greenSPEED Success Story

BEPA BATT4EU Webinar

Dr. Alex Thaler | Virtual Vehicle Research GmbH

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Funded by the European Union

Agenda

- High Level Challenges and Introduction- greenSPEED Consortium
- Technological overview for the project
- Technological Deep Dive:
  - Anode
  - Cathode
  - Cell Approach and Results
- Summary and Project Demo

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The Challenges

LITHIUM-ION CELL TECHNOLOGY NOT SUPPLIED BY EUROPEAN INDUSTRY

HIGHER DEMAND FOR BATTERY ELECTRIC VEHICLES (BEVs)

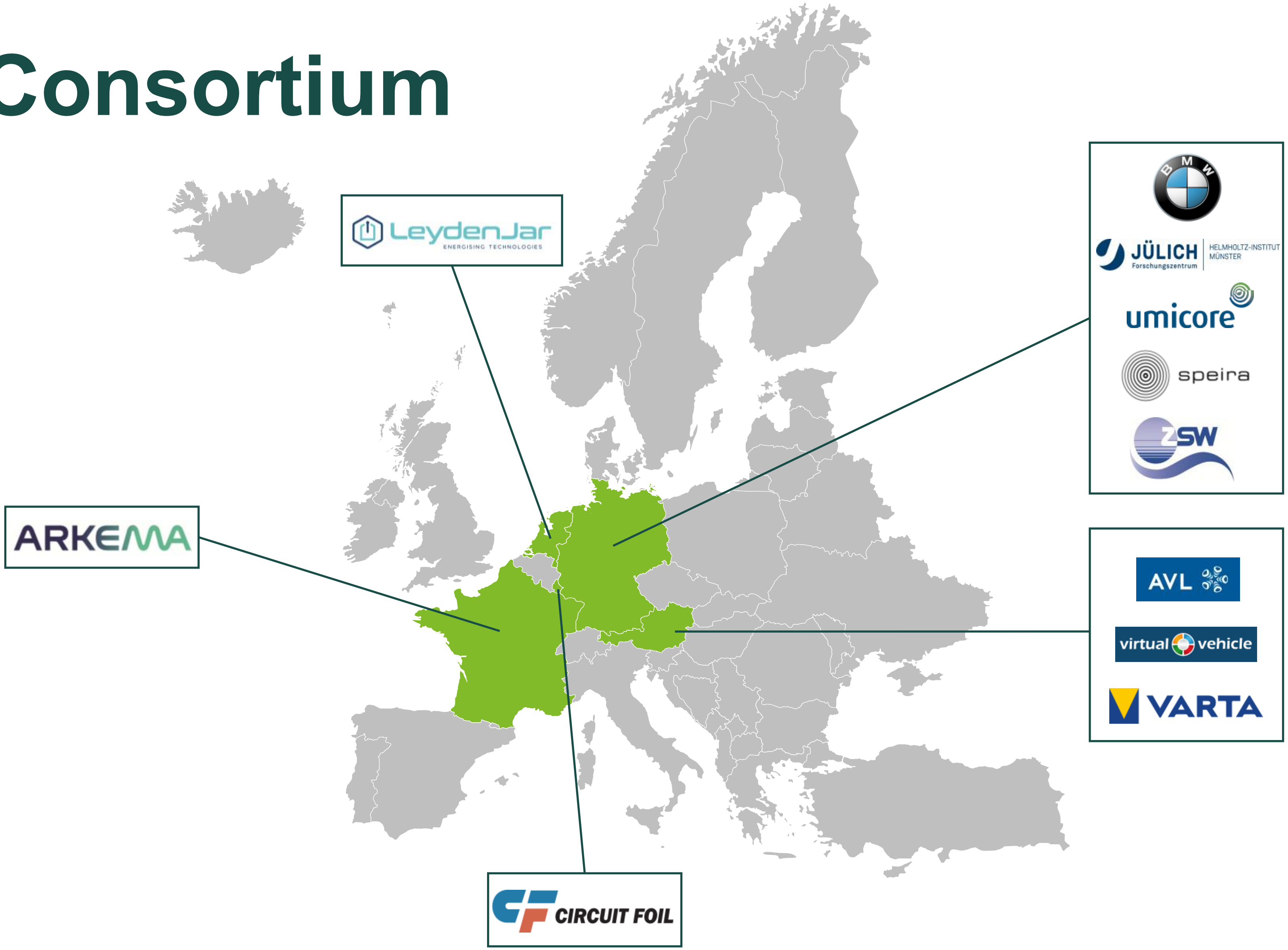
HIGH ENERGY CONSUMPTION OF SINGLE PRODUCTION STEPS

USE OF ENVIRONMENTALLY HARMFUL SUBSTANCES

LOW ENERGY DENSITY

HIGH COSTS OF LITHIUM-ION CELLS

The Consortium



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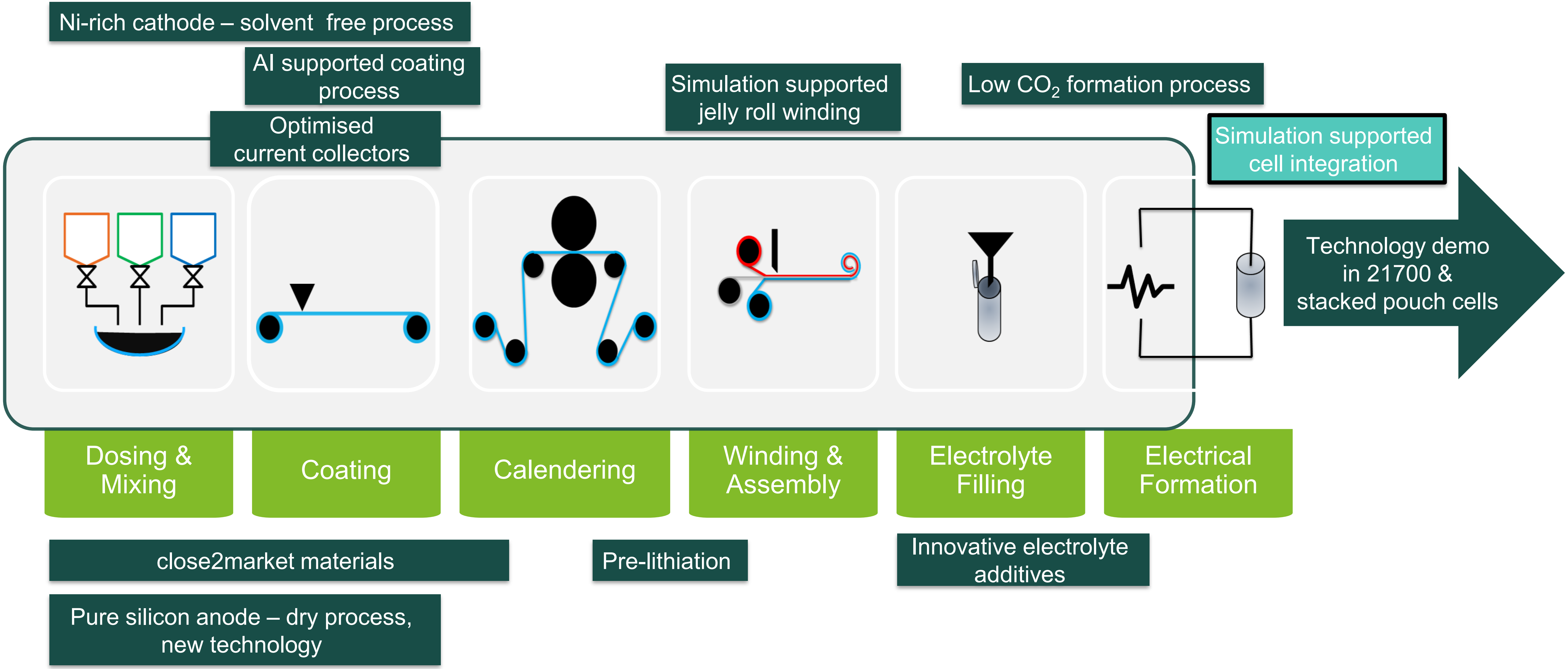
The greenSPEED Approach



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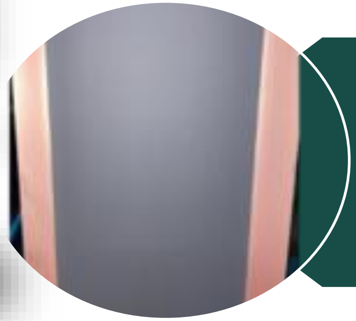
Introduction - Anode Tasks and Partners

VARTA

LeydenJar ENERGISING TECHNOLOGIES

BMW

ARKEMA



Task - Anode Formulation

- Si/C composite produced by wet process
- Pure Si anode produced by MW-PECVD

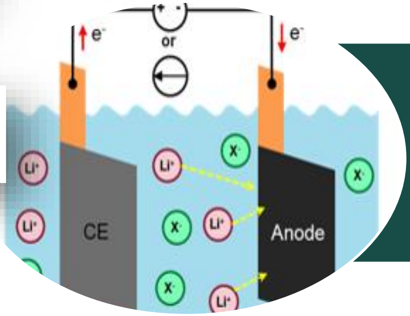
CIRCUIT FOIL

LeydenJar ENERGISING TECHNOLOGIES

Task - Anode Substrate

Cu foil modification/development

JÜLICH Forschungszentrum HELMHOLTZ-INSTITUT MÜNSTER

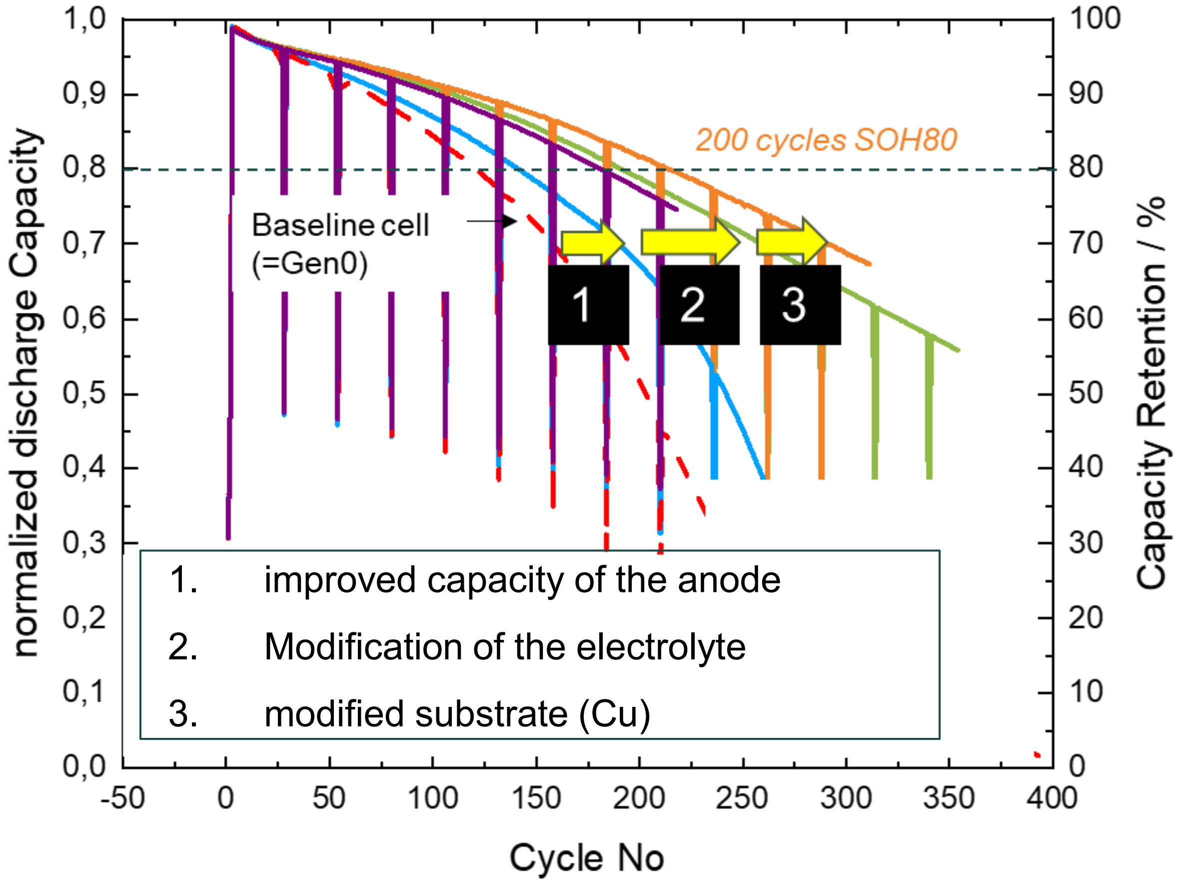


Task - Electrochemical Prelithiation

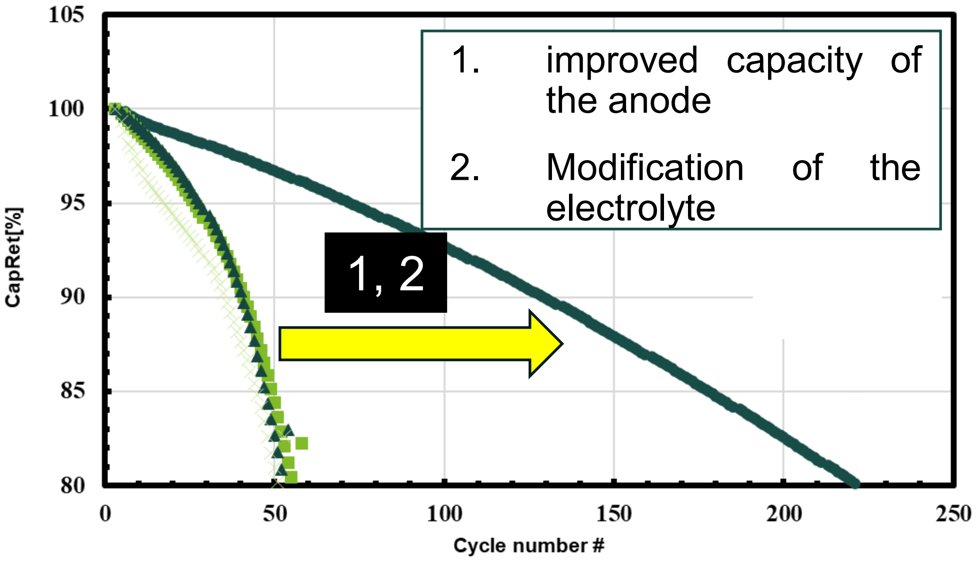
Prelithiation experiments Si/C & Pure Si

