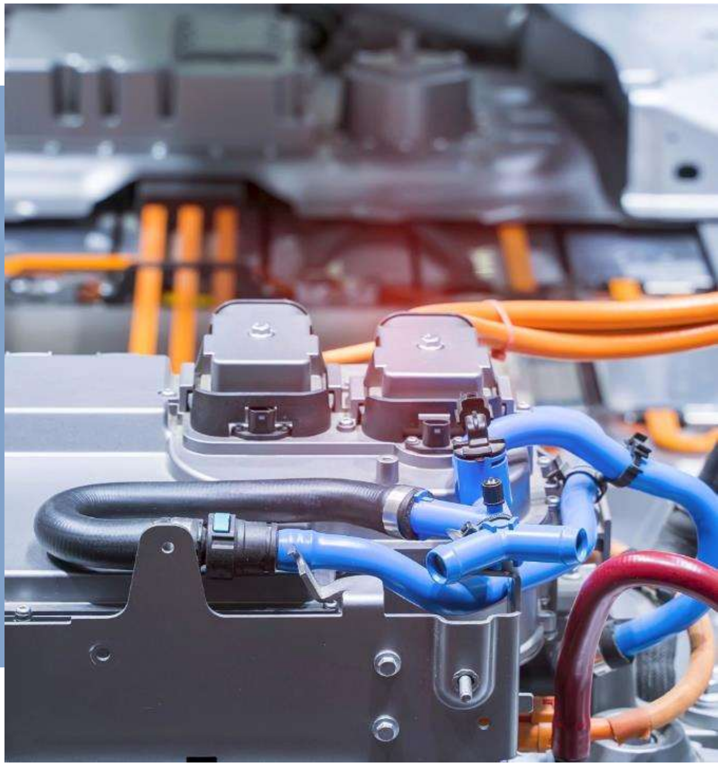
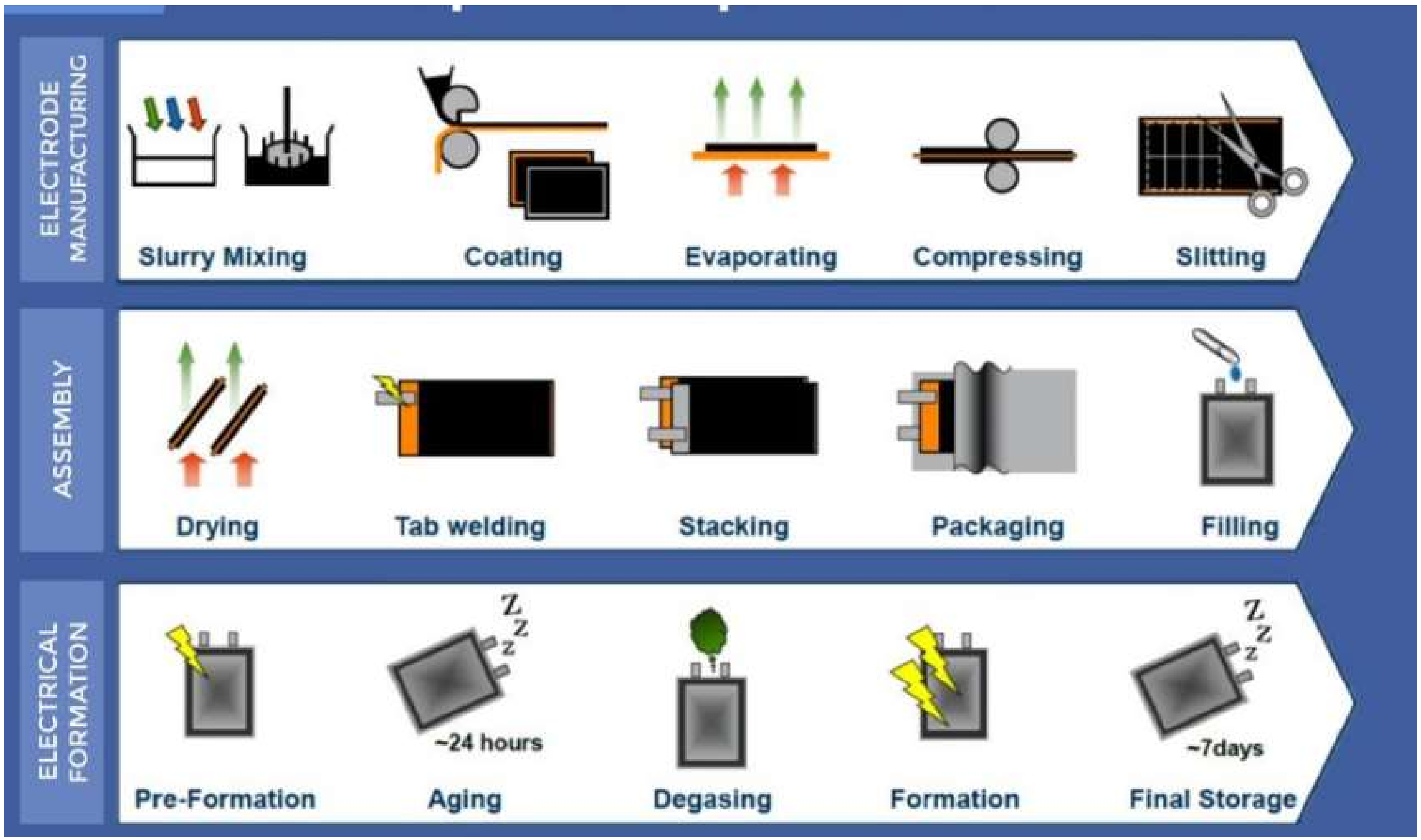
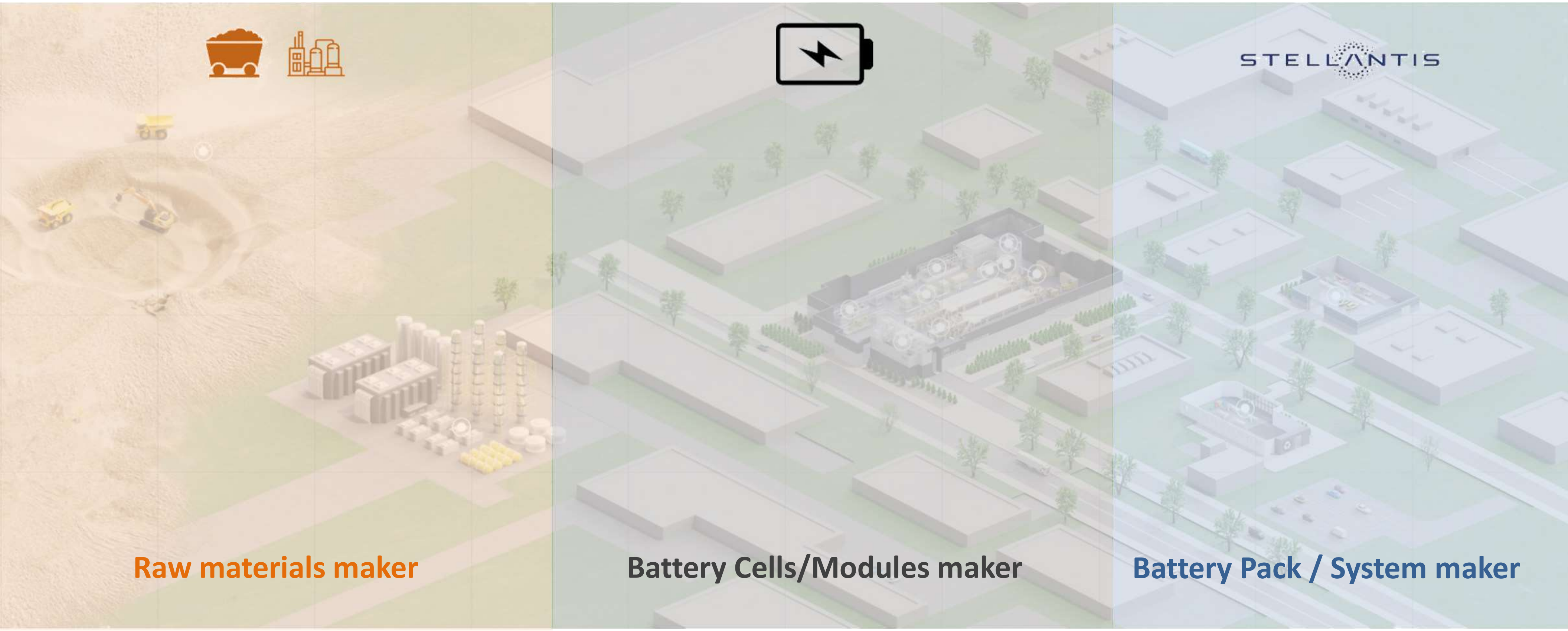
Cells, Modules and Battery Pack Process



