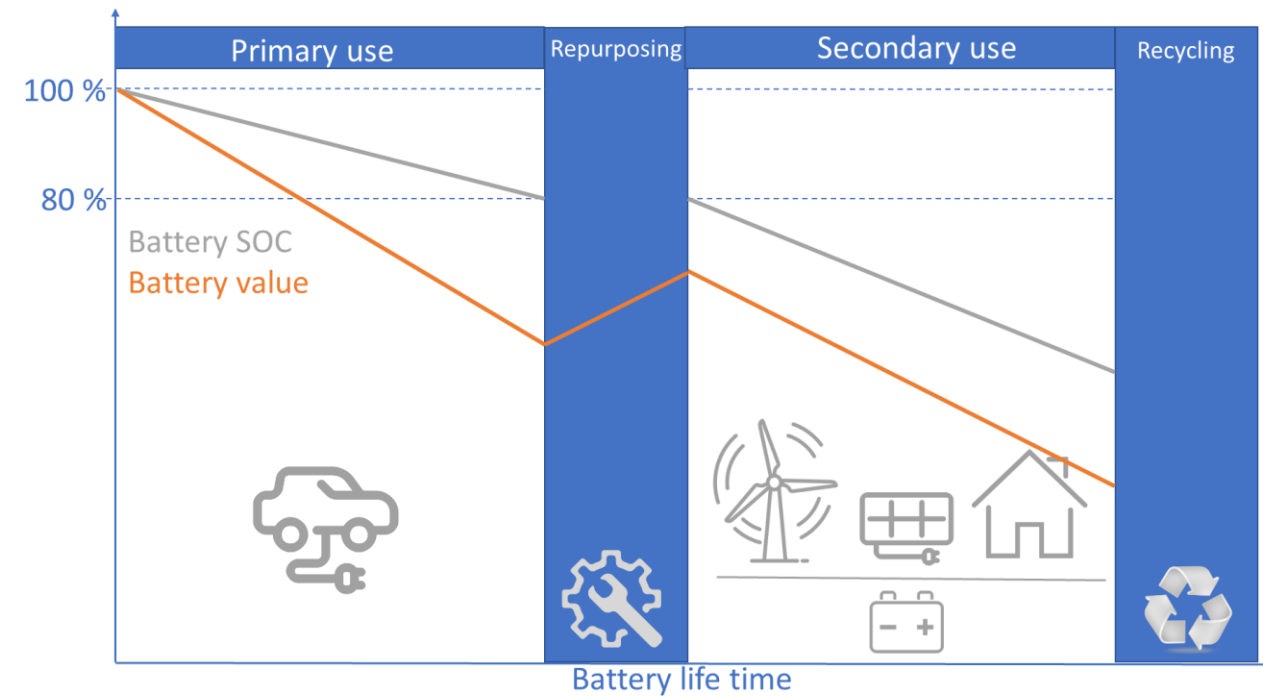
- motivation

- Large need for sustainable handling of used batteries
- Control material flow within Europe
 - Urban mining through recycling possibilities
- Norwegian industry wants to position themselves within recycling
- Norway will be one of the first countries to get large volumes of spent EV-batteries going into recycling or reuse
 - 50 % of all new car sales in 2019 was electric
 - Second largest market worldwide for EVs



Possible reuse of Li-ion batteries (2nd life)

- Starting research on safe and sustainable re-use of batteries
- Evaluating value, safety and cost-optimized use of Li-ion batteries at End-of-Life (EOL)
- Open questions:
 - Economical feasibility (and at what battery cost)
 - Safety ensured in second life use?
 - Integration into current energy system



BATMAN project

Lithium ion BATteries - Norwegian opportunities within sustainable end-of-life MANagement, reuse and new material streams

- Project lead by Eyde Cluster
- Will establish the current Li-ion battery market in Norway, as well control of the material flow analysis
- Will give guidelines to how Norwegian industry should position themselves within battery recycling