Anode Development

G-Si (>60wt%) | NMC811



Si (dry processed) | NMC811



G-Si Anode

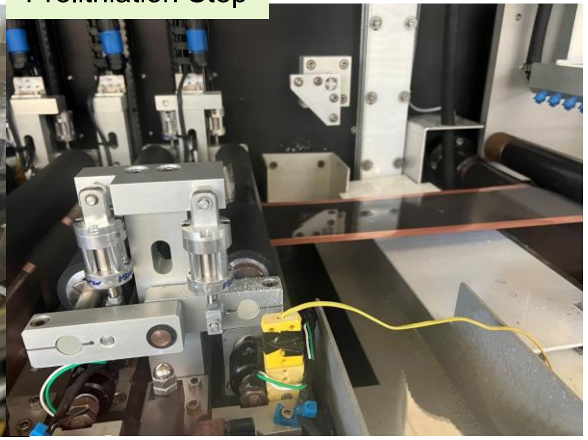
LJ pure Si Anode

Anode Development – Prelithiation

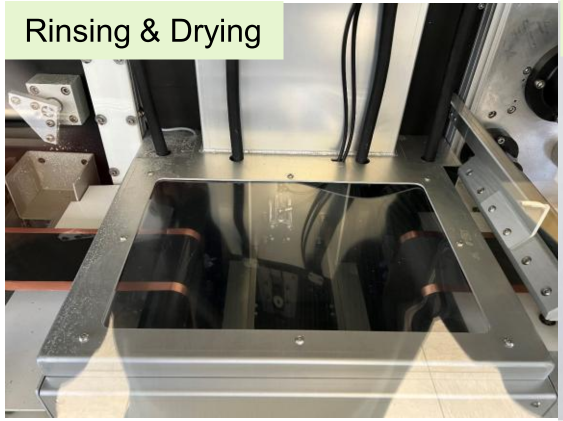
G-Si

Start Prelithiation

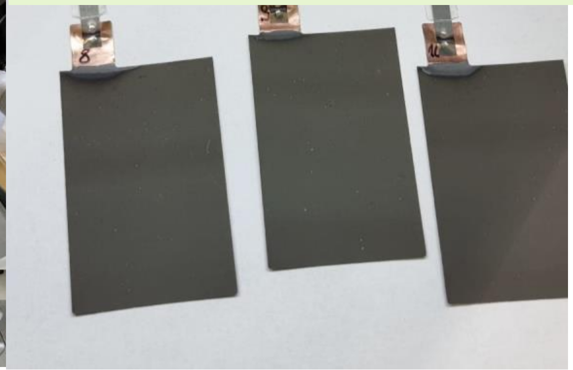
Prelithiation Step

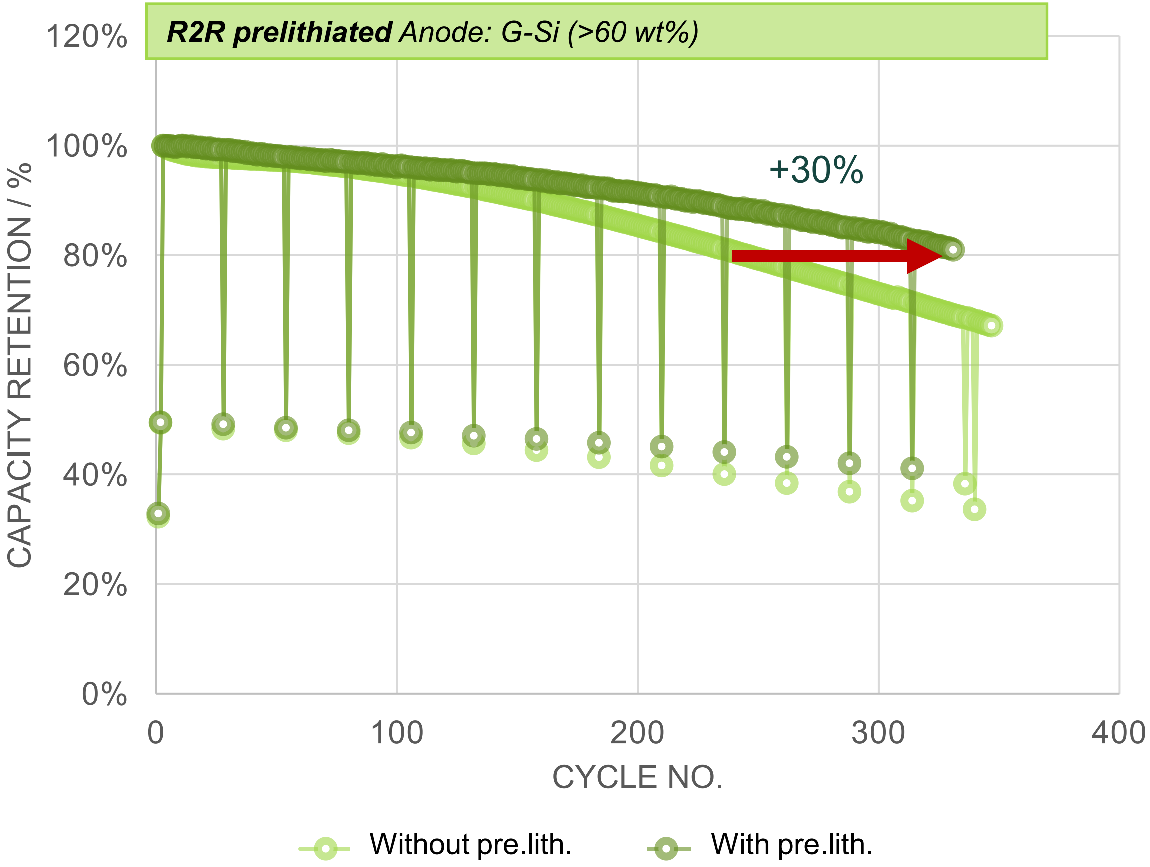


Rinsing & Drying



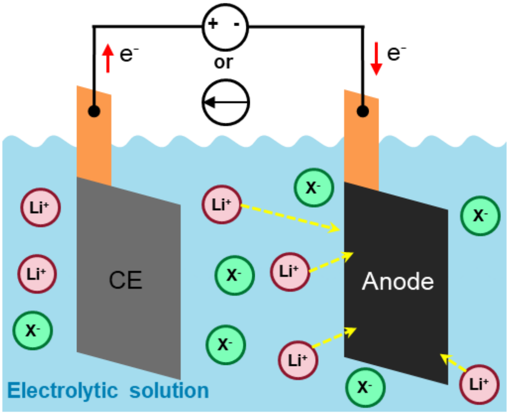
Electrode preparation for cell assembly



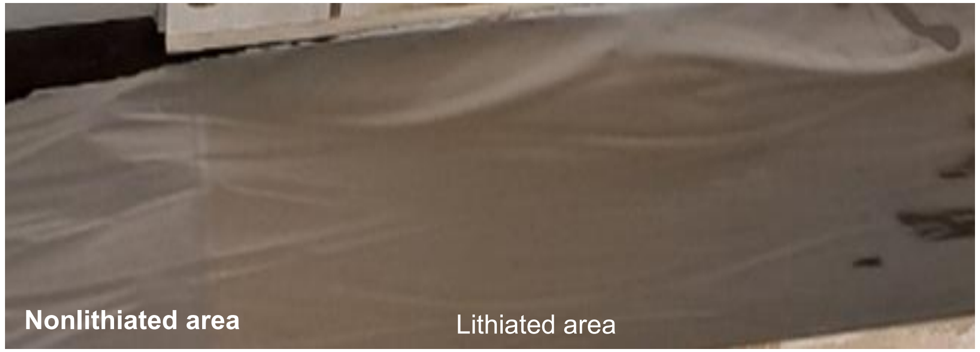


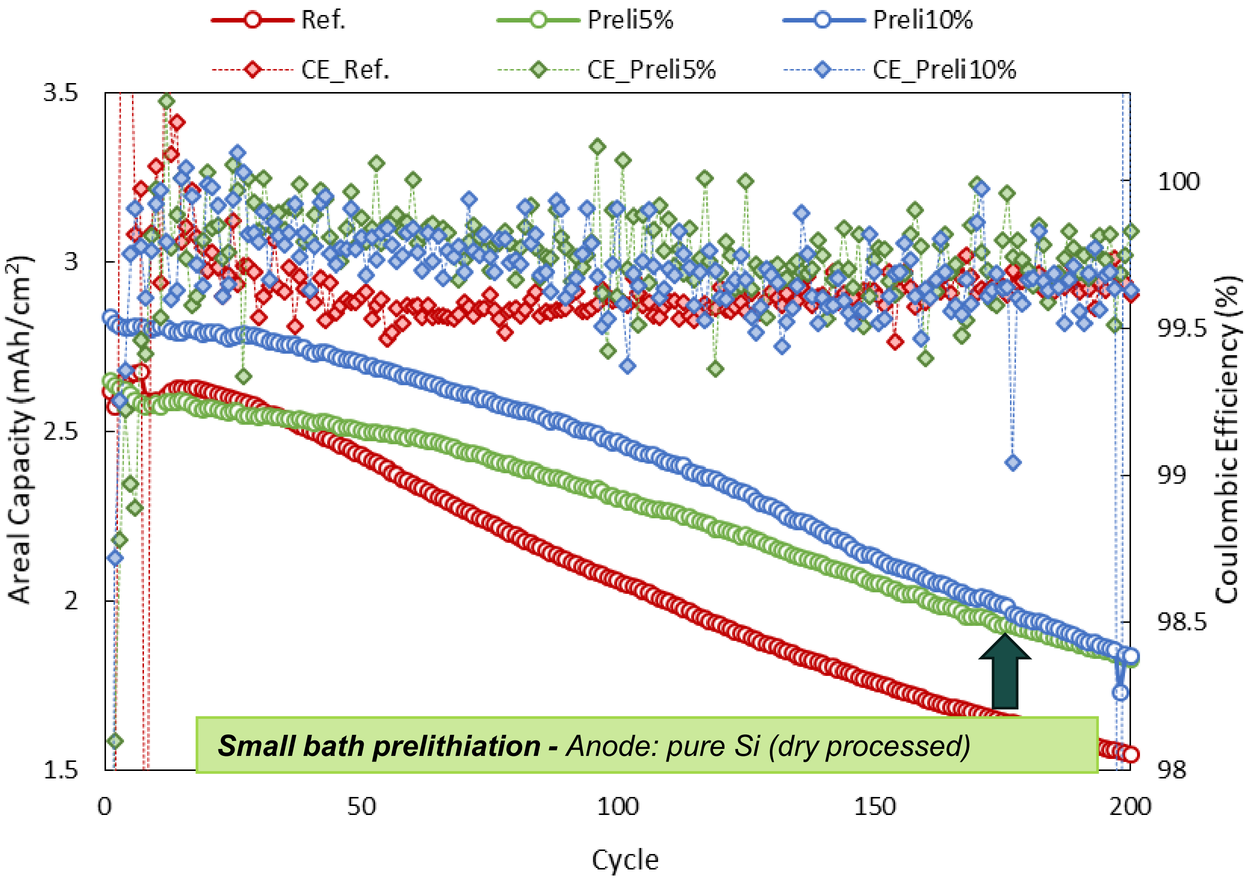
Anode Development – Prelithiation

pure Si



Dissolve the Li salt to the solution
↓
Applying electric field toward the anode side
↓
Taking the anode to the pouch cell

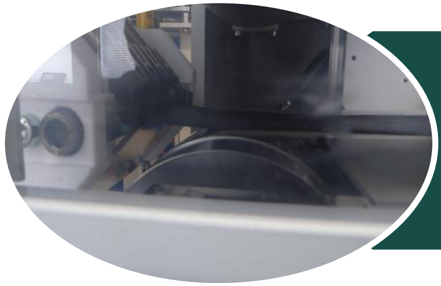




Introduction- Cathode Tasks and Partners

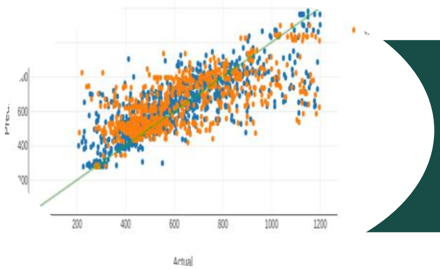
Task - Material Development

Adopted binders and current collectors as well as active material for the dry extrusion and roll-to-roll transfer process



Task - Dry Coating and R2R Transfer Process

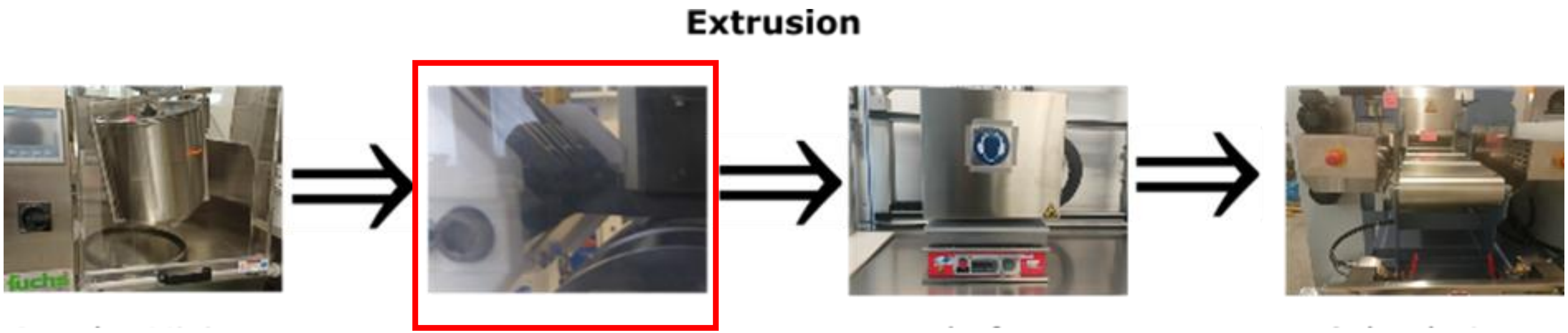
Dry extrusion of the cathodes



Task - Artificial Intelligence

Digital twin of the dry extrusion process

Cathode – Process Overview



Powder mixing:

All powders are premixed dry in tumble mixer
→ Homogeneous dry mix dosed into extruder

Extrusion and R2R transfer:

Homogeneous paste is created and coated directly on the current collector

Removal of ethylene carbonate:

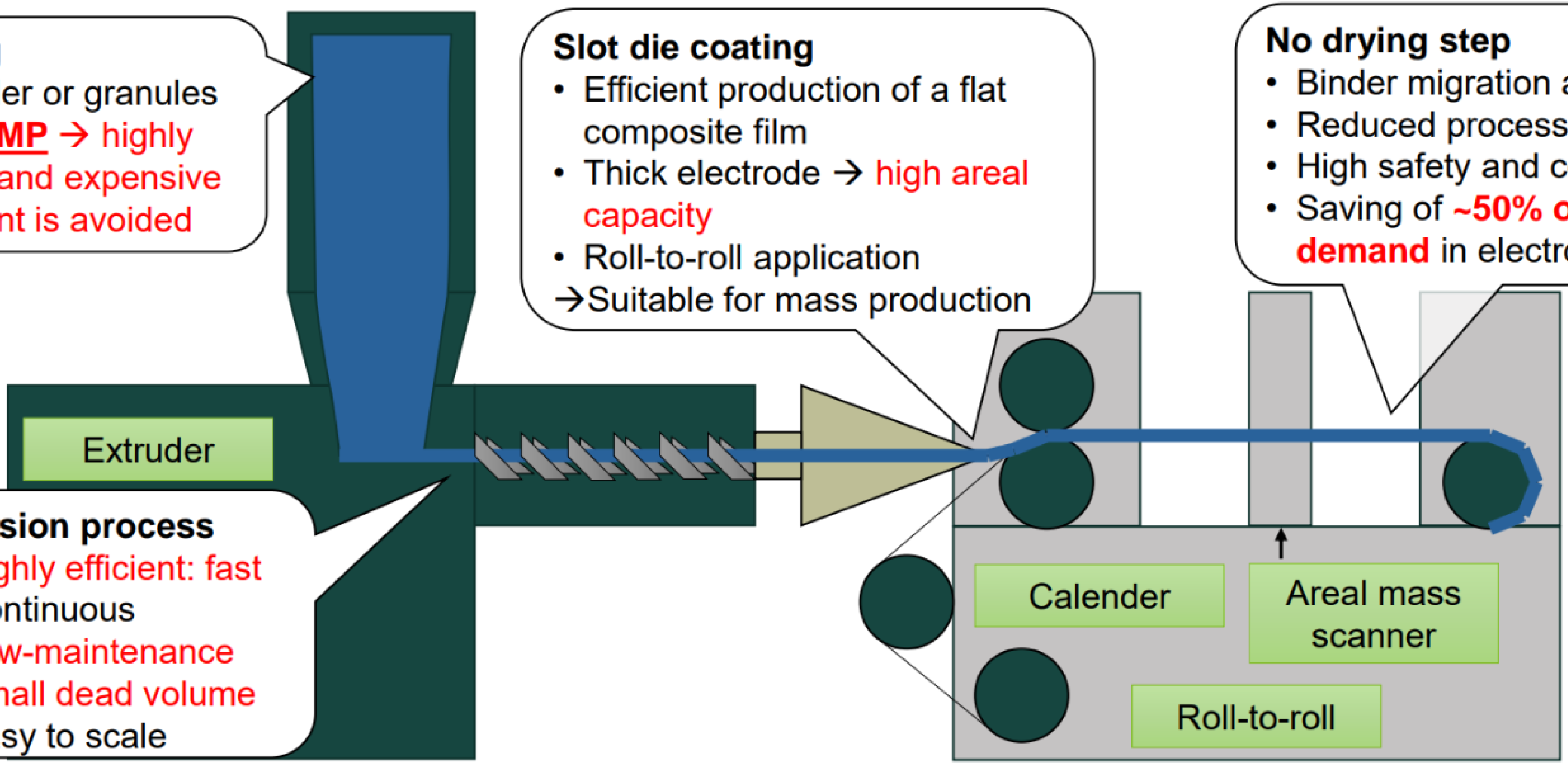
Ethylene carbonate serving as processing additive and pore forming agent is removed

Calendering:

Electrode is calendered to target porosity

Cathode – Process Overview

The ZSW solvent-free extrusion process



Dosing
- Powder or granules
- **No NMP** → highly toxic and expensive solvent is avoided

Extrusion process
- Highly efficient: fast
- Continuous
- Low-maintenance
- Small dead volume
- Easy to scale

Slot die coating
- Efficient production of a flat composite film
- Thick electrode → high areal capacity
- Roll-to-roll application

→Suitable for mass production

No drying step
- Binder migration avoided
- Reduced process time
- High safety and cost are reduced
- Saving of **~50% of overall energy demand** in electrode production

Customized passive materials from project partners

Cathode - Challenges

Main challenges:

- Uniform film thickness, not too thick films
- Homogeneous shape of edge, quality of edges
- Adhesion between current collector and extrudate
- Mechanical stability of extruded films towards bending
- Matching the desired loading on both sides

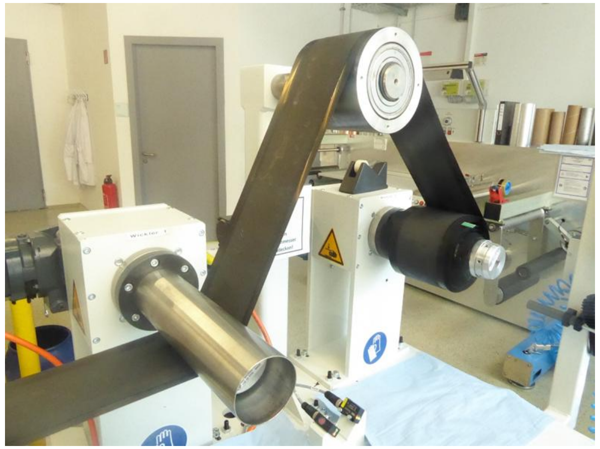
Example of a sample with poor edge quality

Cathode – Results and Outlook

Main achievements:

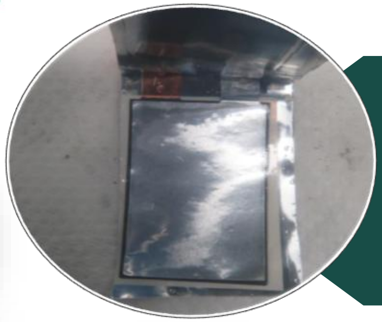
- Influence of binder type on processability & mechanical stability elucidated
- Composition, screw speed and extrusion temperature were optimized
- Adhesion to current collector optimized by using primered aluminium foil
- Electrochemical performance improved by optimized composition
- Stable process enabling double side coating established
- Digital twin involving the different process steps created

  → Beneficial parameters predicted



Double side coated electrode from stable process

Introduction - Cell Tasks and Partners

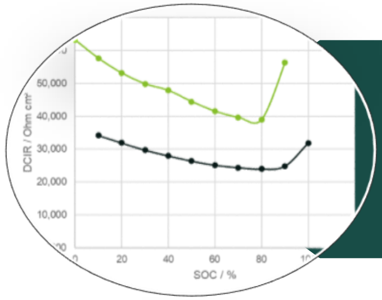


Task - Adapted Electrolyte

- Apdapted Electrolyte by variation of salts and additives

Task - Cell Integration in Pouch & 21700 Cell Format

- Developed electrodes are integrated; different cell formates (pouch & cylindircal)



Task - Testing and Validation

- Electrochemical performance testing & safety testing

greenSPEED's Cell Approach

01

Bi-layer Pouch Cells

Up to 150 mAh

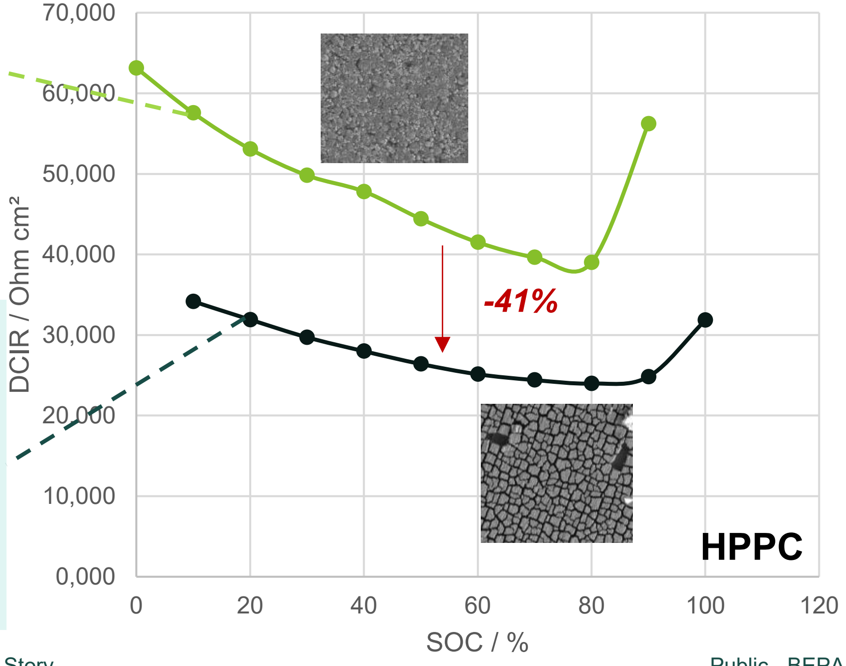
02

Multilayer Pouch Cells

Up to 2 Ah

Anode G-Si:
Wet-processing
H2 evaluation during mixing, Cell gasing
Cycle life ~200

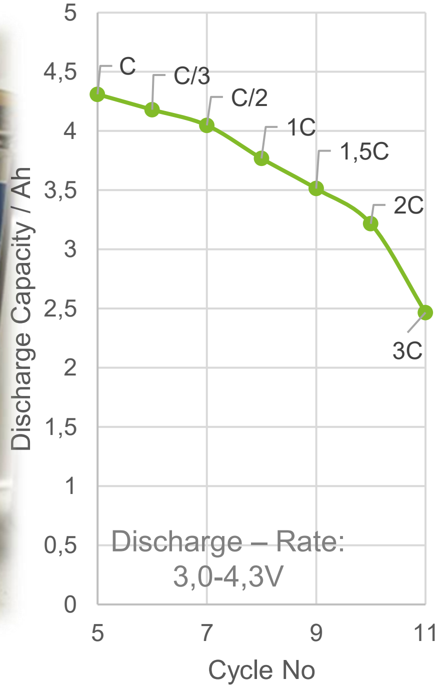
Anode Si:
Dry Process
High volume Expansion (>300%)
High pressure during formation (>>1 MPa); without special set-up
~50 cycles

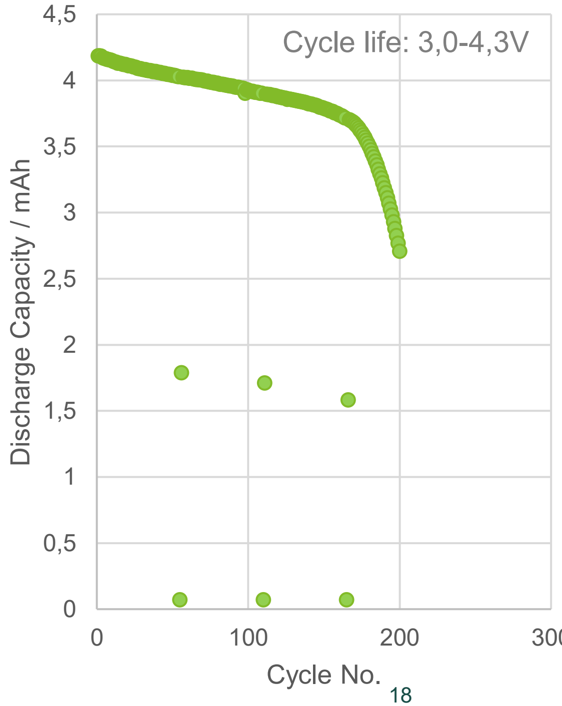


03

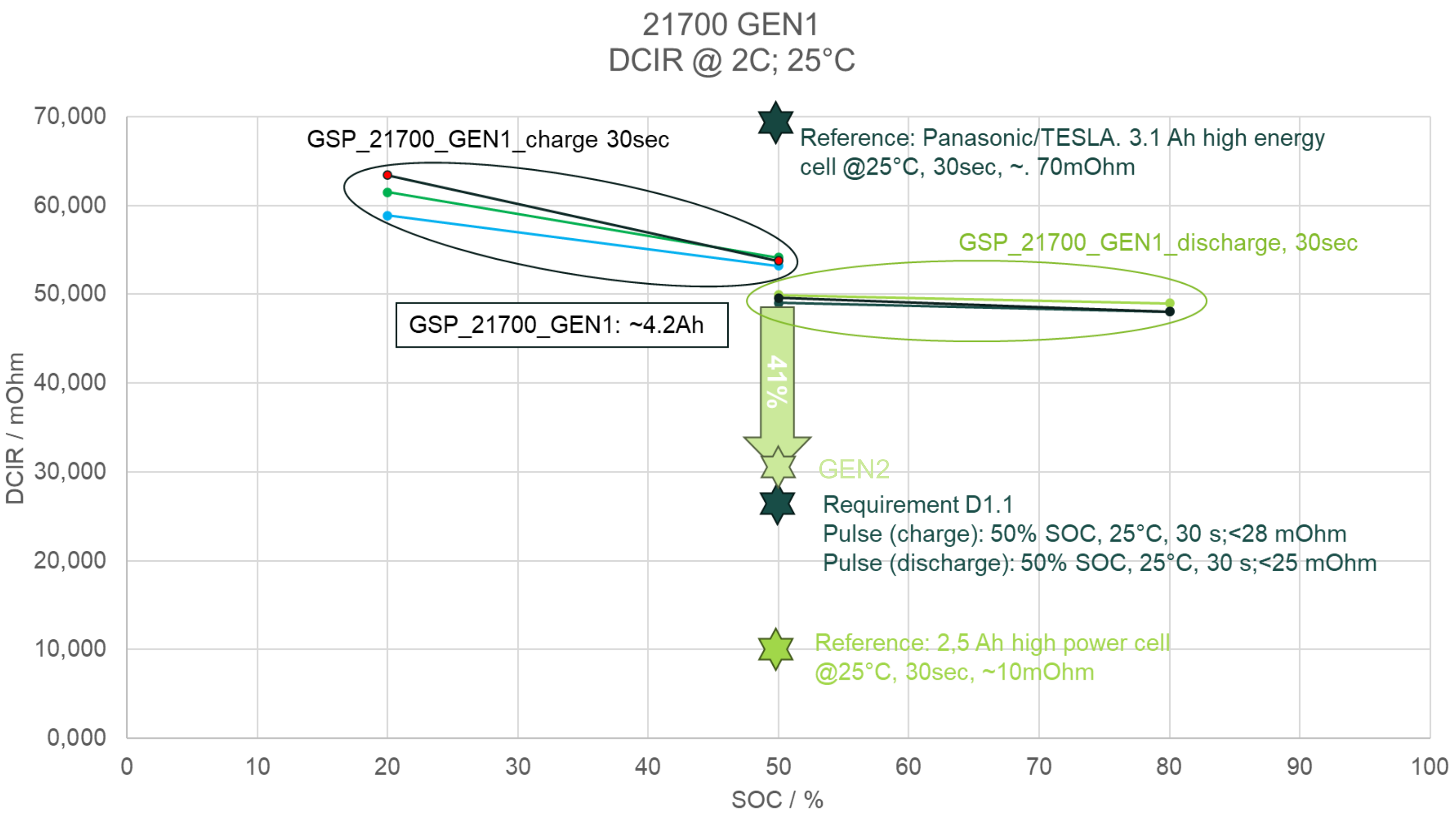
Cylindrical Cell 21700

4.8 Ah (C/10), 4.3 Ah (C/3)





greenSPEED Results vs Benchmark



Comparison of the DCIR of the greenSPEED cell technology vs benchmark cells

Gen1 = G-Si Anode
Gen2 = pure Si Anode

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Summary and Project Demo

- All innovative process technologies applied and demonstrated in full cells
  - High Si-content anode demonstrated in stacked pouch or wound-type cell
  - Dry processed cathode demonstrated in pouch cells
- Toxic solvent (NMP) replaced by innovative processing
- Valuable data gathered along the process chain
- Production energy demand and cost assessed for further decisions, supporting modelling activities established
- Lessons learned on interfaces between partners doing the different processing steps

Webinar

GREEN SPEED

greenSPEED Final Results Webinar: Accelerating a Sustainable Future

Tuesday,
16th December 2025

Time: 9 AM (CET)
Duration: 2,5h

SCAN ME

Register here and find out more:

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Team Lead Battery &
Technical Coordinator

Thank you!

www.greenspeed-project.eu

SCAN ME

TO VISIT THE WEBSITE

greenSPEED has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101069528. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

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Carbon Neutral European Battery Cell Production with Sustainable, Innovative Processes and 3D Electrode Design to Manufacture

EU HORIZON RESEARCH PROJECT

BatWoMan

Carbon Neutral European Battery Cell Production with Sustainable, Innovative Processes and 3D Electrode Design to Manufacture

Towards cost- and energy-efficient lithium-ion battery cell production

Marcus Jahn, Bernd Eschelmüller

BATT4EU Workshop – 13/11/2025

BEPA Batteries European Partnership Association

CONSORTIUM PARTNERS

BatWoMan – Project Consortium

BEPA Batteries European Partnership Association

bat wo man

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Carbon Neutral European Battery Cell Production with Sustainable, Innovative Processes and 3D Electrode Design to Manufacture

EU HORIZON RESEARCH PROJECT

Why are we working on this topic:

To develop sustainable and cost-efficient battery cell production technologies that reduce carbon footprint and strengthen the EU's leadership in green battery manufacturing.