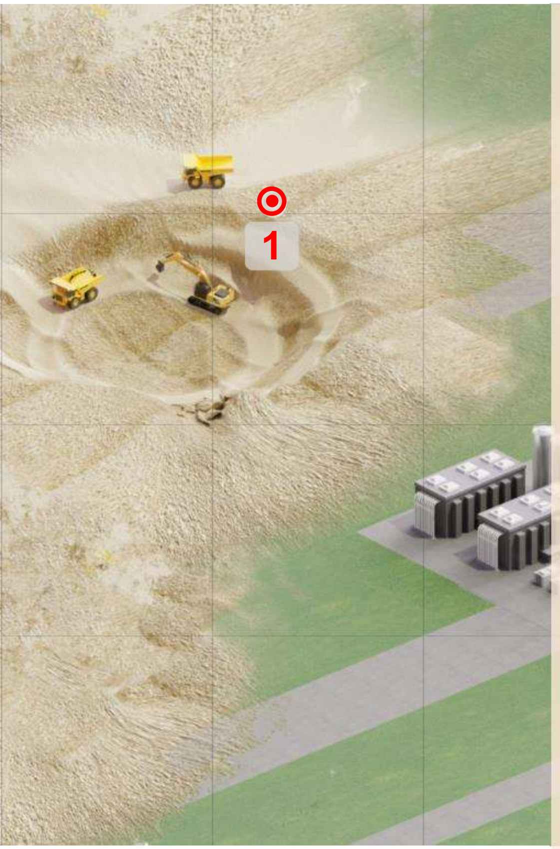
Cell assembly process



The complete supply chain



The complete supply chain: 1 of 13



STEP 1

RAW MATERIAL MINING

The raw materials used to form the anode and cathode of the battery (lithium, nickel, cobalt, aluminum or manganese) are extracted.

The metals used in the manufacture of the cells via suppliers are chosen in accordance with strict criteria, particularly on environmental, social and societal aspects such as:

- non-use of cobalt from artisanal mines in the Democratic Republic of Congo;
- non-use of nickel from mines that dump their tailings at sea;
- no lithium from mines creating residual stress on water supplies or ores from conflict zones

The complete supply chain: 2 of 13

STEP 2

REFINING

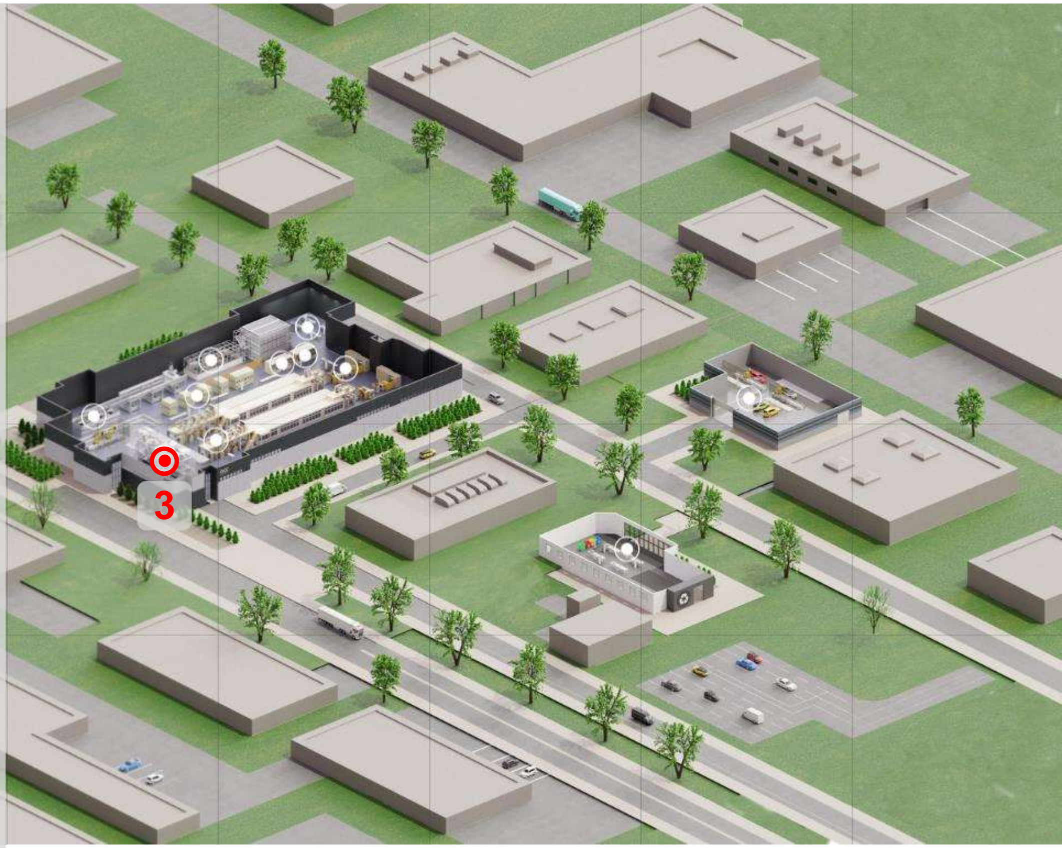
The metals used to form the anode and cathode of the battery are refined (purified and cleaned of all impurities) and ground into powder before being transformed into value-added products (lithium hydroxide, lithium carbonate, cobalt sulfate, etc.)

The complete supply chain: 3 of 13

STEP 3

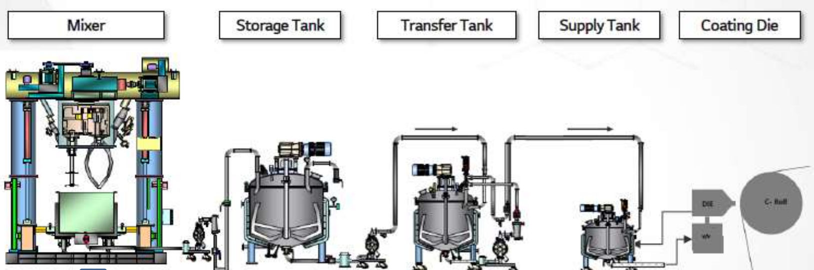
SLURRY MIXING

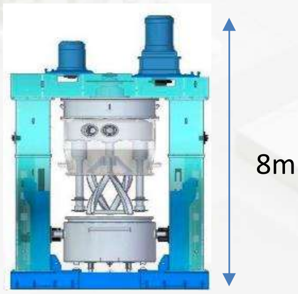
The products necessary for the preparation of the slurries (active material powders, additives and solvents) are introduced into the dedicated mixers, either for the manufacture of ink for the positive electrodes (cathodes) or for the manufacture of ink for the negative electrodes (anodes)



Step 3: Slurry Mixing

- **2 to 3 floors: more than 30 m heigh**
- **Dry Room < 20%**
- **VOCs (Volatile Organic Compounds)**
- **Cleanliness ISO 6 or 7: max part (0.5 microns per cubic meter)**
- **Temperature: 22 to 23°C (+/-2 to 3°C)**





- The CAM and AAM powders are dropped inside the mixers from the upper floors. The powders are mixed (1 to 6 hours) with solvents and binders to get a slurry with the desired viscosity, under vacuum to avoid gas inclusions.
- The slurry is then filtered (magnetic and mesh filters) to remove any undesired particles. All tanks provide continuous mix to preserve the desired viscosity.
- The process is fully automatized, from recipe choice to supply tanks. All equipment are in stainless steel (even floor) to avoid pollution (esp. zinc).
- Anode and cathode mixing are separated in different mixing rooms :
- Anode : planetary dispenser for graphite base + Deionized water + binders (2% SBR - Styrene-Butadiene Rubber + 3% NA CNC - Sodium carboxymethyl cellulose)
- Cathode : Twin blade dispenser for metal oxide + conductive material (graphite 2%) + solvent (NMP - N-Methyl-2-Pyrrolidone) + binder (5% PVDF - polyvinylidene fluoride)

The complete supply chain: 4 of 13

STEP 4

COATING

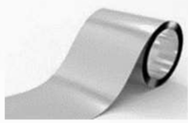
The ink is applied to an aluminum foil for the cathode, and a copper foil for the anode.

