



## Deliverable 3.3

# 50 Gen1 CoinPower cells with 10 % improved capacity manufactured

**Project acronym:** ECO2LIB  
**Project title:** Ecologically and Economically viable Production and Recycling of Lithium-Ion Batteries  
**Grant Agreement number:** 875514  
**Coordinator:** Martin Krebs

*This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 875514.*

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**Funding Scheme:** H2020-LC-BAT-2019-2020 / LC-BAT-2-2019

<b>Delivery Date from Annex I:</b>	31 <sup>st</sup> July 2021
<b>Start date of the project:</b>	January 1 <sup>st</sup> 2020
<b>Project duration:</b>	54 months

<b>Work package:</b>	3
<b>Lead beneficiary for this deliverable:</b>	VMB
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Dissemination level		
PU	Public	x
CO	Confidential, only for members of the consortium (including the Commission Services)	
CI	Classified	

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### 1. Electrode preparation

In preparation of the cell manufacturing, the required electrodes were to coat on the laboratory coating line.

As cathode, a standard recipe consisting of NMC-622, conductive material and PVDF binder was used. As a collector foil, an aluminum foil of 15  $\mu\text{m}$  was chosen. The material loading of the cathode paste was increased compared to the reference to balance the cathode loading adequate to the higher specific anode capacity.

For the anode, a mixture of silicon material and graphite was used combined with a commercially available carbon black and Poly acrylic acid – co-polymer binder which was designed for silicon anodes. The electrode composition was in accordance with previous results from the project partner VARTA Innovation and is summarized in the subsequent table:

**Table 1: Compositions of the lab-scale electrodes**

Material	Amount dry
Silicon material	25 %
Graphite	65 %
LiPAA-Binder	7 %
Carbon black	3 %

For the calculation of the specific capacity of the anode, both capacities, silicon and graphite were used.

The mixing of the anode was performed with a double-planetary mixer, which is equipped with a disperser and two mixing blades.

The anode paste was coated on a copper foil of 10  $\mu\text{m}$  with the lab coater.

Both collector foils for anode and cathode as well were standard materials which are used in the reference cell, too.

The requested tolerance in coating was < 2%. This was finally reached well with a fine control of the viscosity of the slurry by a viscosimeter, check for agglomerations by a grindometer and sieving of the slurry directly during the coating. Despite of the increase of the cathode loading the anode loading was quite low and touched the technical limit of the lab coating line.

Calendering of the electrodes increased the electrode film densities to the requested values. In case of anode densification only a slight compression was applied to give the silicon particles voids inside the electrode to swell. The cathode was compressed to the same density like for the reference cells.

Compressed electrodes were slitted by roll knife and laser to the final electrode width.

## 2. Cell preparation

**As planned, 50 cells in a coin cell format were to build up.** Based on previous experiences, 75 cells were planned to assemble.

In contrast to the reference cells, electrodes from the lab coating line have no intermittence in the coating layer. Therefore, it was necessary to remove the coated material from the final electrode.

Cells were assembled in the sample shop by winding the electrodes and the separator to the given diameter and placing the jelly rolls into the cups.

After contacting the electrodes to the housing and drying of the assemblies, the cells were filled with electrolyte.

**2 different electrolytes were used.** The 1<sup>st</sup> electrolyte was a specialized mixture for silicon developed at VARTA in a regular development process. The 2<sup>nd</sup> material was the mixture delivered by the project partner University of Uppsala.