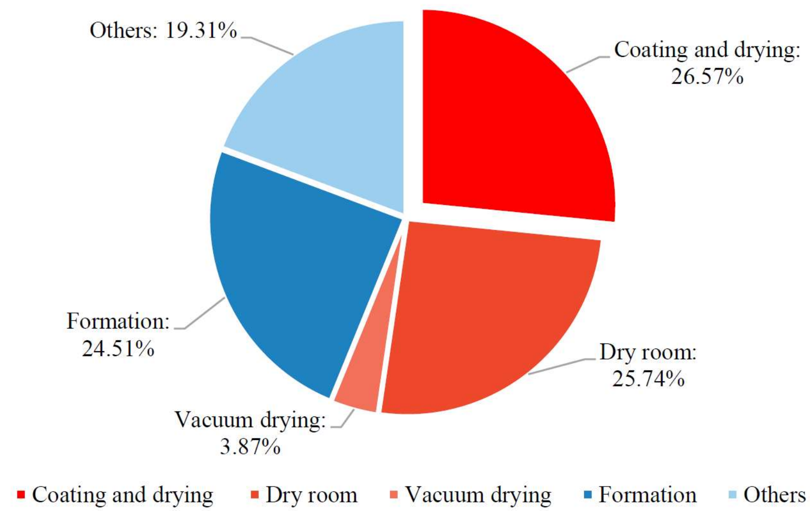
Who benefits from the results:

European battery manufacturers, automotive OEMs, and society at large benefit through cleaner, cheaper battery production and enhanced supply chain transparency.

What is the industrial need for your work:

The industry urgently needs scalable solutions to lower production costs and energy demands while meeting environmental regulations and ensuring high-performance cell quality

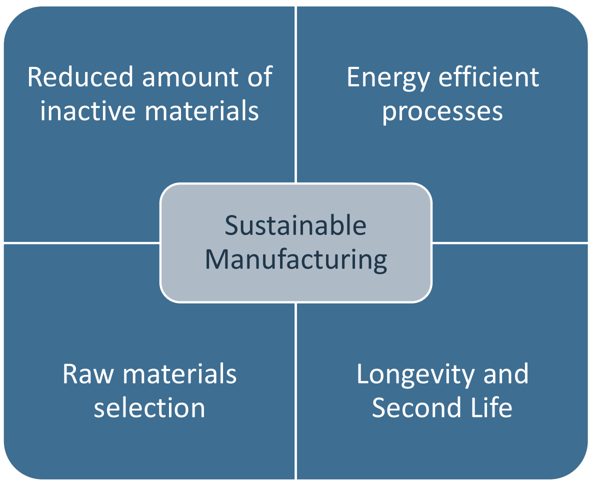
Share of energy consumption for battery manufacturing processes



Batteries 2024, 10, 64. https://doi.org/10.3390/batteries10020064

CONSORTIUM PARTNERS

Sustainability and cell production



- **Reducing inactive materials**

  Increased energy density

- **Energy efficient processes**

  Solvent-reduced slurries

  Dry room need reduction

- **Raw materials selection**

  CRM-free cell chemistries

  Water-based electrode manufacturing

- **Longevity** and Second Life

  Smart Cells and Sensor integration

Possible concepts and solutions

Conventional production process	Proposed new process/concept	Potential energy reduction	Potential cost reduction
NMP-based slurry preparation	Solvent-reduced H_2O based slurries	0.4%	4-6%
Conventional electrode thicknesses	Thick electrodes with high areal capacity > 4 $mAhcm^{-2}$	25-30%	20-25%
Electrode coating with following drying unit and compacting	Single-unit approach of drying and comp… electrodes	2%	4%
Mechanical electrode cutting	Laser-cutting o… electrodes		
Dry room for slitting, stacking, electrolyte filling production steps	Energy-efficien… unit and direct t… electrolyte filler		
Electrolyte filling in several steps and under vacuum	One-step filling with less electrolyte amount	0.2%	5-10%
Conventional formation and ageing	Improved energy and time efficient formation and ageing procedures	1-2%	8-10%
Conventional scrap rate of 5%	Reduced scrap rates of maximum 1%	n.a.	1-3%

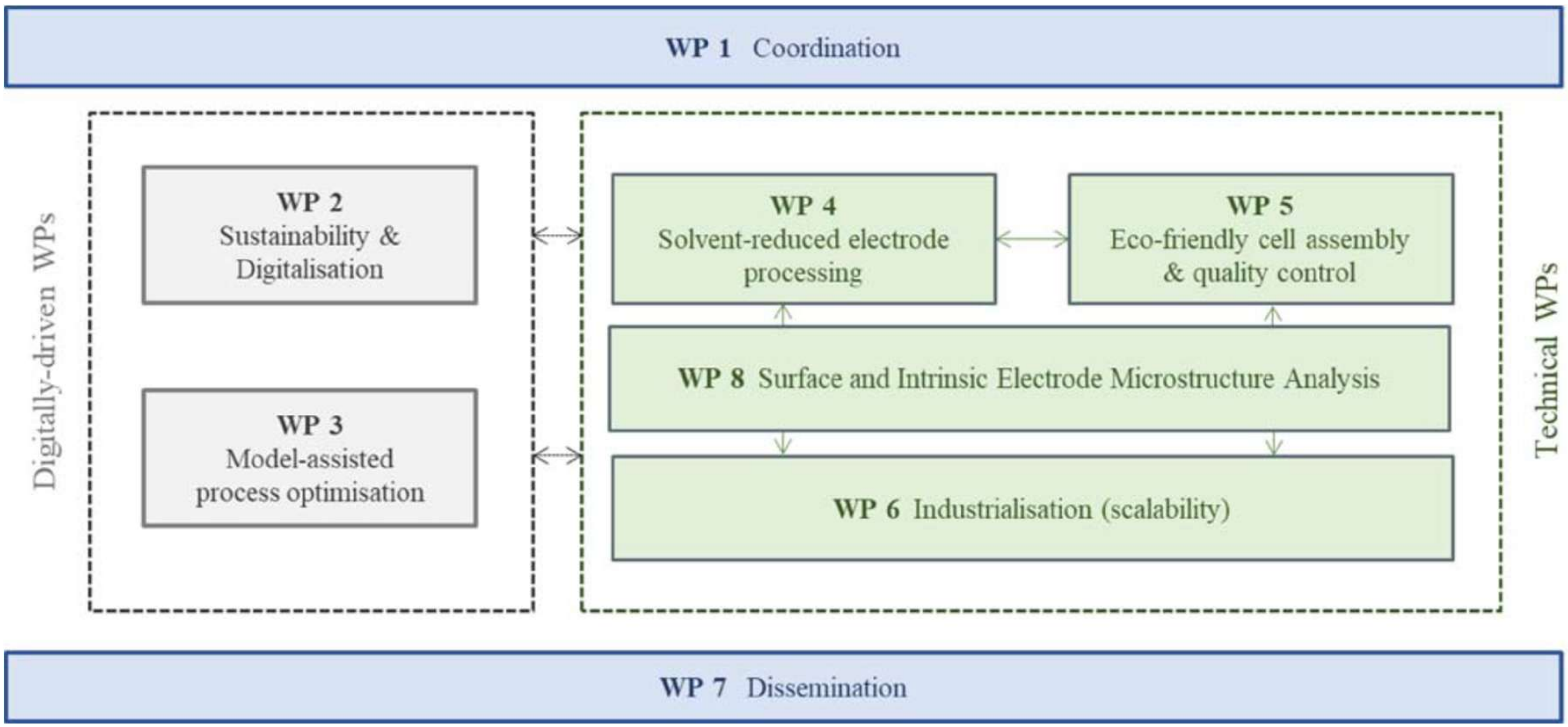
→ Potential cost reduction up to 70%

→ Potential energy reduction up to 60%

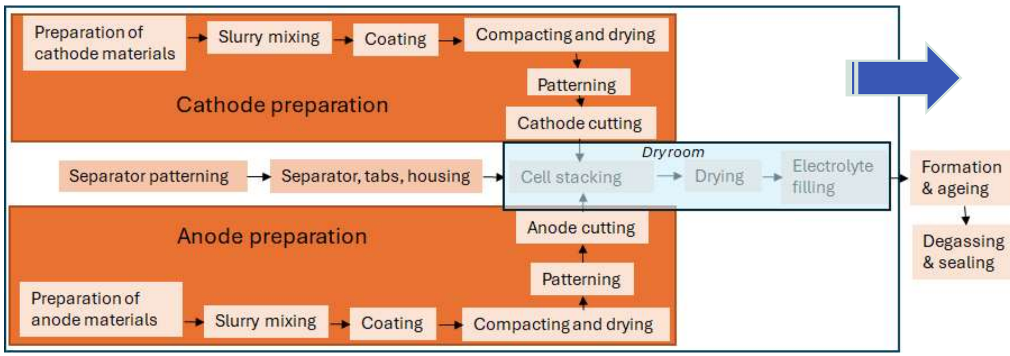
at **cell** level

Wessel et al., Procedia CIRP 98 (2021) 388-393.
Liu et al, iScience 24, 102332, April 23, 2021.
Kwade et al., Nature Energy 3 (2018): 290-300.
Duffner et al., International Journal of Production Economics 232(2021): 107982.

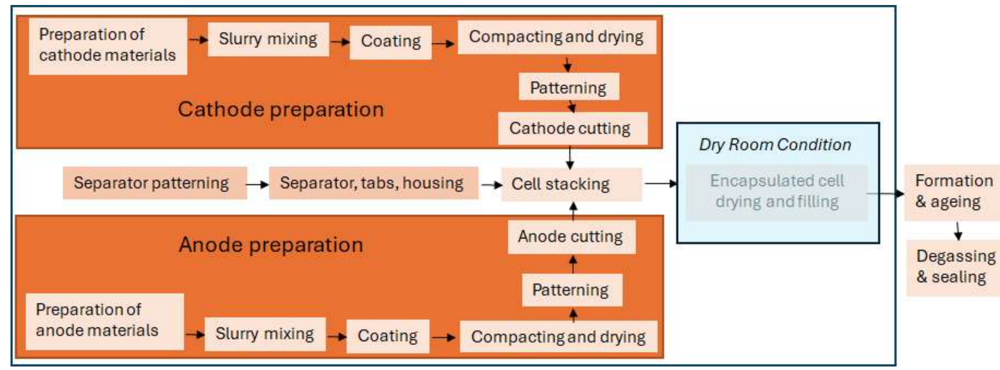
WP Overview


WP 1 Coordination
Digitally-driven WPs
WP 2
Sustainability &
Digitalisation
WP 3
Model-assisted
process optimisation
WP 4
Solvent-reduced electrode
processing
WP 5
Eco-friendly cell assembly
& quality control
WP 8 Surface and Intrinsic Electrode Microstructure Analysis
WP 6 Industrialisation (scalability)
Technical WPs
WP 7 Dissemination

WP2 - Sustainability & Digitalization

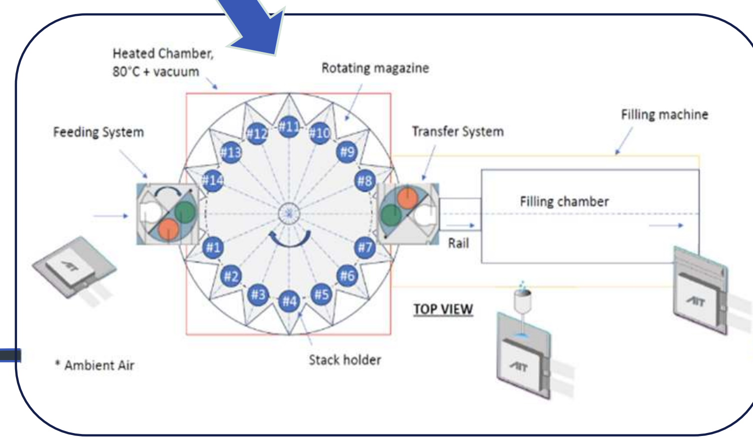


BatWoMan **optimised cell manufacturing** process chart with **reduced dry room area -** only stacking, stack drying and electrolyte filling carried out in dry room



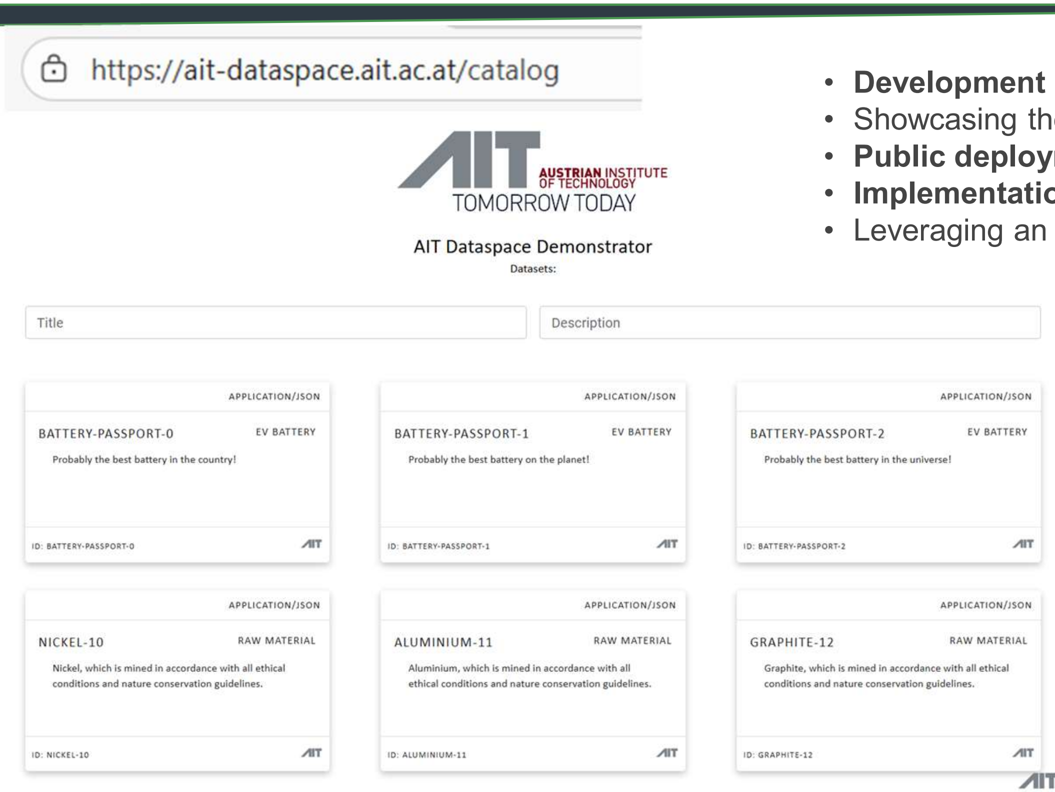
BatWoMan "no dry room assumption" - **stack drying and filling** in encapsulated device.