The coated foil is continuously transferred to a dryer to evaporate the solvents and/or water, before being wound onto a substrate.

Step 4: Coating

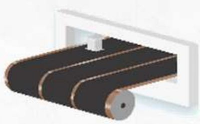
Copper foil

(ANODE)



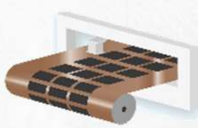
Aluminum foil

(CATHODE)



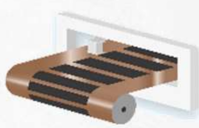
Stripe

Coating



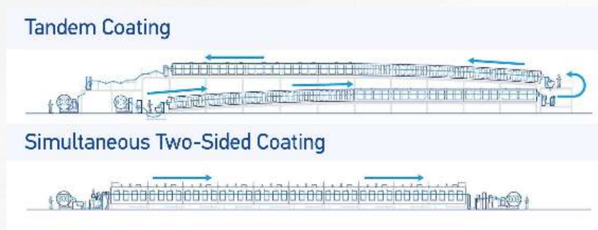
Pattern

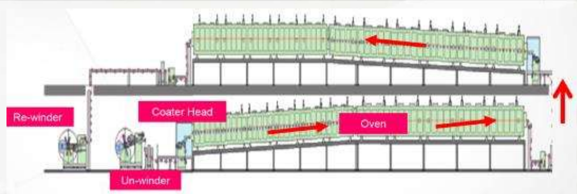
Coating



Patch

Coating





- **More than 10 m heigh**
- **Dry Room < 20%**
- **VOCs (Volatile Organic Compounds)**
- **Cleanliness ISO 6 or 7: max part (0.5 microns per cubic meter)**
- **Temperature: 22 to 23°C (+/-2 to 3°C)**

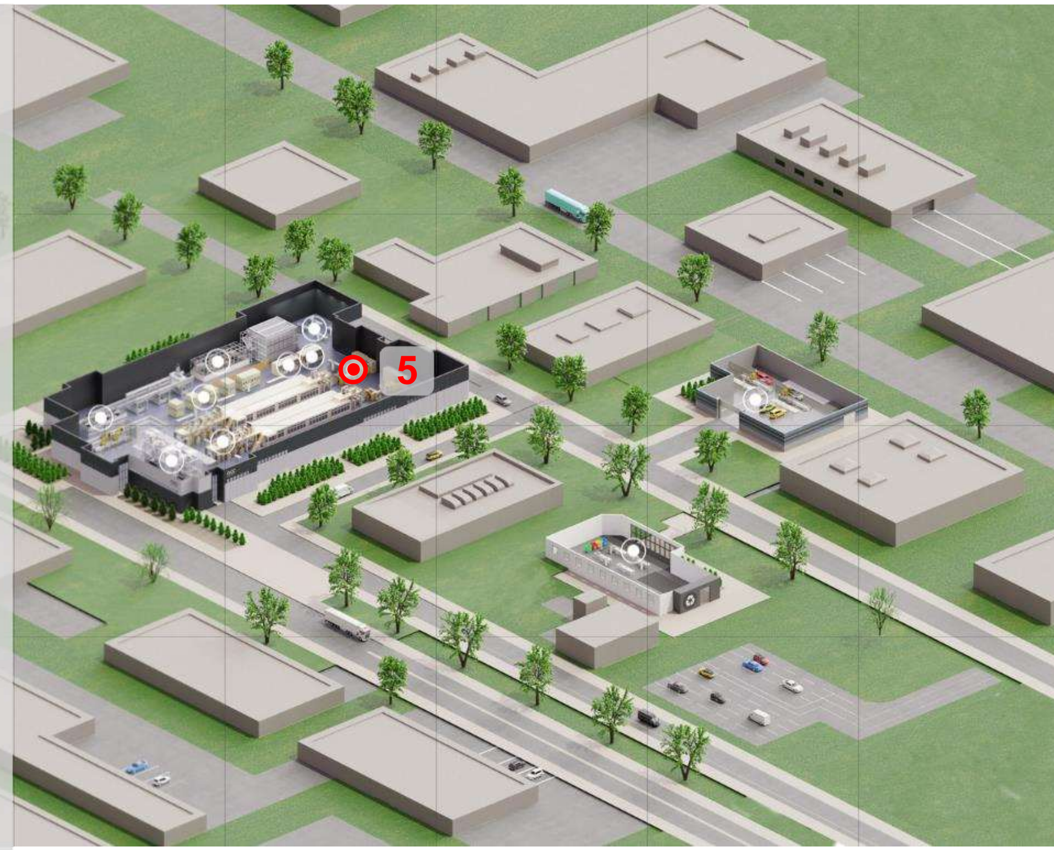
- The aluminum (cathode) and copper (anode) foils are coated with the slurry using an application tool (slot die, doctor blade, anilox roller). The foil is coated either continuously or intermittently.
- Generally, the top and bottom sides of the foil are coated sequentially in a tandem coater. An alternative can be a simultaneous double-sided coating (ex : Durr).
- The transport of the foil is realized either by roller systems or by floatation air streams. The coated foil is continuously transferred to the drying oven (several chambers of 80 to 150 °C, 100m long, air heated by steam or oil). Oven can be equipped with air exchangers to recover hot air for process or buildings.
- Solvent vapors are recovered through condensers cooled with chilled water.
- Foils of 5 to 25 µm thickness and 1 to 2m wide, up to 2 km long. Coating speed of 50 to 80 m/min.
- Quality constantly monitored (surface quality, layer thickness).
- Some suppliers use of DLE - Dual layered Electrode on anode to get a dense layer (autonomy) and a porous one on top (fast charge).

The complete supply chain: 5 of 13

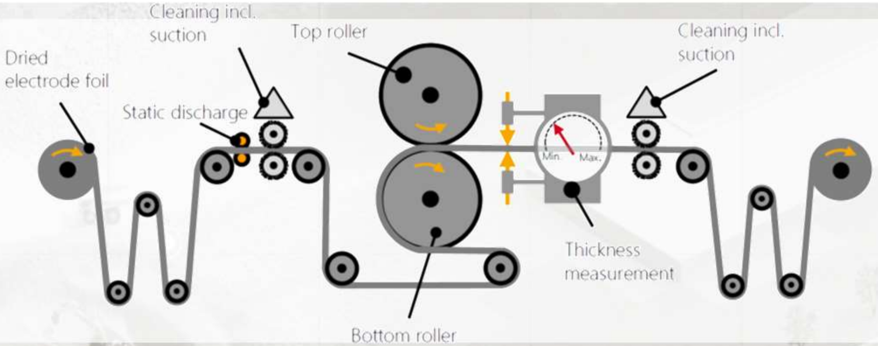
STEP 5

CALENDERING

During calendering, the copper or aluminum foil coated on both sides is compressed by rotating rollers. The rollers generate a precisely defined line pressure, which ensures a precise thickness and porosity of the strips.



Step 5: Calendering (Roll Pressing)



- **Dry Room < 20%**
- **VOCs (Volatile Organic Compounds)**
- **Cleanliness ISO 6 or 7: max part (0.5 microns per cubic meter)**
- **Temperature: 22 to 23°C (+/-2 to 3°C)**