Business Partners

Research Partners

Associated Partners

Project management

Advisory Board

BATMAN project

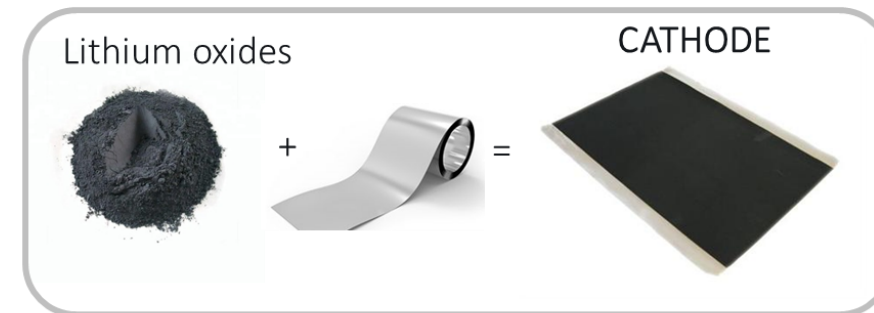
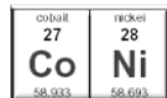
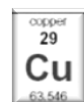
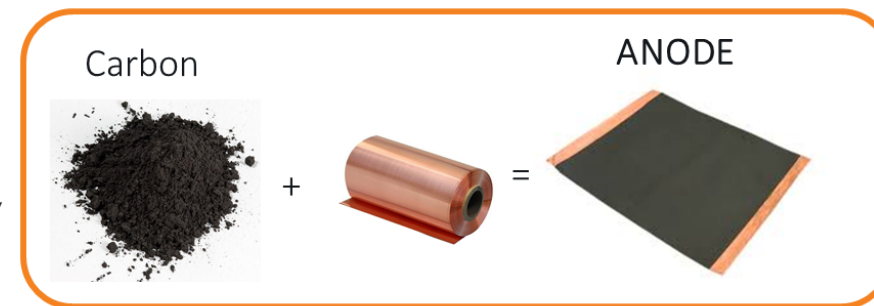
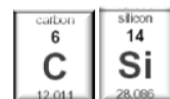
The existing ecosystem



- Silicon carbide (SiC) production
- Anode material (SiC as a raw material)
 - Cathode material (kiln furniture and heating elements based on SiC)



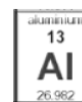
- Proprietary graphitization process
- Ability to tailor make silicon powders
- Sustainable green production at large scale



- Annual production
- 92000 Tonnes Ni
 - 39000 Tonnes Cu
 - 5200 Tonnes Co



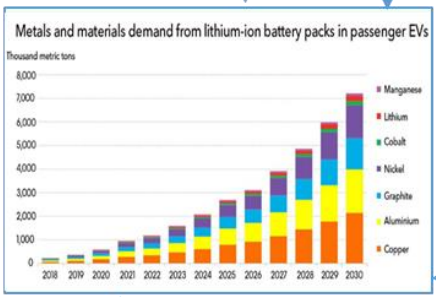
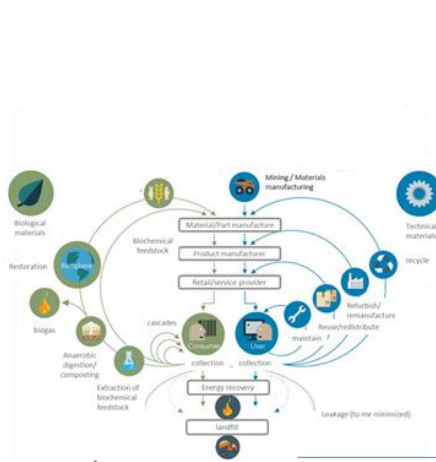
- 8.1 TWh of renewable energy on an annual basis
- Flexible renewable energy systems



- 2 Million Tonnes Al production in 2018
- Karmøy pilot - world's most climate-friendly and energy-efficient aluminium.
- EV battery pack 40% Al by weight