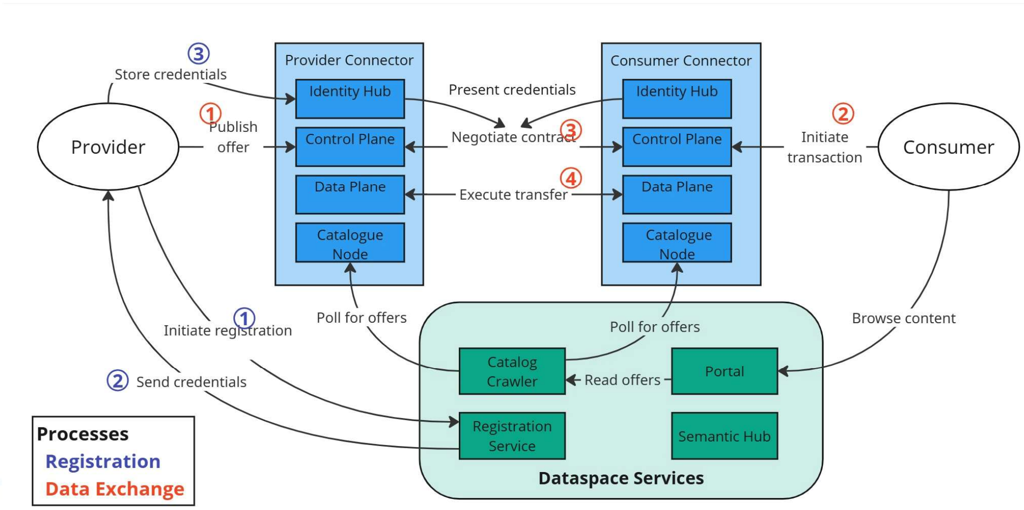
Manufacturing part	Dry room conditions		Total
Scenario	kWh/kg cell	kWh/39 Ah cell	**kWh/39 Ah cell**
State of the art	0.611	0.388	**0.410**
Reduced dry room	0.186	0.118	**0.140**
Dry room condition	0.004	0.003	**0.025**



WP2- Battery Data Space

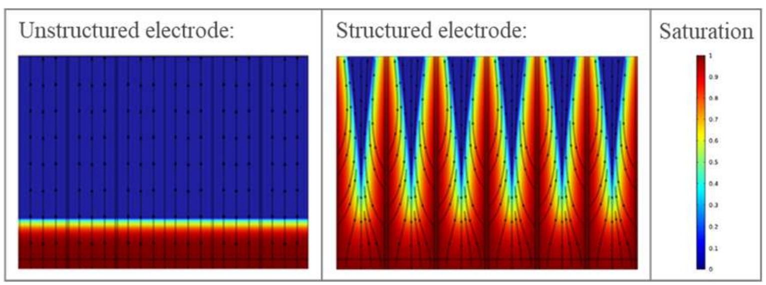
- **Development** of a **Data Space Demonstrator**
- Showcasing the **implementation** of a **Digital Product Passport** (DPP)
- **Public deployment** of the frontend, providing access to an example DPP via a QR code
- **Implementation** based on the **Eclipse Dataspace Connector** (EDC)
- Leveraging an existing **open-source version** from **GitHub**.



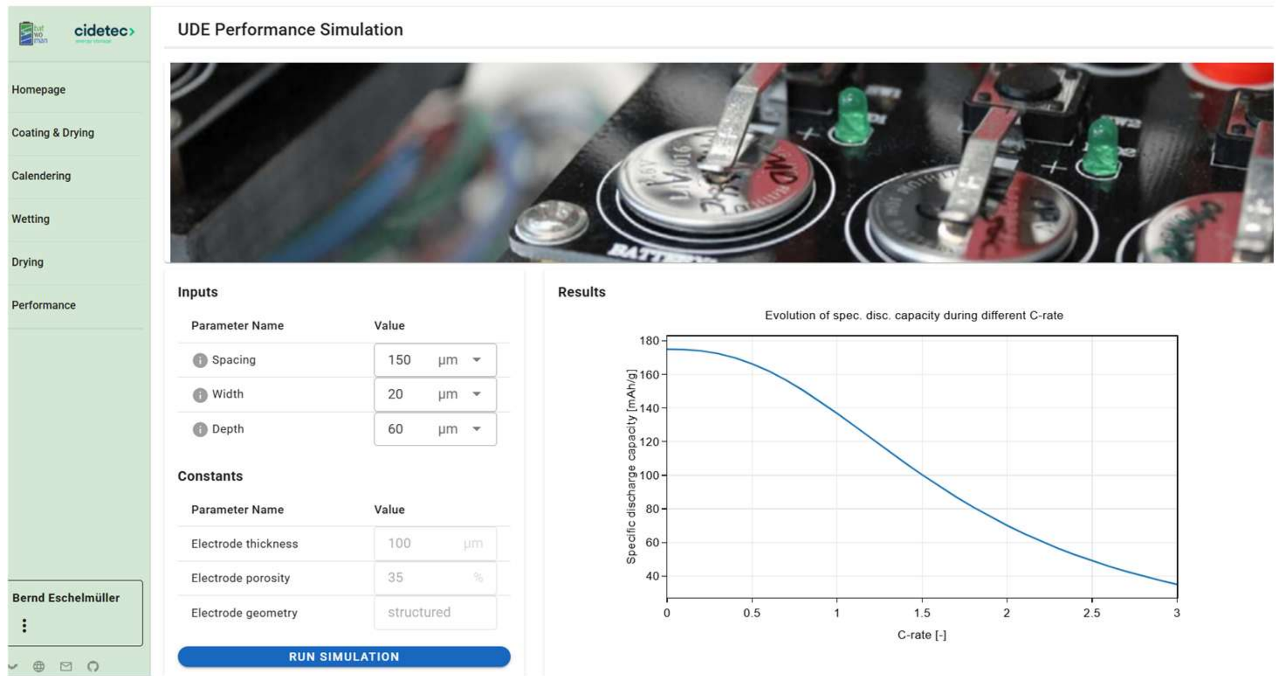


WP3 - Model-assisted process optimization

- **Data analysis** and **modelling**
- **Correlation** of **electrode manufacturing parameters** with resulting **electrode properties**
- **Models** to simulate **coating, drying, and calendering**
- **Laser structuring simulations** implemented



Saturation profile of unstructured (left) and structured (right) electrodes for a specific time step in COMSOL MULTIPHYSICS.

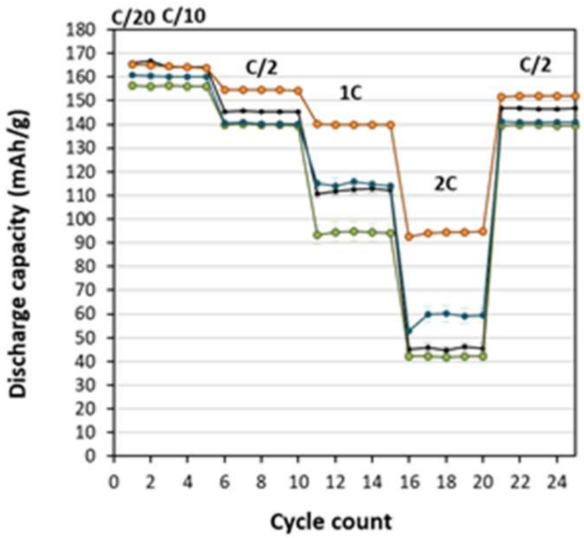


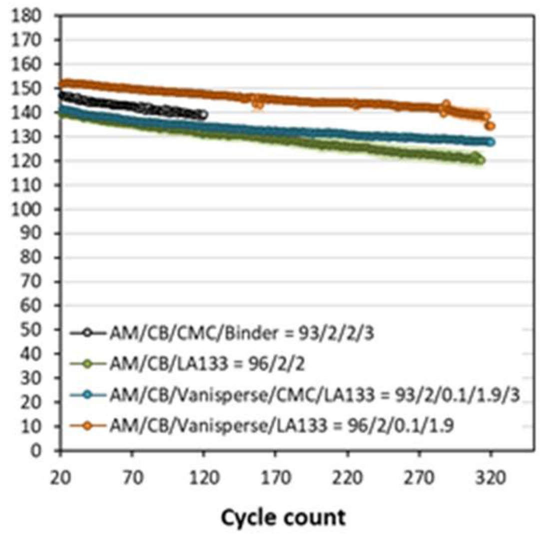
Parameter simulation accessible via: https://batwoman.eu/

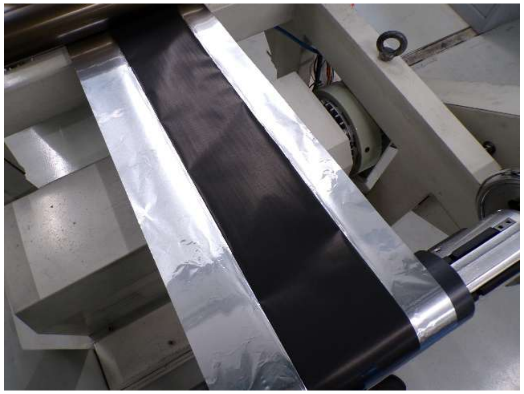
WP4 - Solvent-reduced electrode manufacturing

Cathode formulation	CMC	Binder	SC%	Q_{charge} (mAh/g)	$Q_{discharge}$ (mAh/g)	ICE%
AM/CB/CMC/Binder = 93/2/2/3	T2000 (3%)	BM620B (40%)	59%	186,47	166,01	89,03
AM/CB/**LA133** = **96**/2/2	-	LA133 (15%)	68%	179,10	156,36	87,30
AM/CB/**Vanisperse**/CMC/**LA133** 93/2/0,1/1,9/3	T2000 (3%)	LA133 (15%)	~70%	183,97	160,71	87,35
AM/CB/**Vanisperse**/**LA133** **96**/2/0,1/1,9	-	LA133 (15%)	73%	190,61	165,45	86,80

- Water-based NMC622 processing
- NMC/C45/LA133/VS = 96/1.9/2/0.1
- Solid content (**SC**) increased up to **73 %**



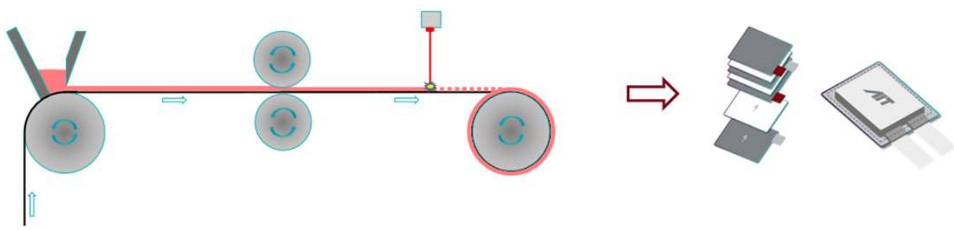




Electrochemical testing results of cathodes with **LA133 binder** and **Vanisperse dispersant** in the waterborne cathode formulations. The cathodes were tested in full coin cell (FCC) vs graphite anode.

WP5 - Eco-friendly cell assembly & validation

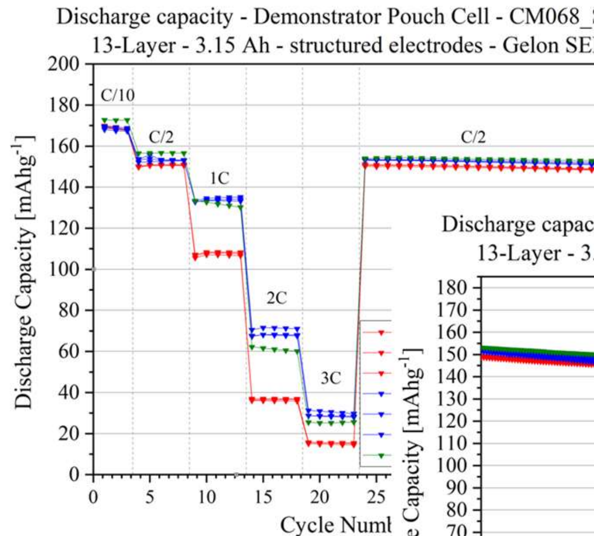
- Validation of the impact of **laser structuring** on cell performance indicators
- **3D** design **electrodes**
- Final **demonstrator** validated with **3.1 Ah capacity**
- **Improvement** of **high-rate capability** by 3D design

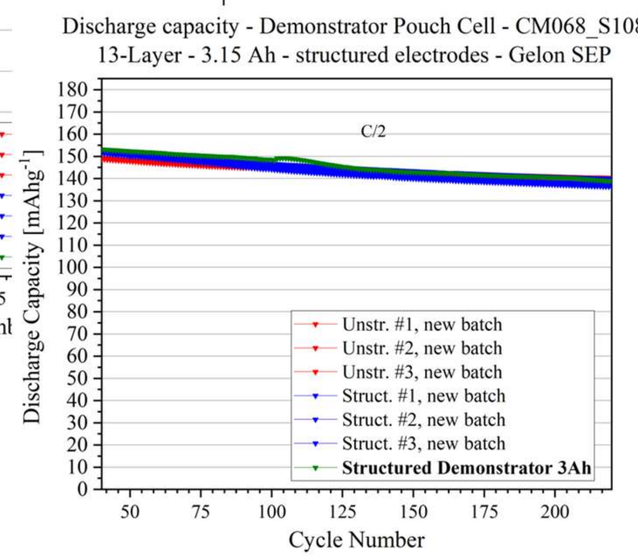


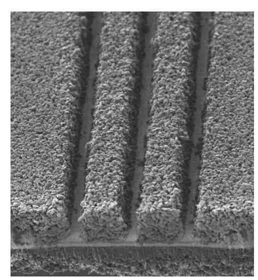
COATING + COMPACTING
R2R process implementation
- Cathode areal capacity: 4.0 mAh/cm²
- Anode areal capacity: 4.6 mAh/cm²
- Drying temperature: 85 °C
- Compacting rate: ~ 25 %

STRUCTURING
OPTEC PS450-TO
- Pitch: 300 µm
- Wavelength: 515 nm
- Pulse repetition rate: 1 MHz
- Laser power: 5 W

CELL ASSEMBLY
Multilayer pouch cells
- Nominal capacity: 2,100 mAh
- 4 double sided coated cathodes
- 5 double sided coated anodes