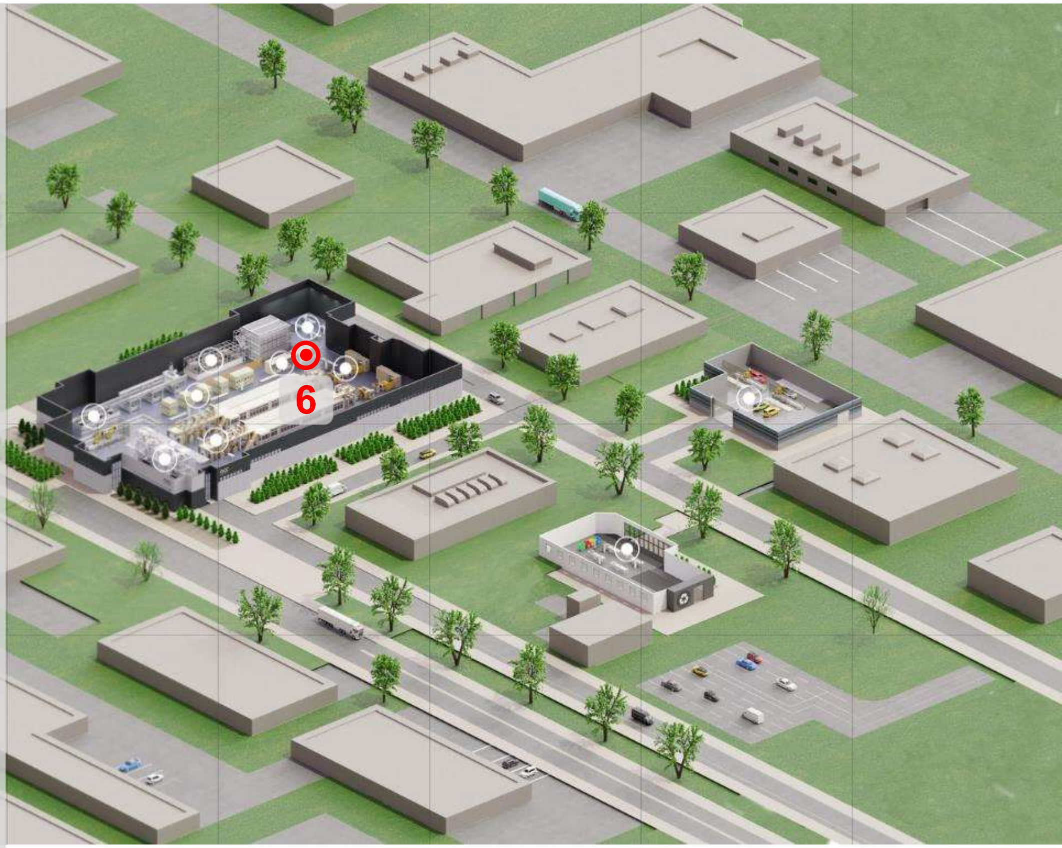
- During calendering, the copper or aluminum foil coated on both sides is compressed by a rotating pair of rollers (2500 N/mm).
- The electrode foil is first statically discharged and cleaned by brushes or air flow.
- The material is compacted by the rollers to achieve **the desired thickness, density and porosity**. Usually, the top roller is fixed and the bottom one adjustable in height.
- **Roll can be heated** (50 to 250°C) to lower the pressure applied and reduce the risks of stress cracks or even foil break off. A double calendaring can be also be realized. On cathode, it might be associated with induction heating before first roll press and a tab press after second press to prevent the curl of the aluminum foil.
- After calendering, the electrode foil is cleaned and rolled up again (roll-to-roll process). Calendering speed ranges from 60 to 120 m/min.
- Rolls are resurfaced (every 3 month for cathode, 1 year for anode). This maintenance operation last 1 shift.
- The OEE is affected by the length of foil removed manually for non good coated areas. Splicing of the roll can be automatized.

The complete supply chain: 6 of 13

STEP 6

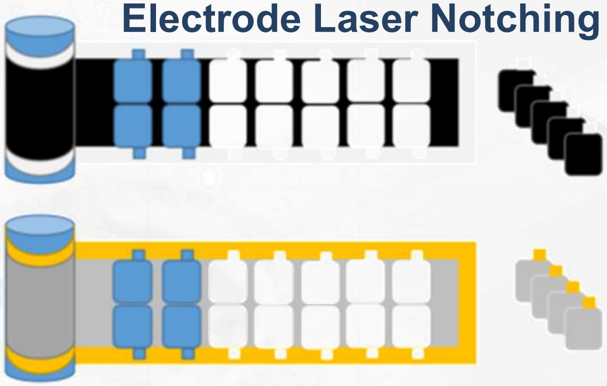
LASER NOTCHING & SLITTING

The strip coils are notched on their edge in order to cut out the ears of each electrode. The strip is slit on its axis to obtain the desired width.



Step 6: Laser Notching / Slitting

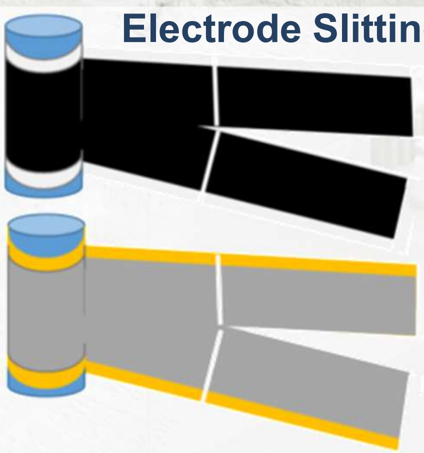
Electrode Laser Notching (Punching)

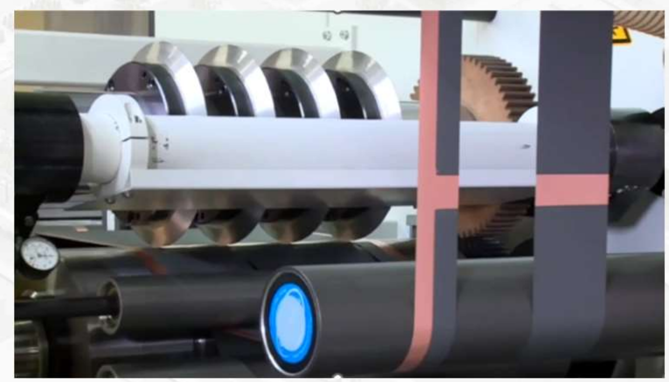


- **Punching or slitting should be burr and debris free**

- **Dry Room < 20%**
- **VOCs (Volatile Organic Compounds)**
- **Cleanliness ISO 6 or 7: max part (0.5 microns per cubic meter)**
- **Temperature: 22 to 23°C (+/-2 to 3°C)**