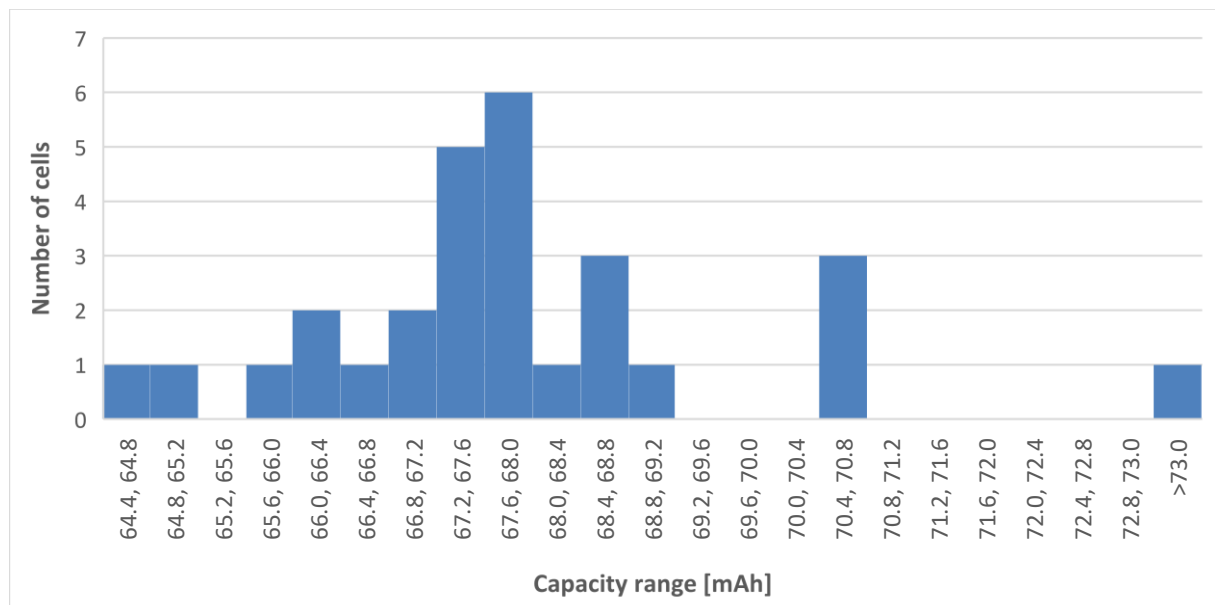
The cells were finally sealed, and the formation process was started.

## 3. Results after formation

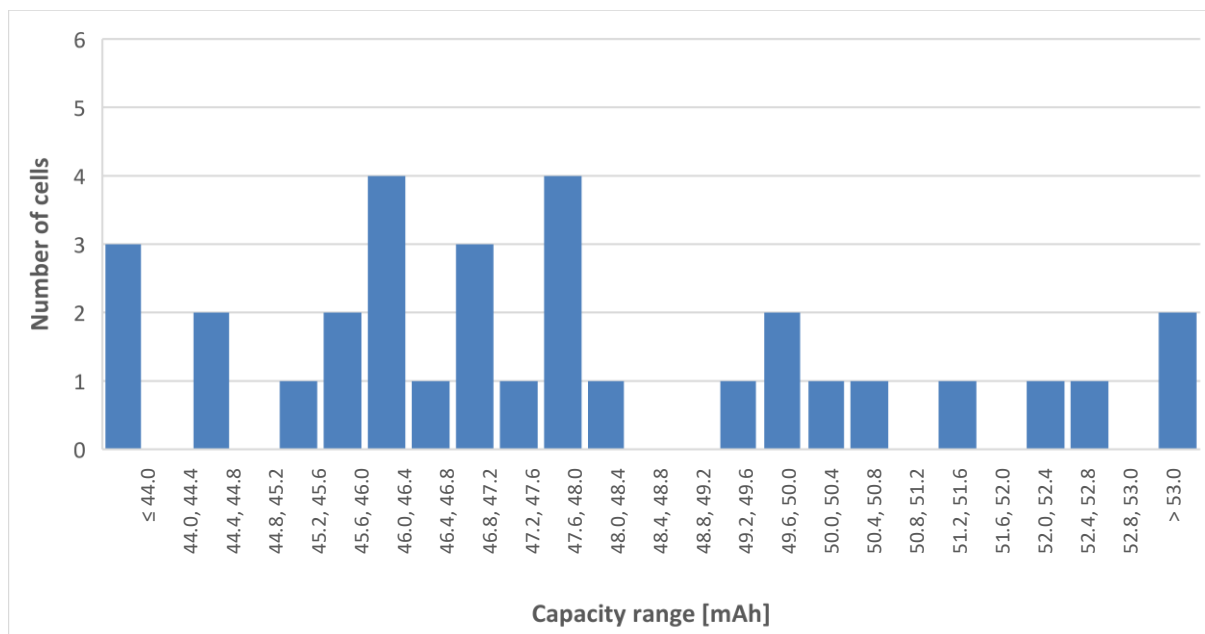
**As a result, 60 cells were received from the cell building run.** Cells with the electrolyte from VARTA showed a significant lower yield due to strong gas formation. An appreciable number of cells exceeded the maximum height and opened the vent holes.

In the following graphs the capacities of the formation are shown.