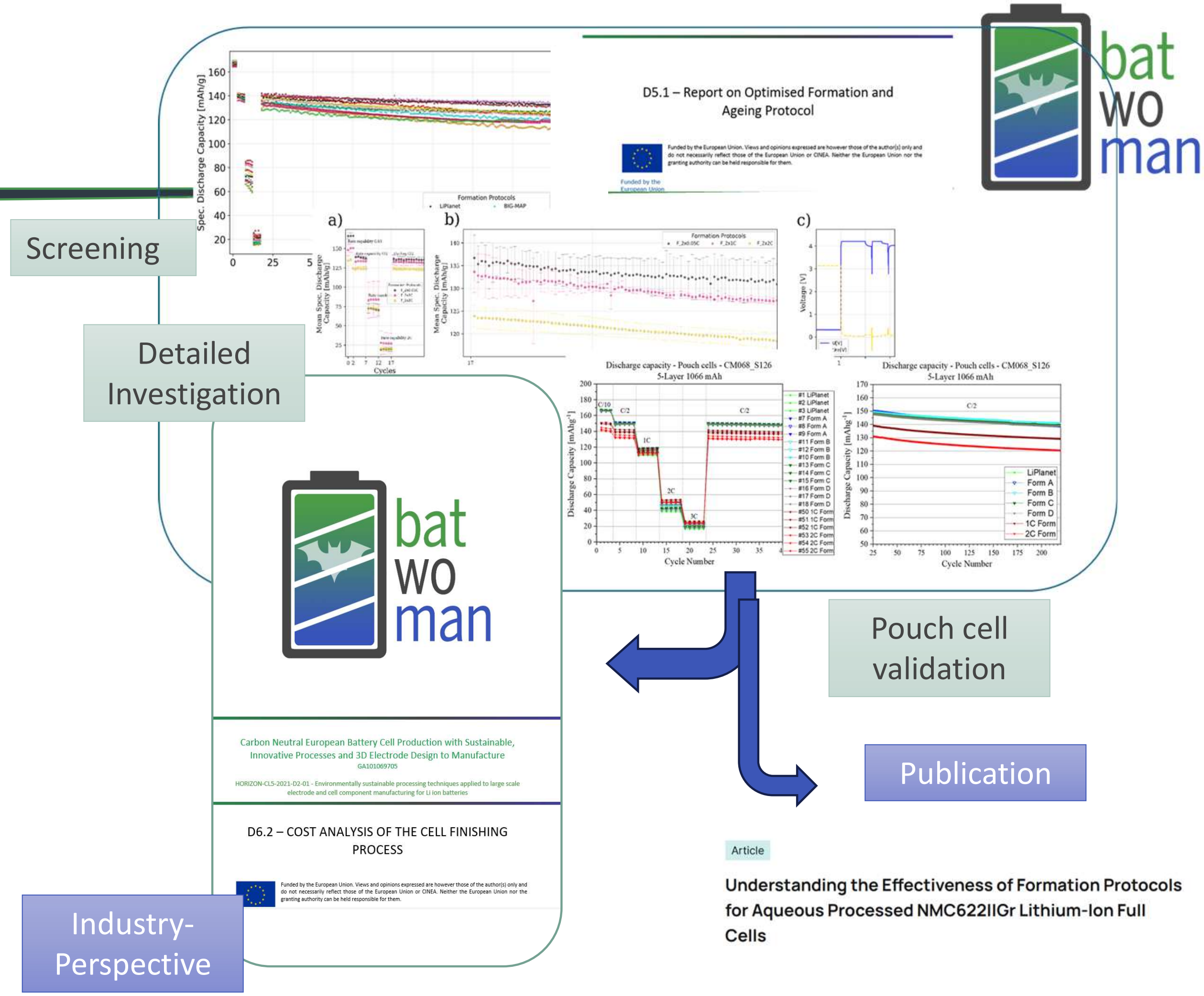






WP5 - Formation

- **Formation protocol optimisation** for cost efficiency and quality measures.
- **Electrochemical testing** of resulting cells and comparison with conventionally manufactured cells.
  - T5.4: Formation **time** can be **reduced significantly** to save costs and energy
  - Very successful **collaboration** within WP5 and with partners from other WPs:
  - Result **transfer to WP6** – Industry perspective
  - Scientific **publication** in collaboration of CID, AIT and CERTH



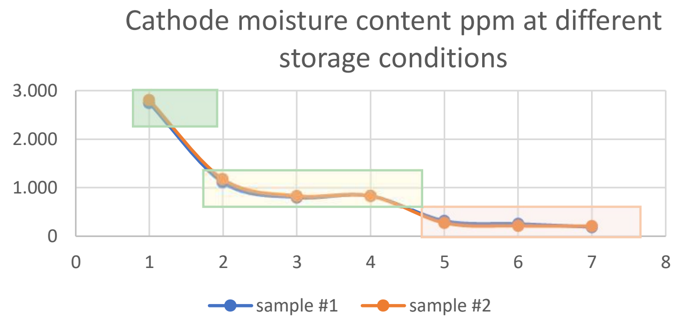
WP5 - Drying Concepts
Component level

BEPA Batteries European Partnership Association

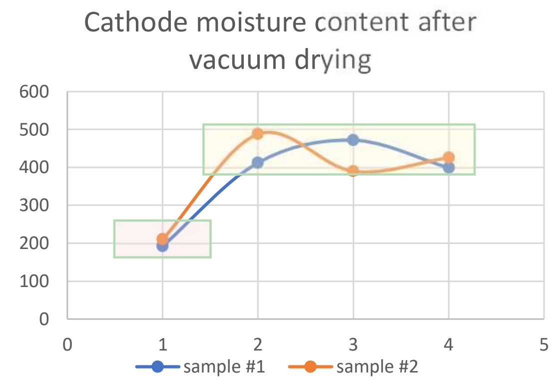
bat wo man

Condition #	Condition
1	Ambient Air 2d

Cathode CM068



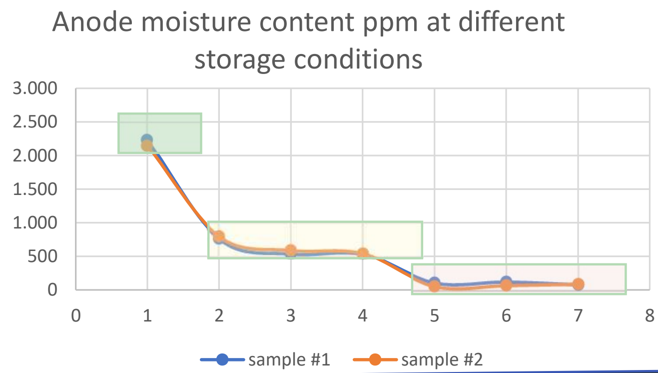
Dry room storage



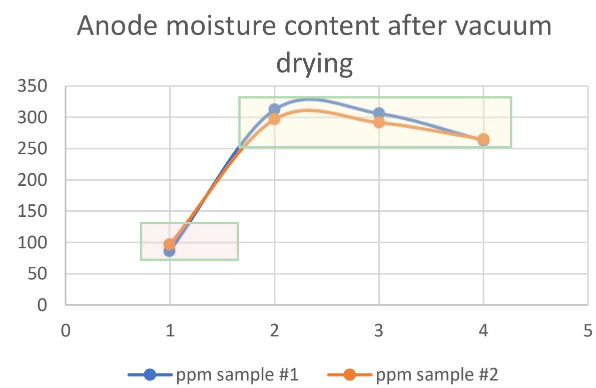
KF Titrator

Condition #	Condition	ppm sample #1	ppm sample #2
1	Vacuum O. 80°C 90m	193,68	211,04
2	Stored in D.room 1h	412,90	487,32
3	Stored in D.room 2h	471,66	390,61
4	Stored in D.room 3h	400,01	426,09

Anode S126



Dry room storage



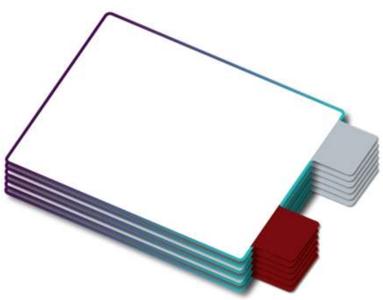
Condition #	Condition	ppm sample #1	ppm sample #2
1	Vacuum O. 80°C 90m	86,83	96,81
2	Stored in D.room 1h	312,23	296,96
3	Stored in D.room 2h	306,30	291,83
4	Stored in D.room 3h	263,52	265,19

WP5 - Drying Concepts
Stack level

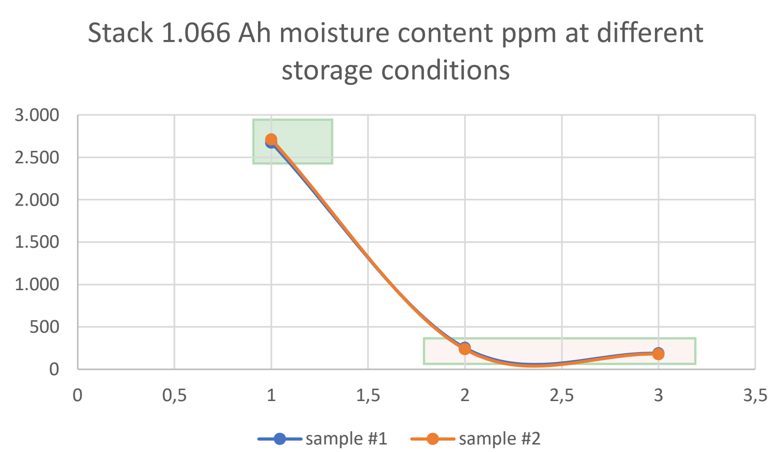
KF measurements to investigate the time-dependent change in wetting/drying behavior under specific and relevant conditions for separator elements and 1.066 Ah pouch stacks

Pouch Stack 1.066 Ah

Condition #	Condition	ppm	
		sample #1	sample #2
1	Ambient Air 2d	2673,60	2712,36
2	Vacuum O. 80°C 30m	254,11	236,78
3	Vacuum O. 80°C 60m	187,48	179,43



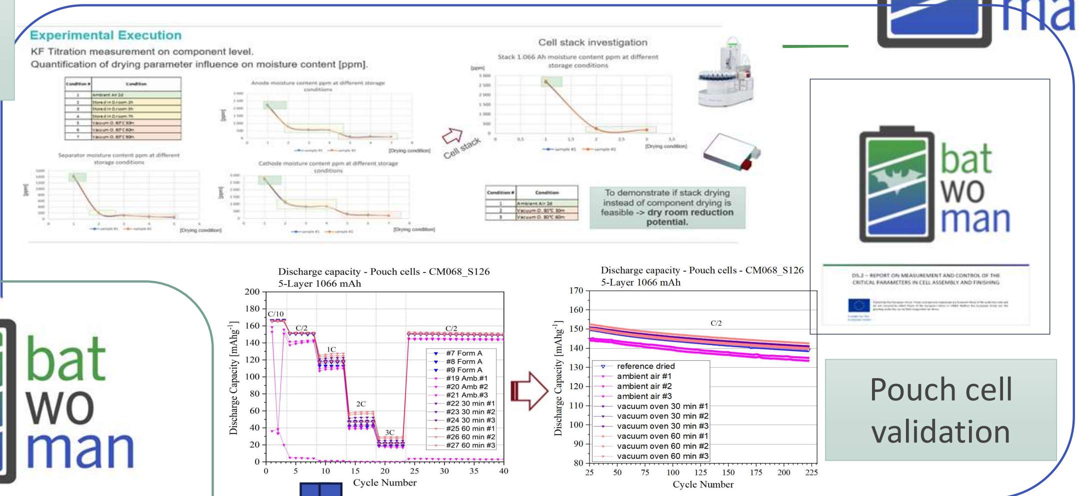
To demonstrate if stack drying instead of component drying is feasible -> **dry room reduction** concepts in WP6



WP5 - Drying Concepts

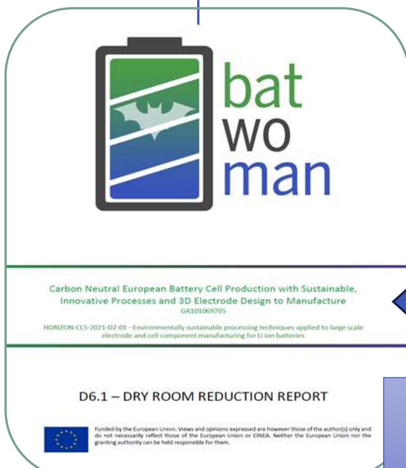
- Material investigation was conducted on **component** and cell **stack** level
- Holistic **validation** in full **pouch cell** configuration to investigate impact on **performance**
- Result transfer to **WP6** – **concept developed**
- Result transfer to **WP2** – Results served as base for **LCA**
- **Publication** submitted (under review)

Material Investigation



Pouch cell validation

Publication



Industry-Perspective

Draft Article for Submission to the Journal of Cleaner Production

Title:

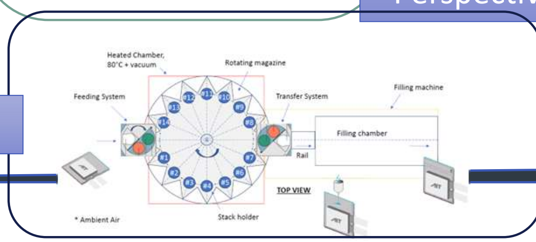
Life Cycle Assessment of a Low-Impact NMC622 Battery Cell: Innovations in Manufacturing and Material Efficiency from the BatWoMan Project

Authors:

Emanuel Bengtsson[1], Mats Zackrisson[1], Steffen Schellenberger[1], Lisa Skedung[1]

[1]RISE Research Institutes of Sweden

Concept



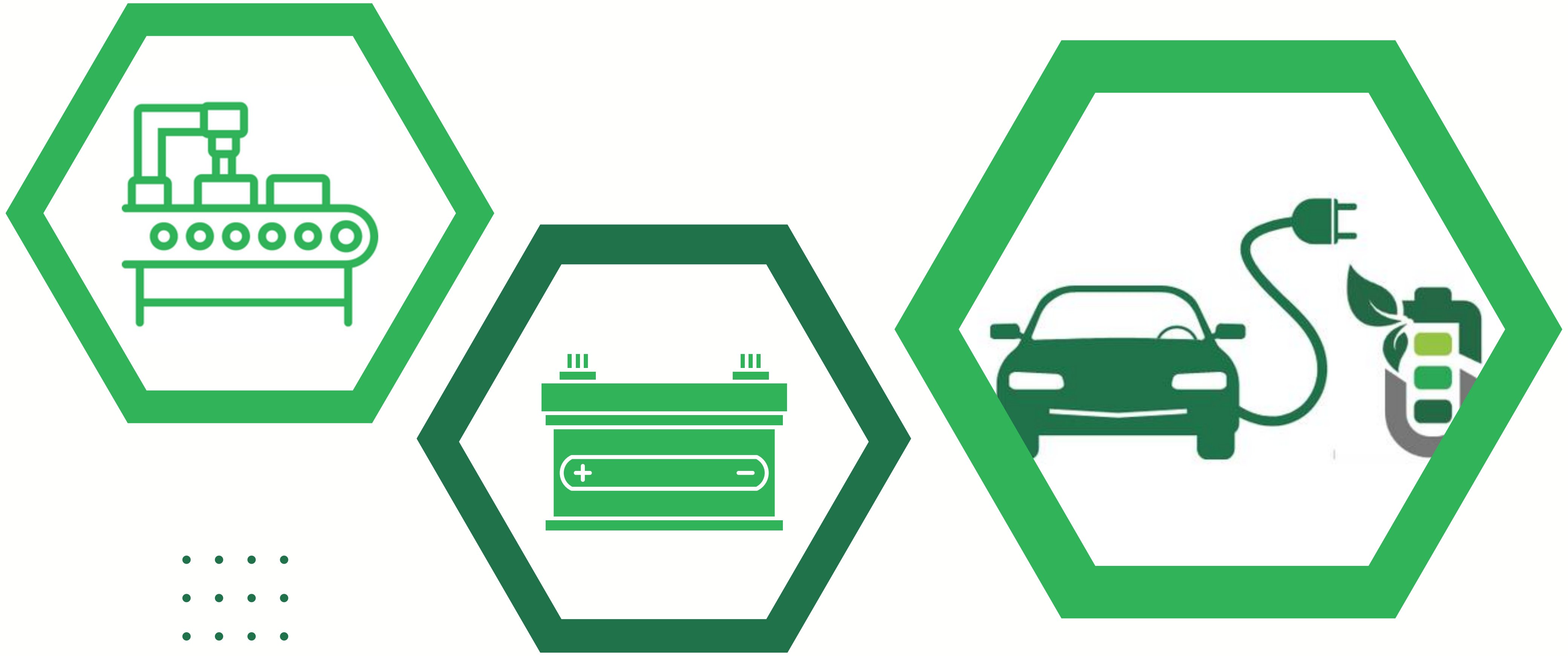
Thank you for your attention!