Electrode Slitting type



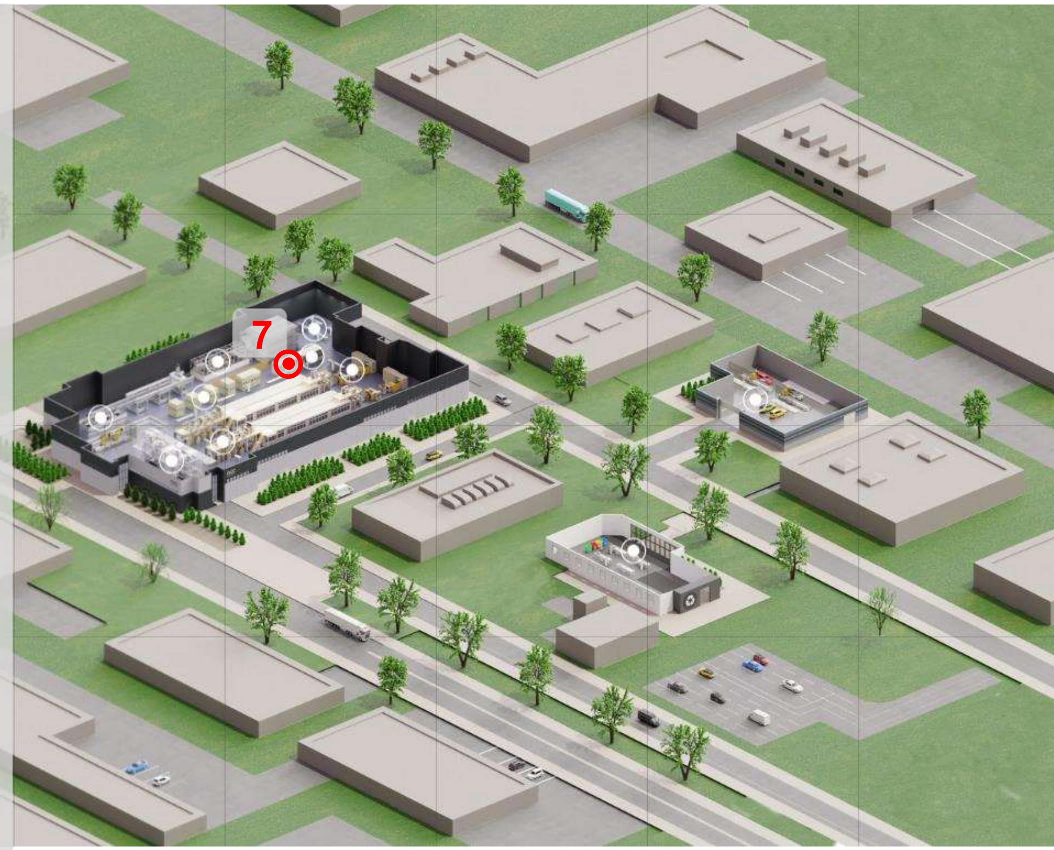


The complete supply chain: 7 of 13

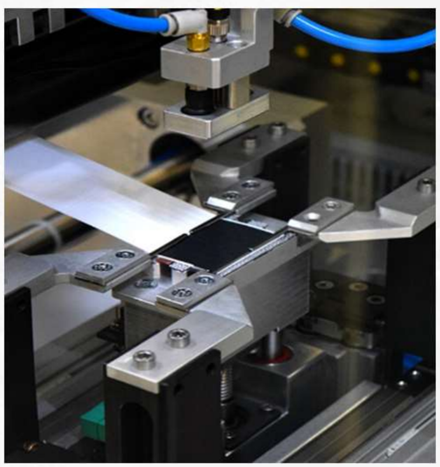
STEP 7

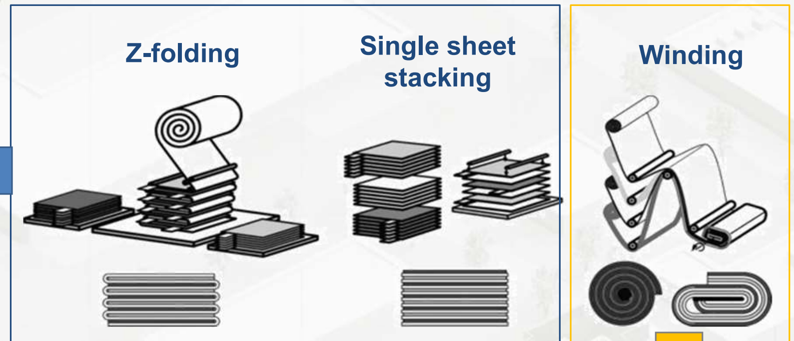
STACKING

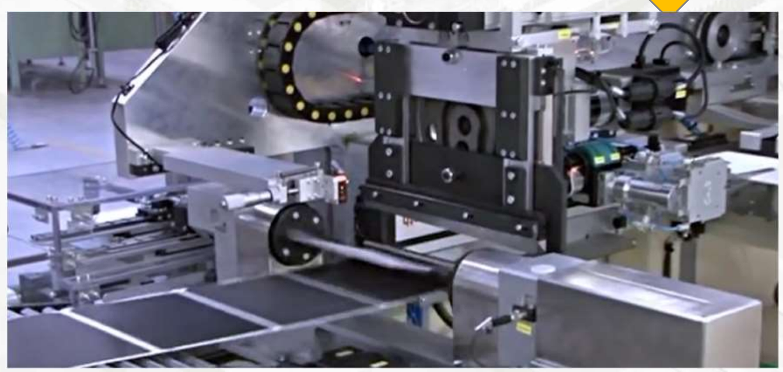
During the stacking process, the separated electrode sheets are stacked in a repeating cycle of anode, separator, cathode, separator, etc.
One of the most used technology is the so-called Z-folding. The anode and cathode sheets are inserted alternately from the left and right into the Z-shaped folded separator. The separator is used in the form of an endless tape and is cut off after the stacking process. The cell stack is then fixed with adhesive tape.



Step 7: Stacking / Winding







- Cathode and Anode edges must have sufficient separator overhang so that they do not touch each other.

- Design must cover all the bare surface to prevent the exposure of cell voltage to outside can

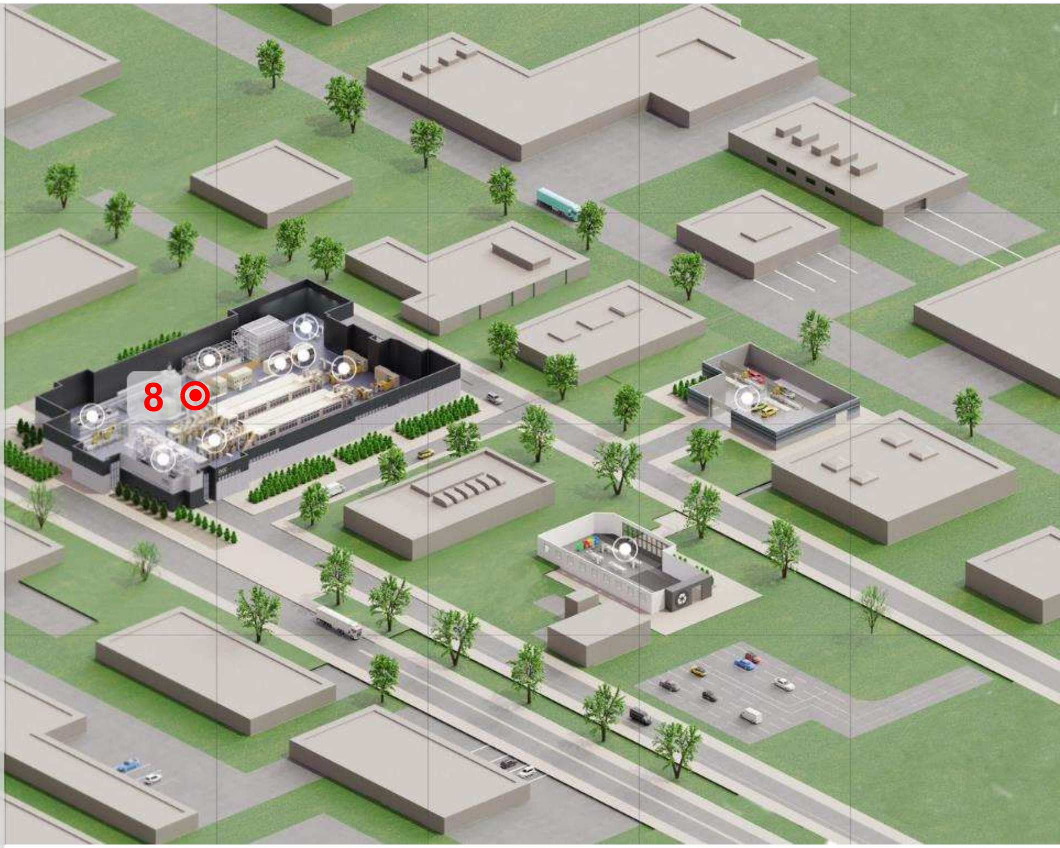
- Dry Room < 20%
- VOCs (Volatile Organic Compounds)
- Cleanliness ISO 6 or 7: max part (0.5 microns per cubic meter)
- Temperature: 22 to 23°C (+/-2 to 3°C)

The complete supply chain: 8 of 13

STEP 8

LASER AND ULTRASONIC WELDING AND CELL ASSEMBLY

Stacking is followed by a process of ultrasonic or laser welding for fixing the lugs together, joining the stacks in pairs and finally soldering the stacks to copper or aluminum connectors which are themselves soldered to the cell cover.
The resulting welded stack is then inserted into a prismatic can and the cover is welded around its entire periphery to ensure tightness. The assembly is subsequently closed by a temporary cap



The complete supply chain: 9 of 13

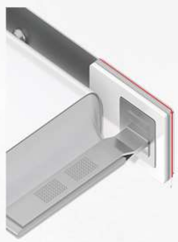
STEP 9

BAKING AND FILLING

The cell undergoes a drying cycle to remove the last traces of moisture and then the electrolyte is inserted into the cell.

Step 8 and 9: Welding, Assembly, Baking, Filling

The tabs of the electrode sheets are welded together, and collectors are welded to the tabs.



The covers and collectors are welded together.

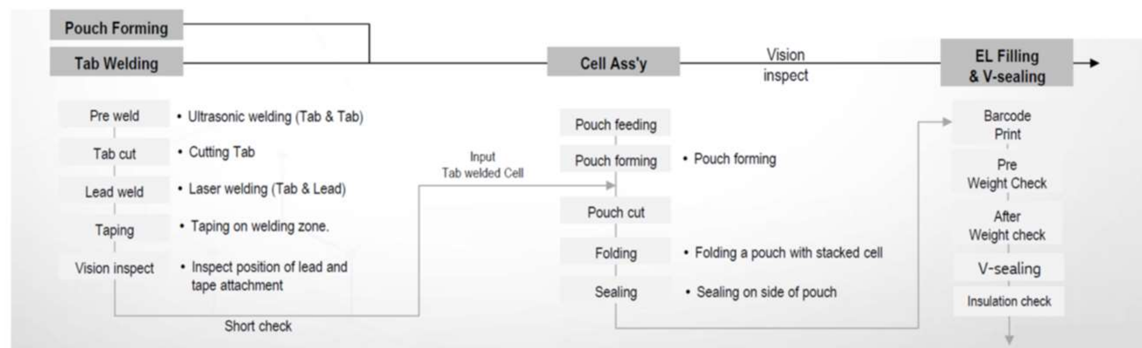
The stack or jelly roll is inserted into the can

The covers and the can are welded together.