BATMAN project

Predictive model for material demand and secondary use/recycling volumes



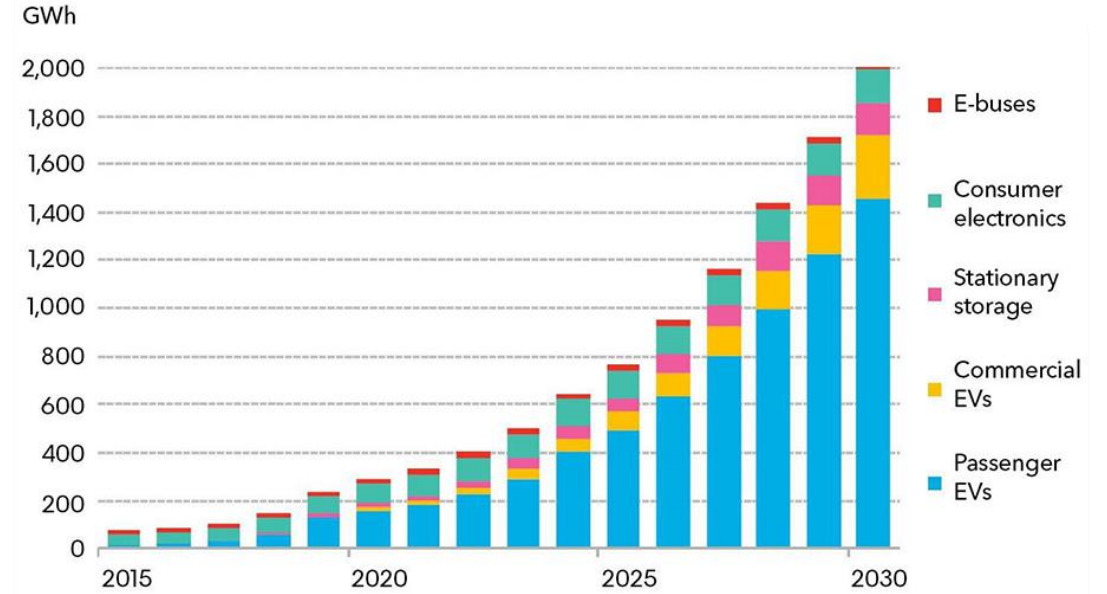
Regulatory framework - EU policy

Technology trends

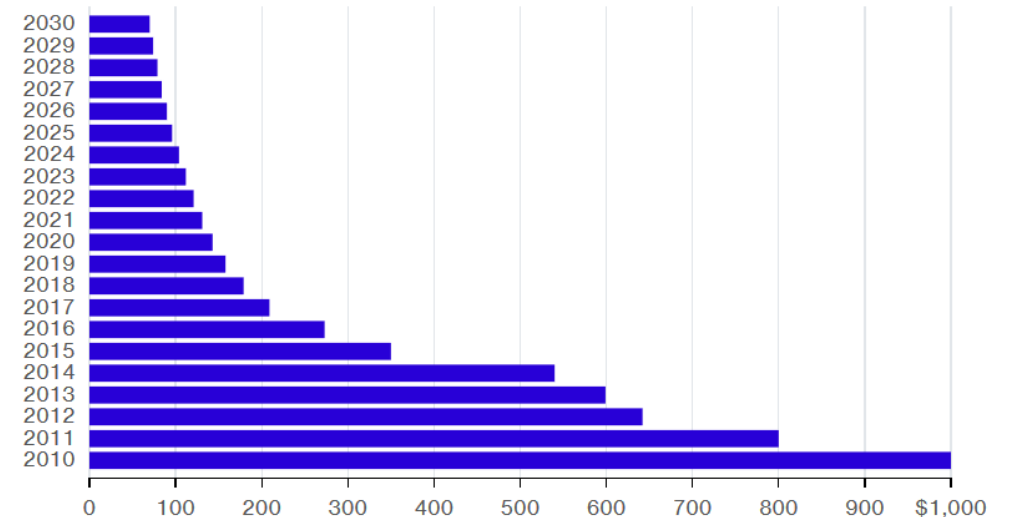
Vehicle fleet

Future battery market

- Battery demand estimated to 2000 GWh in 2030
 - Need for many new gigafactories
 - Battery prices dropping
-
- New areas opening up with market developments:
 - Stationary storage
 - Recycling/urban mining
 - 2nd life batteries
 - Battery production



Source: BloombergNEF, Avicenne



Source: BNEF
Note: Figures for 2018 and beyond are projections

Thank you!

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Battery Technology



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