Marcus Jahn, Bernd Eschelmüller

This project has received funding from the European Union’s H2020 research and innovation programme under Grant Agreement no. 101069705.

ELIMINATING VOC* FROM BATTERY MANUFACTURING THROUGH DRY OR WET PROCESSING

* Volatile Organic Compounds



This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101069612.

OUR MAIN OBJECTIVE

Implementation of an environmentally friendly, non-toxic lithium-ion battery production

OUR AMBITION

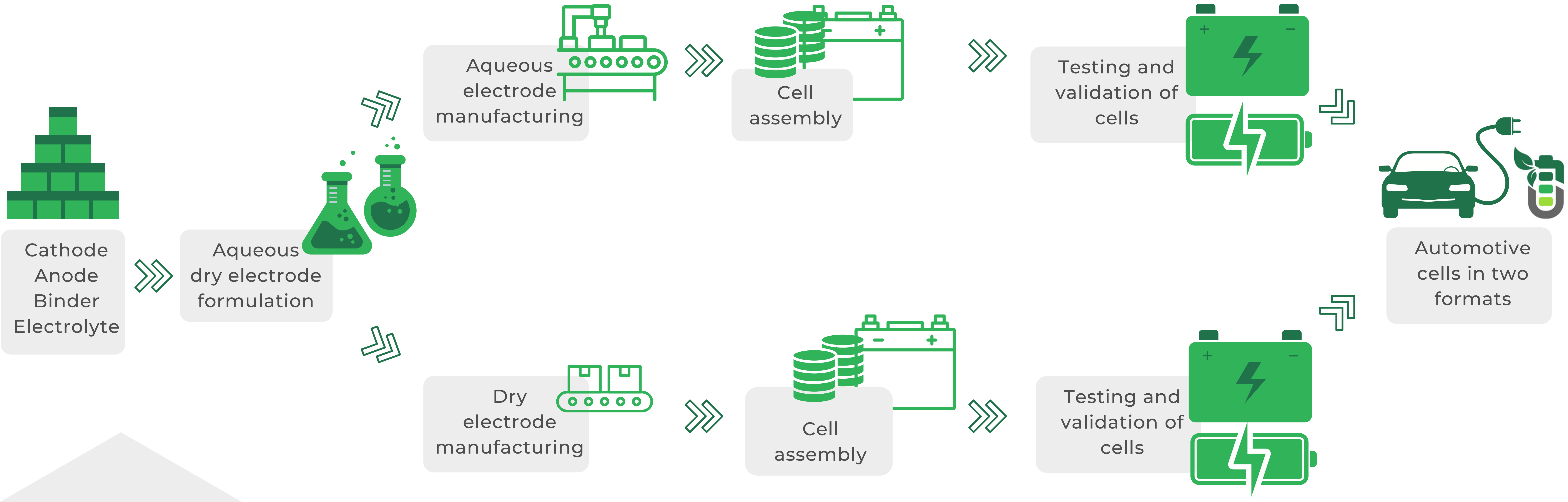
Brand new strategic technology

Competitive low cost and environmentally friendly lithium-ion batteries in both cylindrical and pouch format for the fast-growing electromobility landscape.

- Funded via Horizon Europe
- Duration: 48 months
- Start Date: 01 Sept 2022
- Project Budget: €5,415,728.25
- Coordinator: RISE Research Institutes of Sweden
- 15 partners from all over Europe

BACKGROUND INFO

THE NOVOC CONCEPT



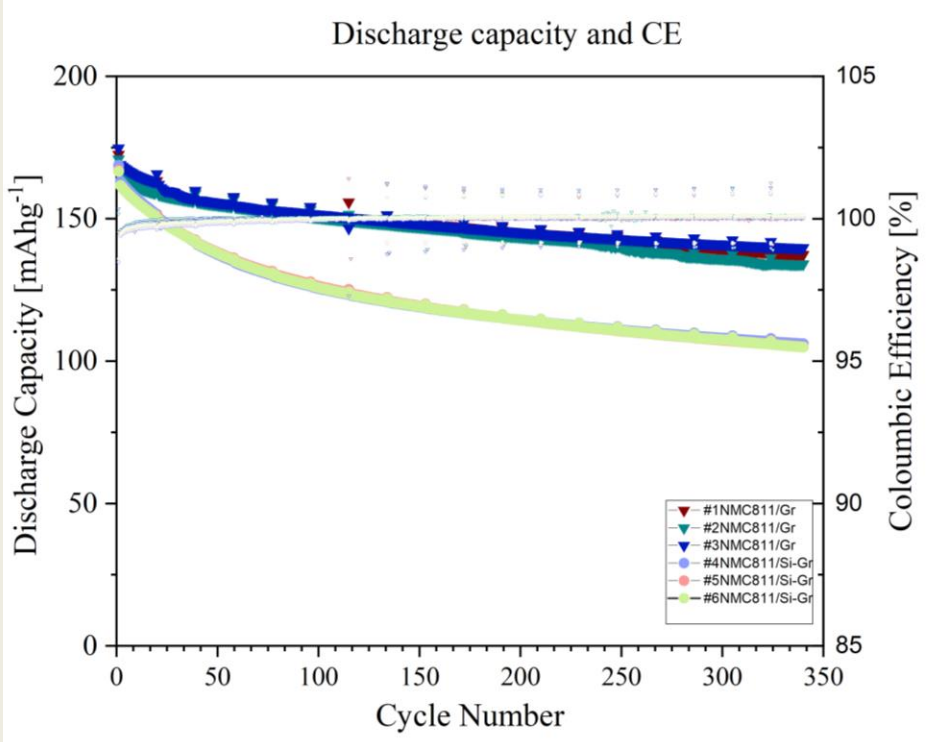
48 MONTHS OF NOVOC

	Stage 1	Stage2		Stage3	
Input	**Formulation**	**Electrode optimisation at lab scale**	**Electrode manufacturing at pilot scale**	**Cell assembly and validation**	**Output**
Cell Requirements 21700 10Ah pouch	Active materials Anode: Si/C Cathode: NMC811	Aqueous processing Anode Cathode	Aqueous processing Anode Cathode	18650 cell Performance Safety Post mortem	Data for cells in two formats 21700 10 Ah pouch
Specifications	Binders Aqueous binders Dry binders	Dry processing Anode Cathode	Dry processing Anode Cathode	2-10 Ah pouch cell Performance Safety Post mortem	Performance (Cell level) 235-400 Wh/kg (650-750 Wh/L)
Test procedures		Cell harmonisation Pouch cells Cylindrical	Cell harmonisation Pouch cells Cylindrical		Cost (Cell level) 75-85€/kWh
	TRL 3	TRL 3	TRL4-5	TRL6	

Modelling, Digitalisation, Recycling, LCA / LCC

Aqueous wet cathode manufacturing process

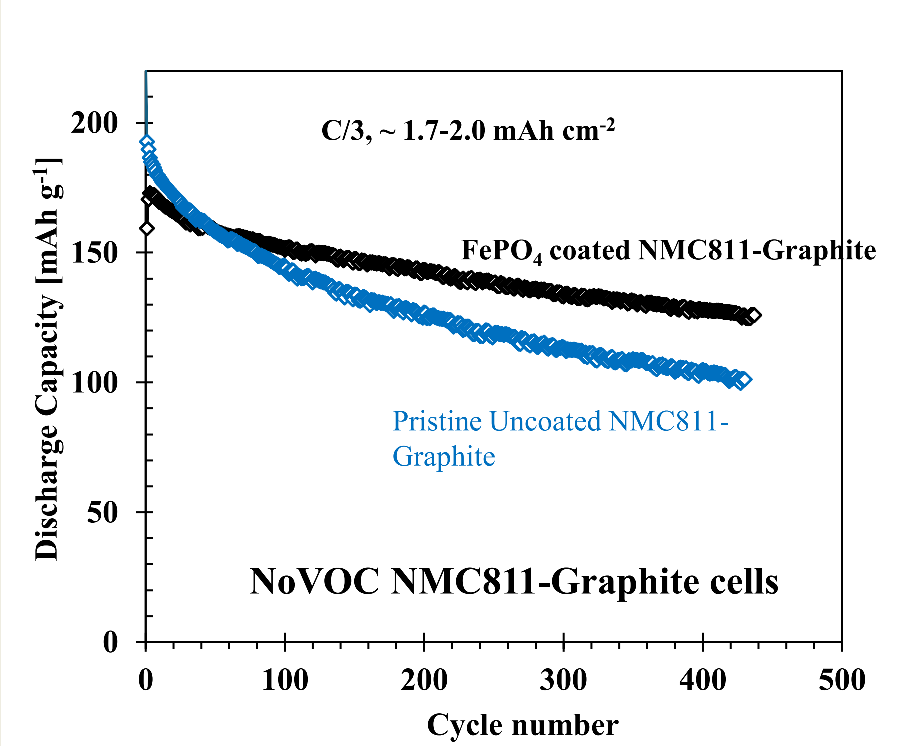
Cathode pre-development
Lead: Austrian Insitute of Technology (AIT)



*Electrochemical result of 5-layer pouch cell (≈ **1 Ah**)*

Composition: 95% NMC811, 3% C65, 2% binder

Surface coating of NMC811
Lead: RISE Research Institutes of Sweden AB



Scale up of $FePO_4$ coating NMC811

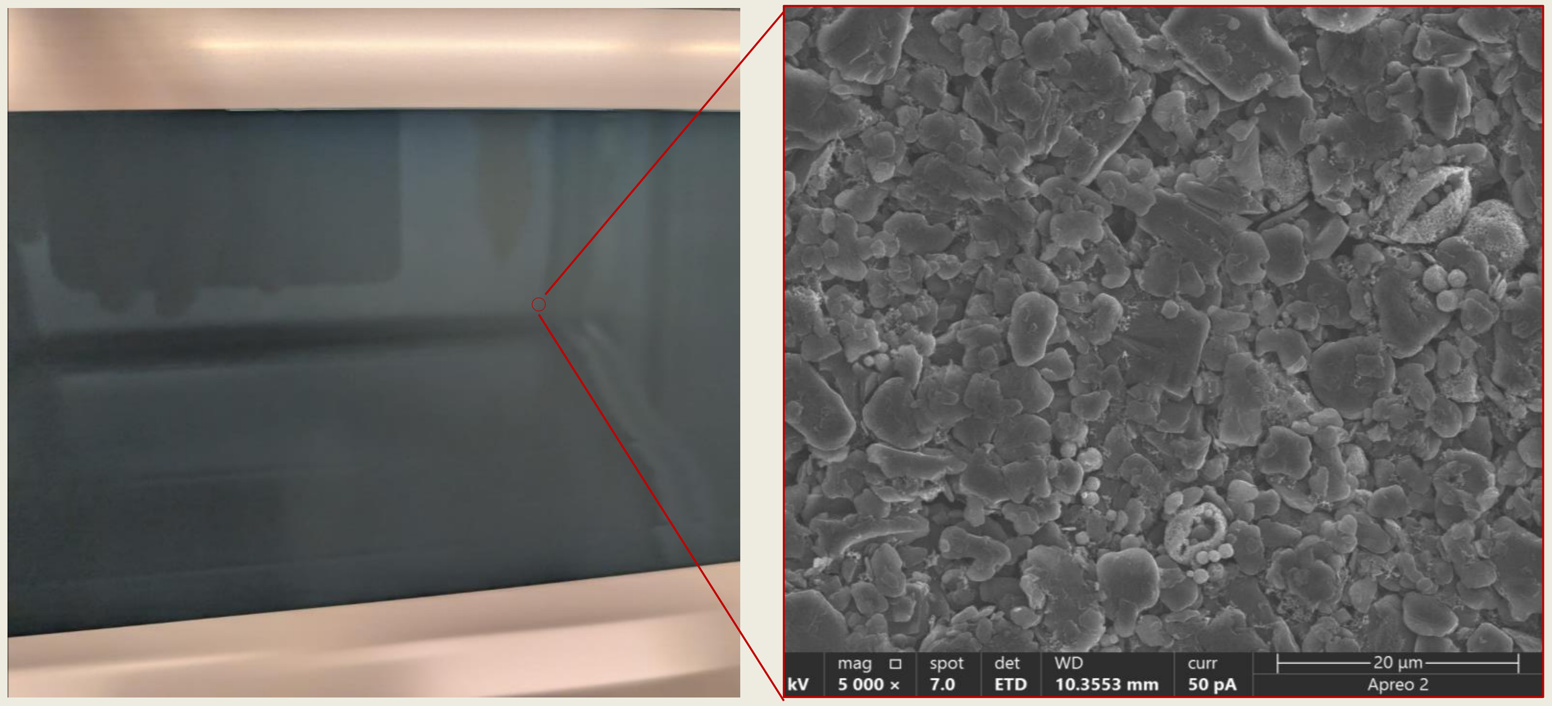
Upscaling
Lead: Avesta Battery and Energy Engineering (ABEE) and AIT

- Challenges with bubbles forming when using slot die coating. Investigation to find solutions to this issue in ongoing.
- Meanwhile pilot scale cathode manufacturing will be done by AIT using comma bar coating.