Electrolyte is filled via the electrolyte port.

- **Laser welding presents a high risk of metallic burr projection into the cell, leading to potential short circuit**
- **Humidity control <50%**
- **Temperature: 22 to 23°C (+/-2 to 3°C)**

- Cell assembly lines are continuous process. After loading, tabs are pressed and ultrasonically welded (not anymore at SDI). The welded tabs are then laser welded to the contact terminals attached to the cap of the cell. The stack is wrapped into an insulation foil and then inserted into a can.
- The can and lead are sealed by a laser welding process. Leak test is then performed.
- Electrolyte is then filled into the cell under vacuum (filling) with a high-precision dosing needle. The pressure profile (supply of inert gas and/or generation of a vacuum), activates the capillary effect in the (wetting).
- Afterwards the cells are temporarily sealed with a lid.
- Some suppliers use vacuum heating to dry cell before first filling. A first filling of electrolyte (90%) is realized. Degassing in done several hours later and the final filling performed.

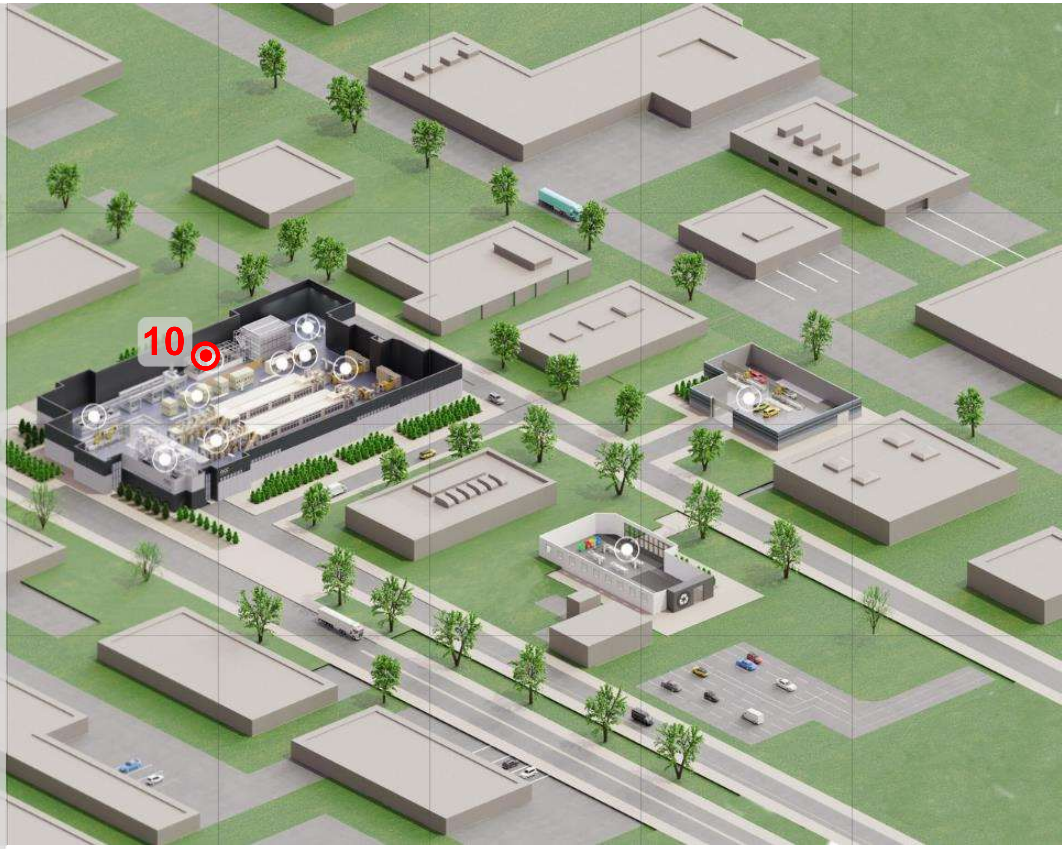


The complete supply chain: 10 of 13

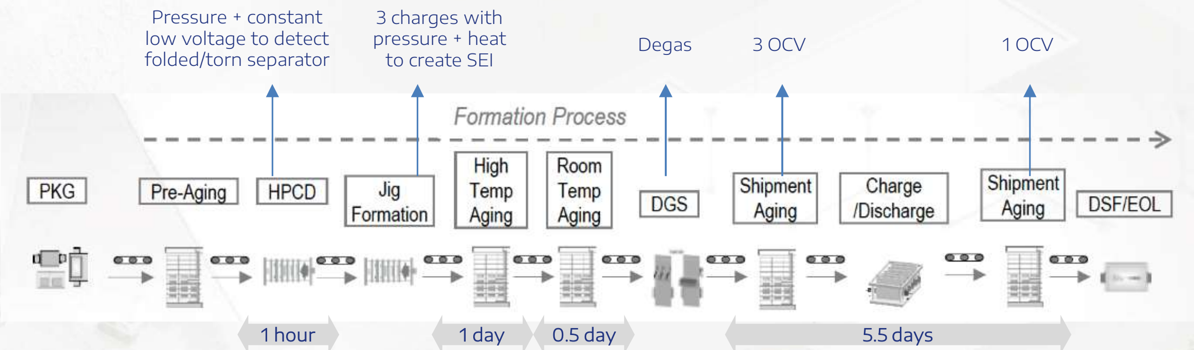
STEP 10

ELECTRIC FORMATION

The electric formation describes the first charging and discharging processes of the battery cell. The cells are set in specific compression formation racks and contacted by contact pins.
The cells are then processed through different charge and discharge cycles as well as various tests to ensure the quality and charge/discharge repeatability. A complementary filling is performed if needed, before the cell’s final hermetic sealing.



Step 10: Electric Formation



- **Fire Protection**
- **Humidity < 50%**
- **Temperature: 22 to 23°C (+/- 2 to 3°C)**

- After assembly, cells are rested to let electrolyte penetrate all the electrodes. They are then put in special carriers in formation racks and contacted by spring-loaded contact pins. The cells are then charged or discharged according to precisely defined current and voltage curves.
- During formation, lithium ions are embedded in the crystal structure of the graphite on the anode side (Solid Electrolyte Interface - SEI). SEI is a passivation layer produced by electrolyte decomposition. The quality of the SEI plays a critical role in the cyclability, rate capacity, irreversible capacity loss and safety.
- Cells are then degassed and sealed (definitive lid). For pouch cells, the bag is pierced in a vacuum chamber and the escaping gases are sucked off. The cell is then finally sealed under vacuum.
- During aging, cell characteristics are monitored by regularly measuring the open circuit voltage (OCV) of the cell. The cells are stored in aging shelves. No significant change in the cell properties over the entire period of time means that the cell is fully functional.
- At the End Of Line, prismatic cells are cleaned with plasma and a protective wrapping realized. Pouch cells need a final folding (DSF - Double Side Fold) and gluing of the seal edges to reduce the external dimensions. After final testing, many suppliers sort the cells according to their performance data (grading).
- The whole process varies from 3 to 15 days, depending on the chemistry, and the formation sequence can be adjusted depending on clients & chemistry.