**Figure 1: Distribution of capacities of cells with VARTA electrolyte**



**Figure 2: Distribution of capacities of cells with University of Uppsala electrolyte**



The capacity check during the formation process was done with a discharge rate of 1.5 C. Clearly visible is a strong deviation in the reached capacity between both electrolytes. Cells with electrolyte from University of Uppsala show a significant lower capacity and a wider capacity distribution as well.

#### 4. First test results

For performance tests cells with both electrolytes were send either to the project partner VARTA Innovation and were tested at our side as well.

One of the tests examines the cycling stability at 0.5 C and 1 C cycling rate. For both tests each 5 cells were started with the following cycling protocol.

**Table 2: Protocol for cycling tests**

Step	Action 1	Action 2
1	Start Cycle 1	
	Start cycle 2	
2		Charge cc-cv to 4.3 V / 0.2 C
3		Discharge cc to 2.75 V / 0.2 C
4	Repeat Cycle 2	Repeat for 2 times
6	Start cycle 2	
7		Charge cc-cv to 4.3 V / 0.5 C or 1C
8		Discharge cc to 2.75 V / 0.5 C or 1C
9	Repeat cycle 2	Repeat for 48 times
10	Repeat Cycle 1	Repeat for 10 times

The next table demonstrates the discharge capacities at the 2<sup>nd</sup> discharge cycle at 0.2 C.

**Table 3: Discharge capacities at 2<sup>nd</sup> 0.2C cycle step**

Cell	VARTA 0.5 C	VARTA 1.0C	Uppsala 0.5C	Uppsala 1.0C
1	87.99 mAh	88.07 mAh	87.33 mAh	87.65 mAh
2	88.44 mAh	88.24 mAh	87.96 mAh	87.59 mAh
3	88.44 mAh	87.95 mAh	87.89 mAh	87.40 mAh
4	88.64 mAh	87.55 mAh	88.43 mAh	87.83 mAh
5	88.45 mAh	87.84 mAh	87.86 mAh	87.72 mAh

In the Table 3, we can see that **capacity check-up cycles with 0.2 C** show for both electrolytes quite similar **discharge capacities of 87.4 – 88.6 mAh**. In comparison, a discharge capacity of a graphite-based reference cell shows about 63.5 mAh in average. **This clearly demonstrates a capacity increase of about 24.5 mAh or 38.5 %.**

The next cycle increases the rate to 0.5 C or 1 C symmetric in charging and discharging. With these both rates a good comparison for rate capabilities and dependencies of the electrolyte compositions is possible.

The following table show the results for the next step.

**Table 4: Discharge capacities for the next cycle at higher rates**

Cell	VARTA 0.5 C	VARTA 1.0C	Uppsala 0.5C	Uppsala 1.0C
1	84.11 mAh	80.73 mAh	77.43 mAh	59.65 mAh
2	84.43 mAh	80.06 mAh	77.40 mAh	57.09 mAh
3	84.55 mAh	80.11 mAh	78.23 mAh	66.32 mAh
4	84.89 mAh	80.66 mAh	78.39 mAh	61.99 mAh
5	84.55 mAh	80.30 mAh	77.99 mAh	66.65 mAh

The increase in cycling rate shows a clear dependency on the electrolyte compositions. In Table 4 the different discharge capacities show **a capacity deviation of about 4 mAh for a rate of 0.5C** and **about 8 mAh for a cycling rate of 1.0C** for the **mixture from VARTA**. In contrast to these results, the **electrolyte from the project partner Uppsala lost about 10 mAh when the rate was increased from 0.2 C to 0.5 C** and **between 22 and 29 mAh** when the rate was increased to 1.0C. The formulation of Uppsala appears to increase the SEI more than the VARTA mixture. It is reasonable that the SEI formation affects the inner resistance, and it is clearly visible that this effect leads to lower discharge capacities at higher charge and discharge rates.

## 5. Summary

Electrodes with the given anode recipe were built successfully on the lab coater. The anode and cathode loading were adjusted to the higher anode capacity.

**The cell manufacturing of 75 cells in the coin cell format yields in 60 cells with 2 different electrolytes.**

**The capacity check at 0.2C showed a value of about 88 mAh which is 38 % higher than the capacity of the reference cell.**

The discharge capacities at higher rate show a larger deviation for the different electrolytes. The mixture of University of Uppsala appears to generate a thicker SEI layer which results in a lower capacity at higher rates.