- Stable slurry pH over long time using >1.5 M phosphoric acid, comma bar coating.
- Comparable specific capacity with stable rate performance and cycle performance
- Recipes and methods transferred to **upscaling that is ongoing.**

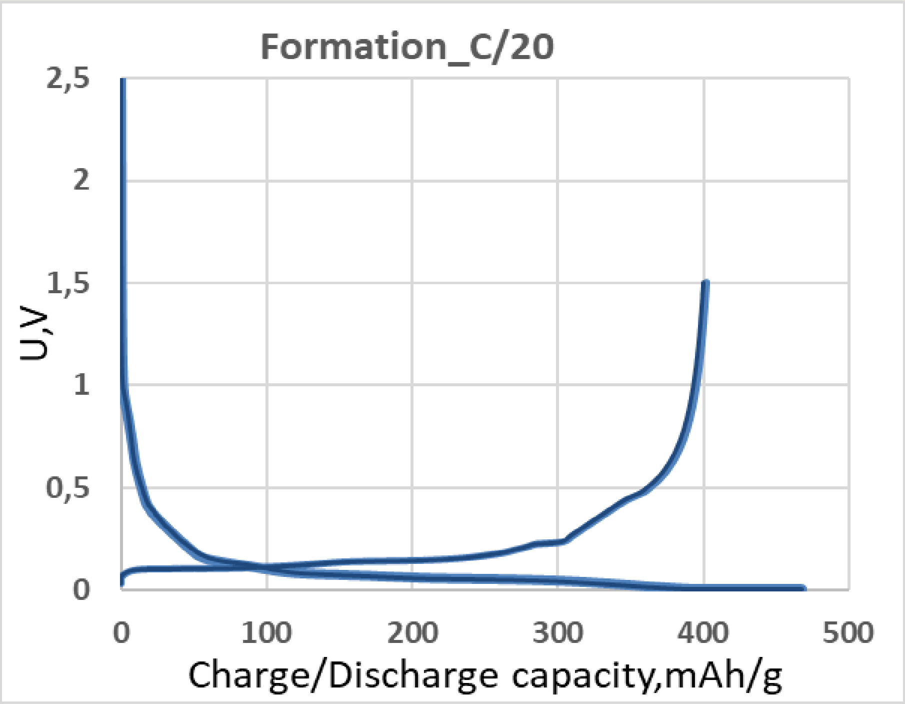
Aqueous wet anode manufacturing process

Anode Pre-development (Lead: CIDETEC) with anode material provided by Talga.



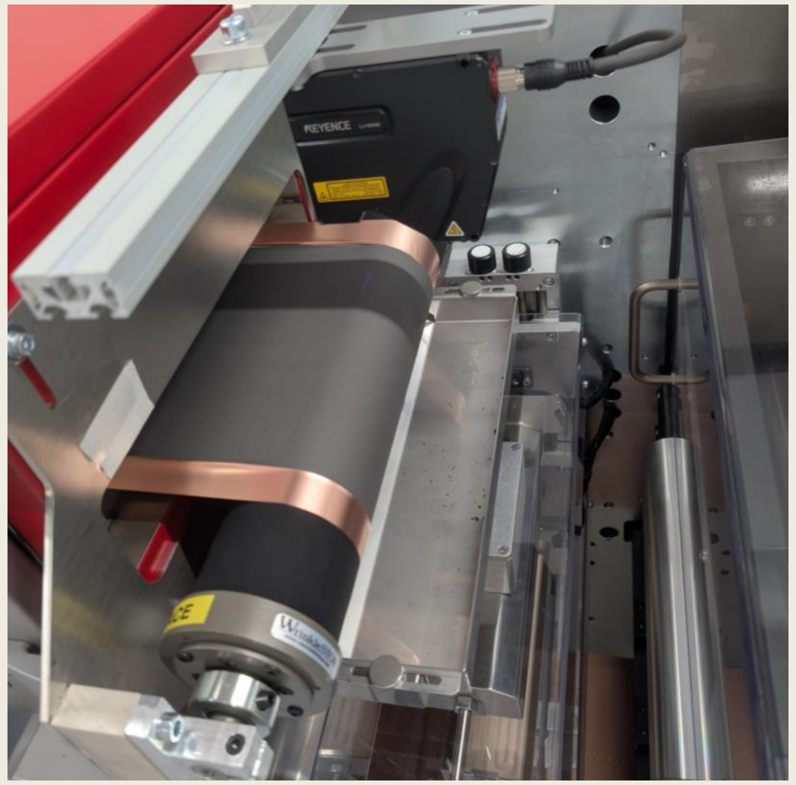
5% Si-graphite anode Electrodes with SEM morphology

Composition: 90% Gr, 5% Si, 1% C45, 2% CMC, 2% SBR



Electrochemical result in half cell (coin cell).

Upscaling (Lead: ABEE)

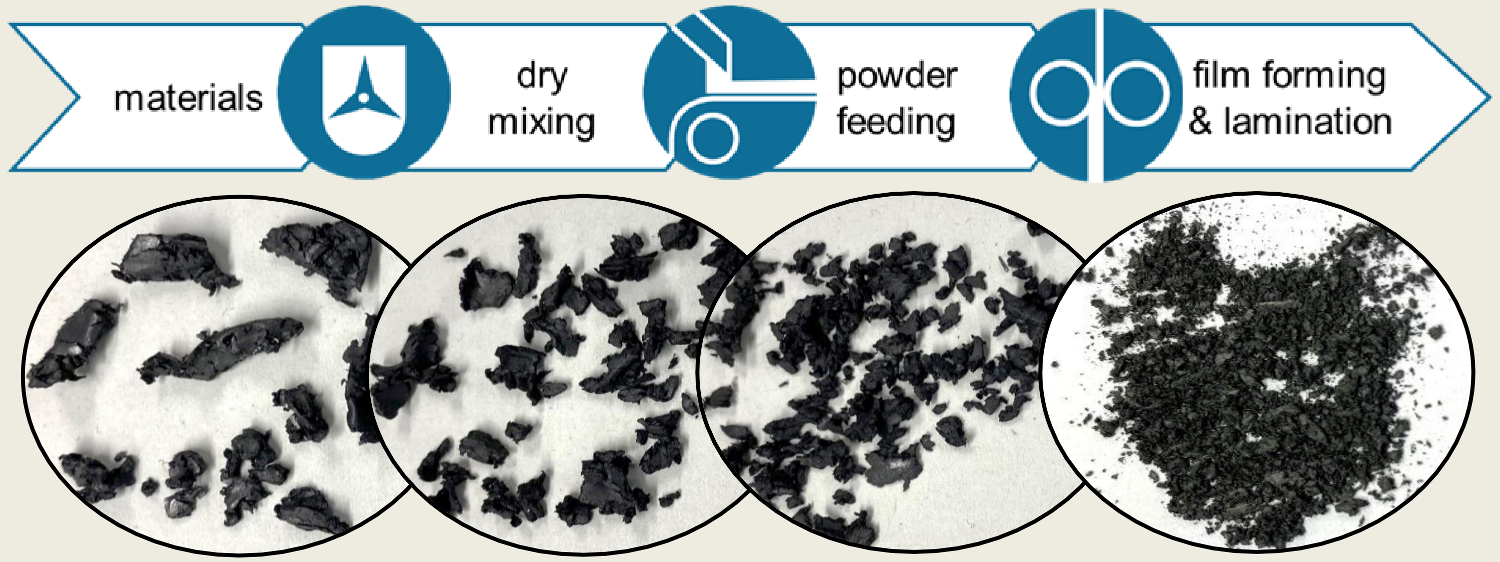


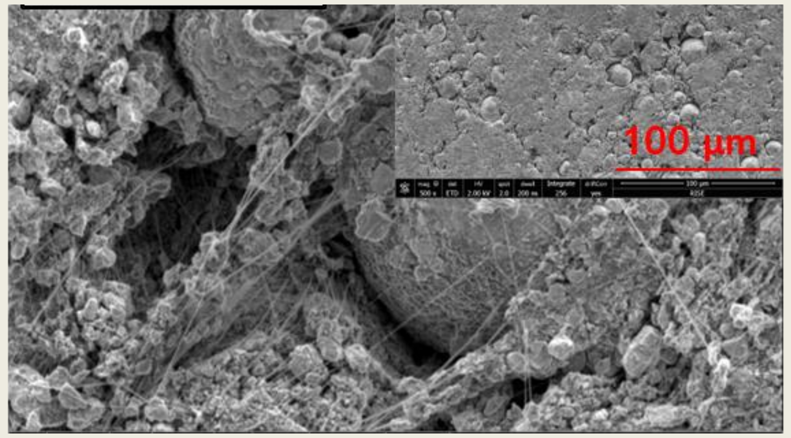
Upscaling at ABEE

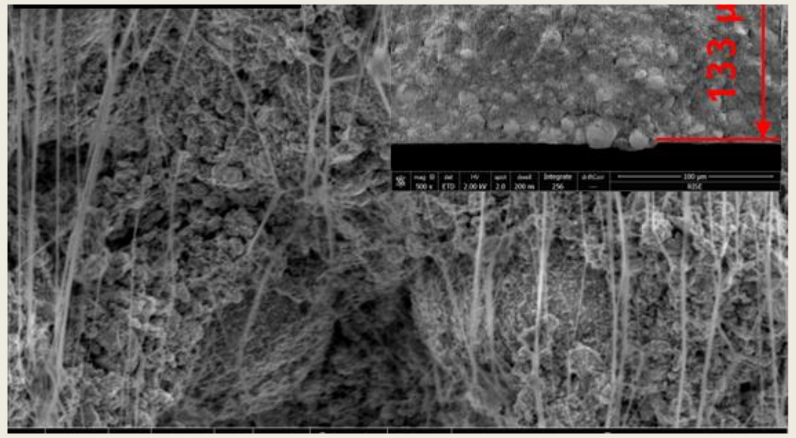
- New mixing protocol is adopted for 5% Si-graphite slurry which achieves stable rheology and uniform coating, comma bar coating.
- Half coin cell testing of the anode shows reversible specific capacity of 423 mAh/g with 99% CE
- Recipes and methods transferred to **upscaling that is ongoing.**

Dry Manufacturing process – Pre development

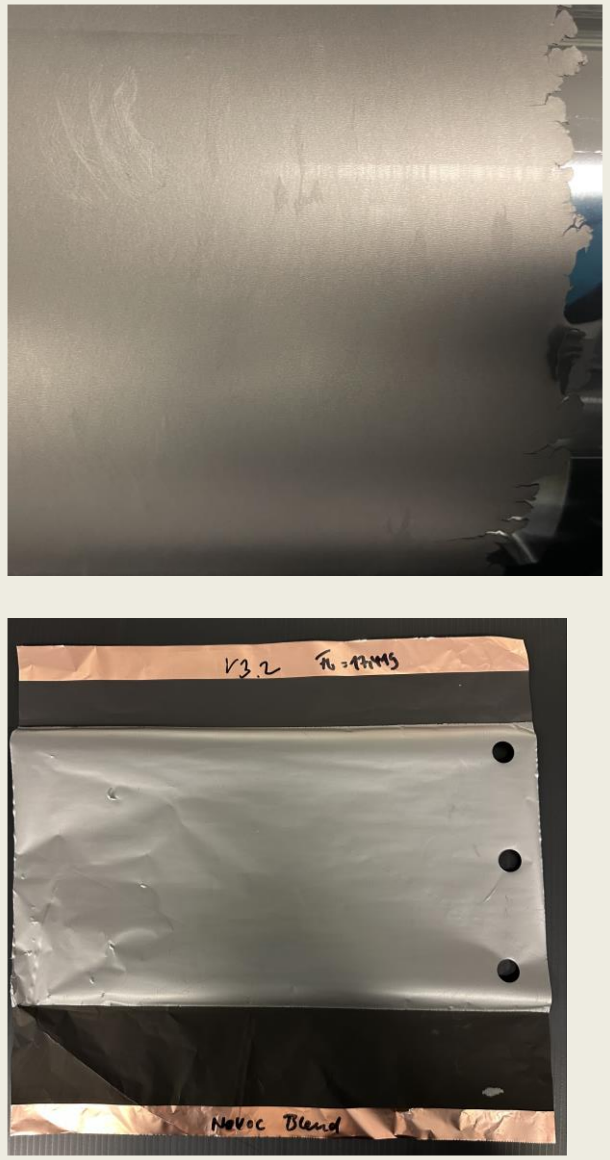
Anode and Cathode development
Lead: Technische Universität Braunschweig, TUBS







Cathode dry electrode fabrication



Anode dry electrode fabrication

Key findings:

Anode composition: 97.5 (graphite):1.5 (C65):1 (PTFE)

Cathode composition: 95 (NMC811): 2.5 (C65): 1.5 (PTFE)

Electrochemical evaluation in half cell is completed, and high initial capacities and stable cycling is achieved for cathode and anodes

Dry Manufacturing process – Upscaling (Ongoing)

Anode and Cathode development
Lead: Technische Universität Braunschweig, TUBS

Pilot scale cathode coating trials not successful without automatic powder dosing unit.

Cathode dry electrode fabrication

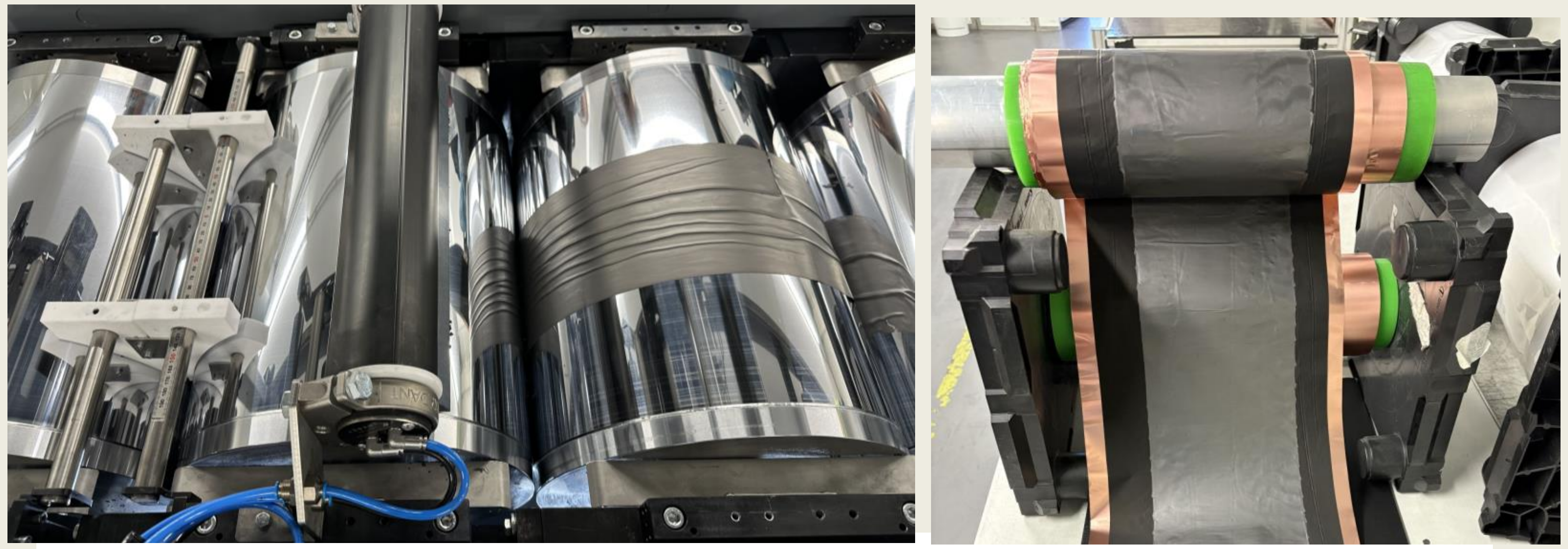


Illustration of non-homogenous granule size on calendaring for anode trials

Anode dry electrode fabrication

Challenges:

1) Inhomogeneous dosing causes “ribbing” of electrode in subsequent calender gap.
2) Inhomogeneous size of extruded granuless is causing curling effect.
3) Challenges in freestanding anode electrode adhesion.

48 MONTHS OF NOVOC

	Stage 1	Stage2		Stage3	
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Modelling, Digitalisation, Recycling, LCA / LCC

TRL 3 → TRL 3 → TRL4-5 → TRL6

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Project Manager: Sara Stibing
RISE Research Institutes of Sweden

WEBSITE

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DISCLAIMER

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This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101069612.