Cycler charging and discharging

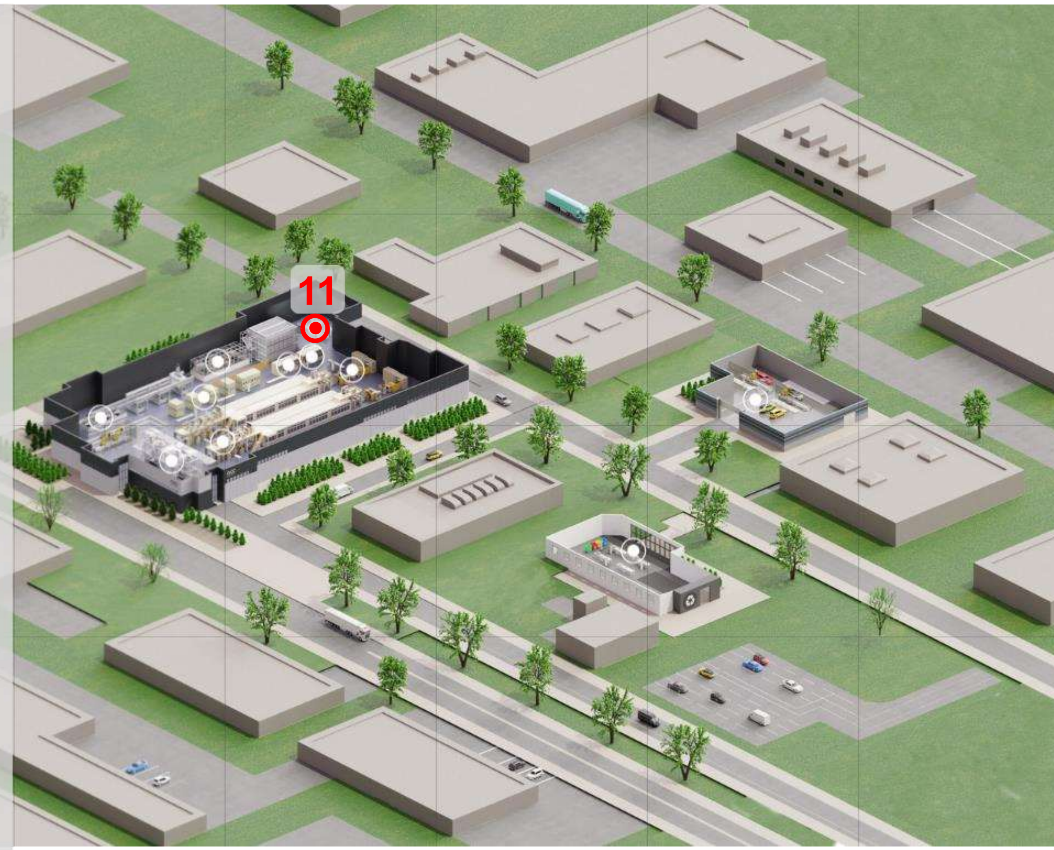
Aging shelves

The complete supply chain: 11 of 13

STEP 11

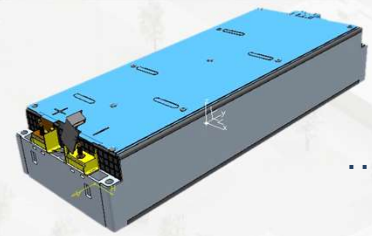
MODULE ASSEMBLY

Like "Russian dolls", the cells having passed all validation phases are assembled into a module and connected to each other.
The product is now finished and it’s ready to be combined in what is known as a "battery pack", i.e. a combination of several modules.

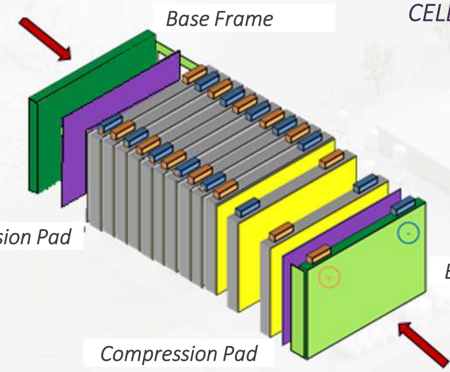


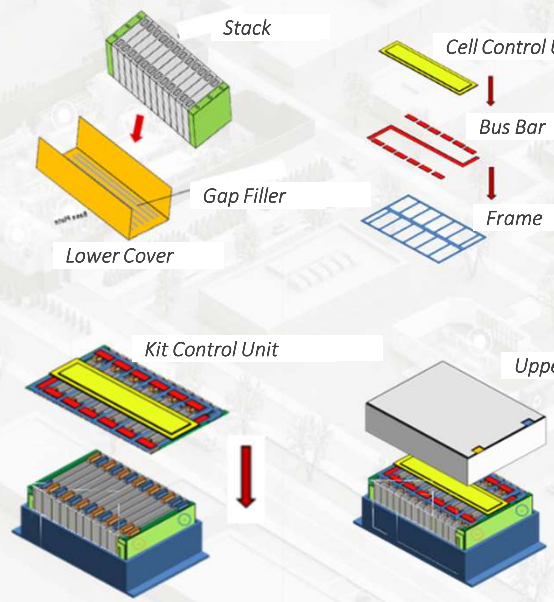
Step 11: Module formation

From the **Cell** …

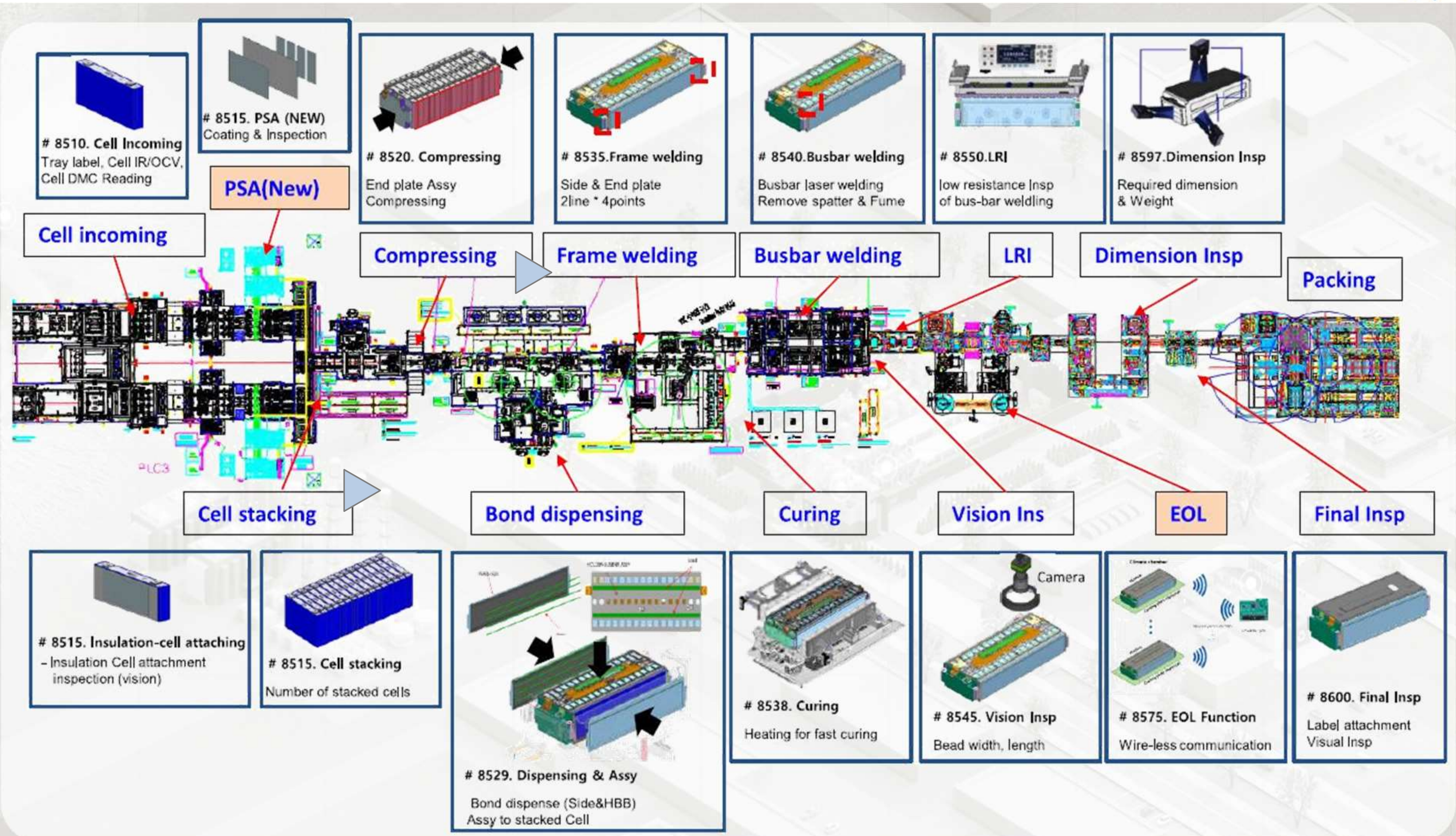


… to the **Module**





Step 11: Module formation



Stellantis in the Europe Battery Cells and Module business: ACC

Source: ACC.

The complete supply chain: 12 of 13

STEP 12

BATTERY ASSEMBLY AND INTEGRATION IN THE VEHICLE

After being tested, evaluated and sorted, the modules are delivered to battery pack manufacturers where they are assembled into a final product that meets the technical, environmental and safety specifications of the end user creating the Battery Pack and the Battery System

They are then integrated into vehicles, directly under the chassis.

Maserati Battery Pack: General architecture

MAIN SUBGROUPS

Frame

Cover

Modules

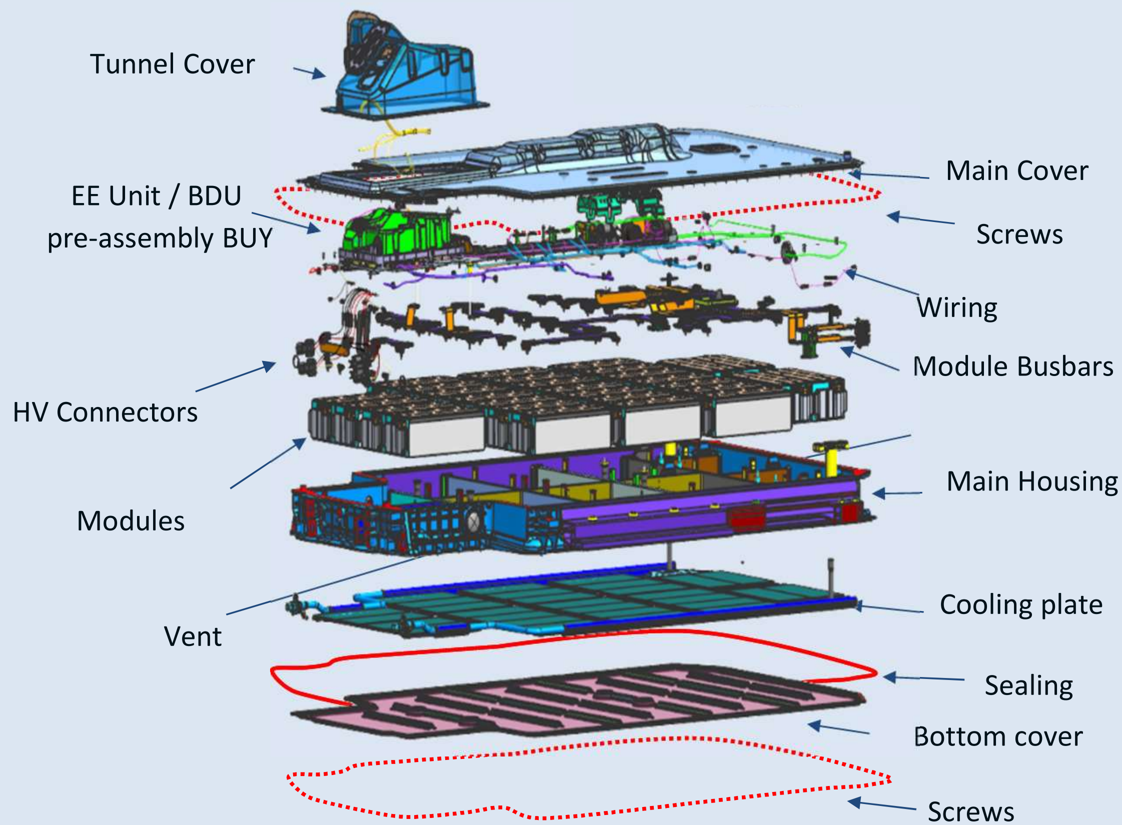
Cooling system

Busbar & Electrical parts (BDU)

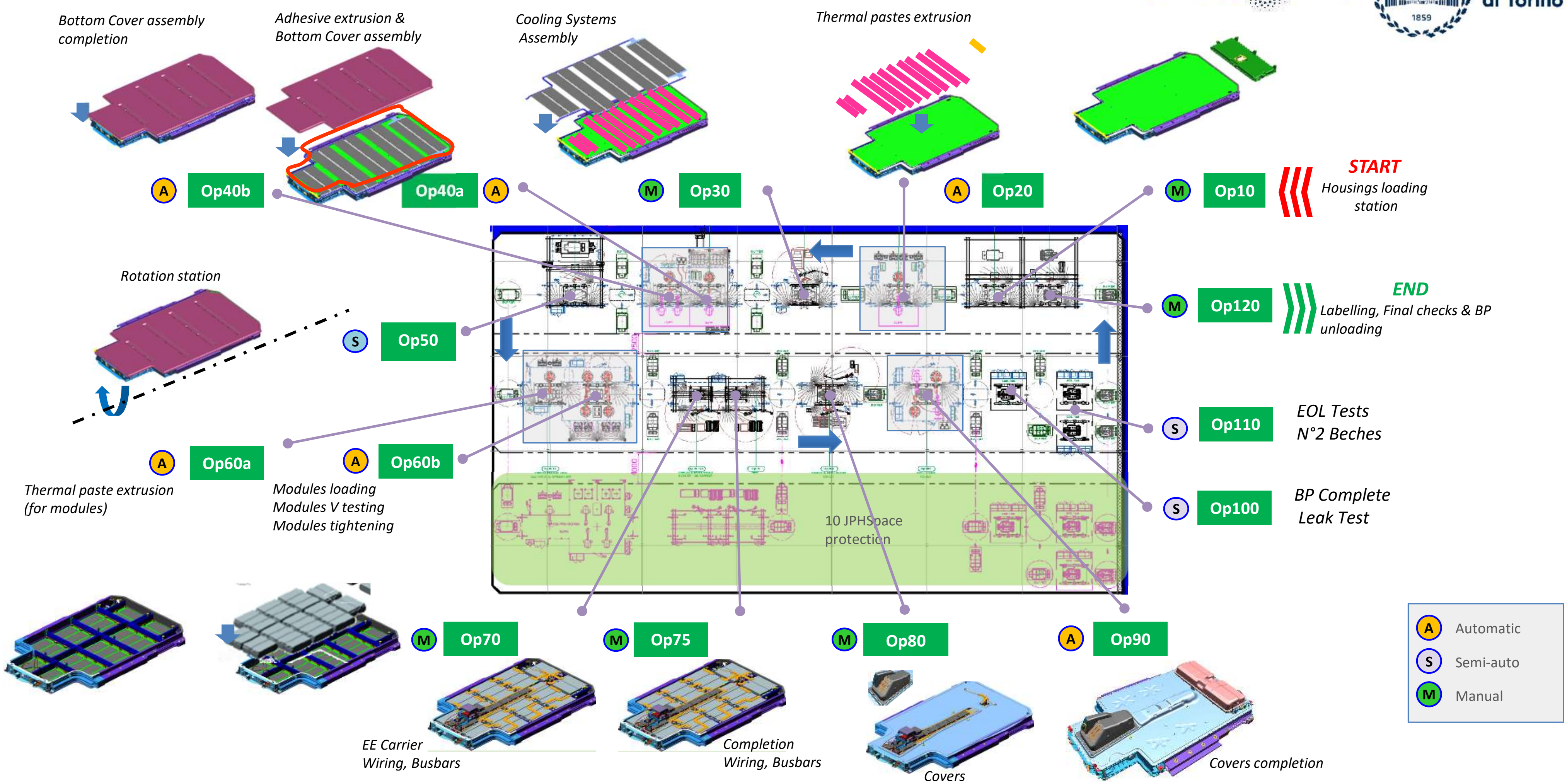
Wiring Parts

Venting system

Others



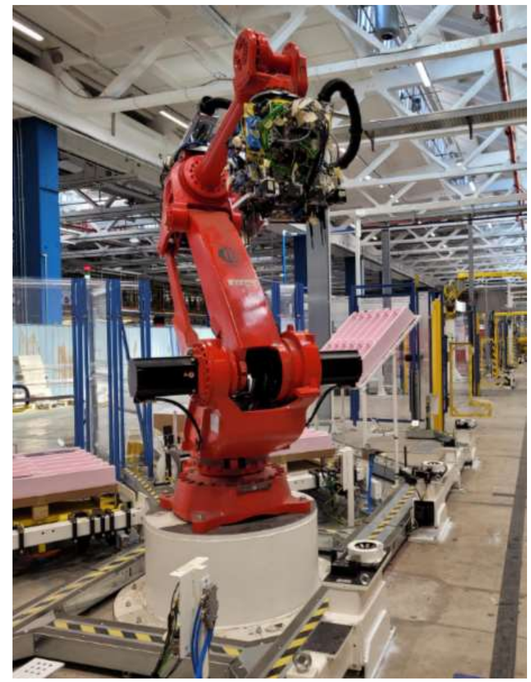
Maserati Battery Pack: Process



Maserati Battery Pack: Process

Bottom Cover Pressing

Bottom Cover Pressing



Modules loading

The complete supply chain: 13 of 13

STELLANTIS

STEP 13

RECOVERY/RECYCLING

At the end of their life, batteries are retrieved from the vehicles by the vehicle manufacturers, whose responsibility is to recycle the batteries. Batteries are being repaired or dismantled and recycled.

This is part of the “Circular Economy” business unit of Stellantis located in Mirafiori (Torino).