Tulevaisuuden energiatehokas tehdas

LOPPURAPORTTI

28.6.2018

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Oy Merinova Ab: Tehtaan energiatarve ja –huolto

- Tausta
- Li-Ion (LIB) akkuvalmistuksen energiatarve
- Vaasan tehtaan energiantarve ja ylijäämäenergia

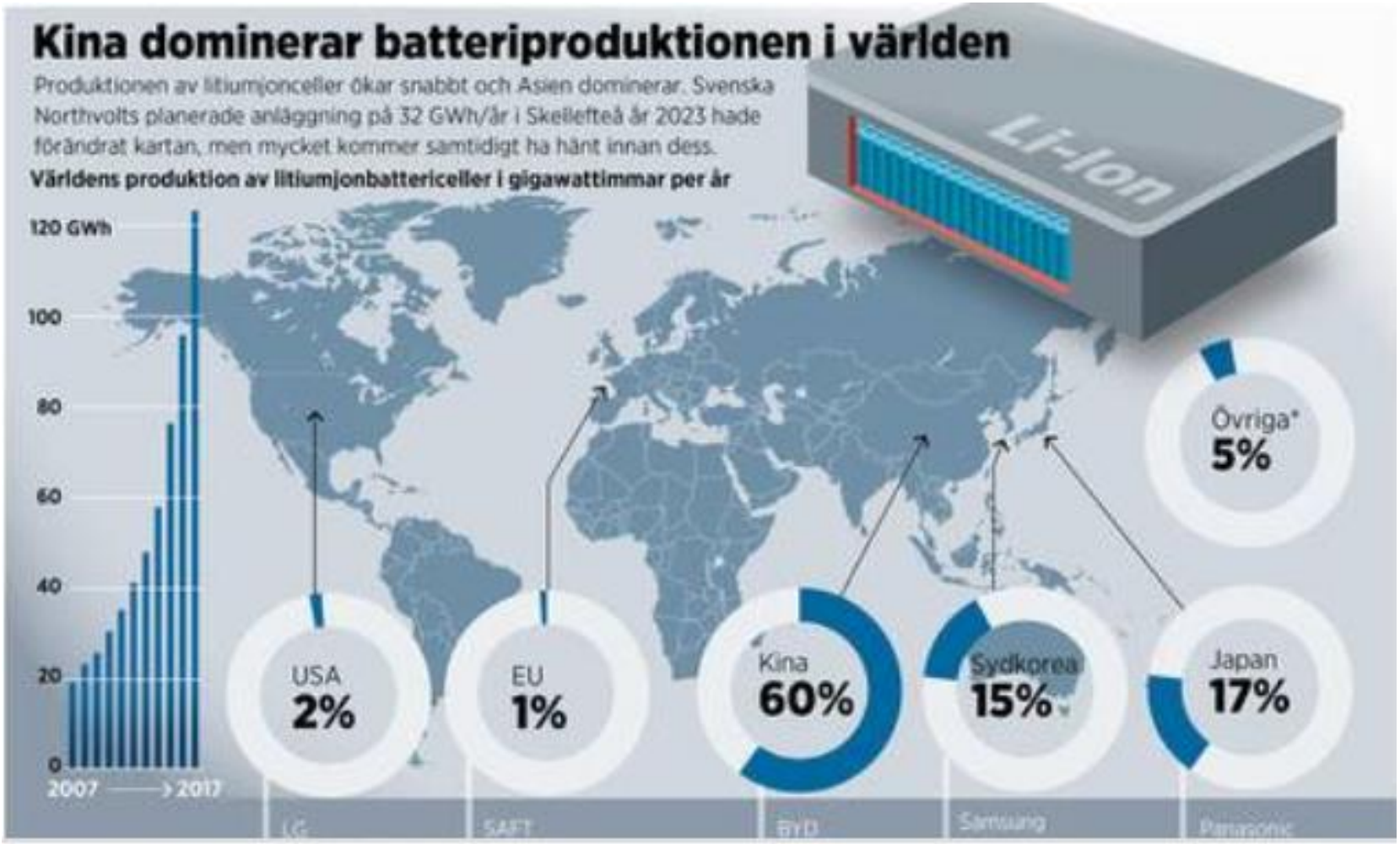
VAMK: Akkupaketin kookoonpanosolun kehitys ja valmistus

- Tausta
- Kokoonpanosolun suunnittelu, simulointi ja ohjelmointi
- Solun rakentaminen ja testaus
- Robottisolun jatkokäyttö ja kehitys

Vaasan ylipoisto : 3 D design to validate LIB factory capacities for realistic and efficient conception of equipment and quantities for improved production performance

- Site and factory overview
- The production process
- Raw material, equipment, number of robots and power requirements
- Production process simulation

Tausta: Euroopassa vain 1-2 % Li-Ion akkuvalmistuksesta v 2017 Lähde: Ny Teknik Mars 2018



Tausta..

- 26 uutta tehdasta suunnitteilla vuosille 2018 – 2021, suunniteltu uutta tuotantokapasiteettia yhteensä **344 GWh/v**
- 169 GWh, **49% uudesta kapasiteetistä**, suunnitellaan Kiinaan
- Arvioitu kysyntä 2017: **100 GWh**
- Li-Ion akkujen arvioitu globaalikysyntä v. 2025: **400 GWh/v**

Uudet tehtaat – ”investointipäätökset tehty.”

Eurooppa

- LG Poland: **5 GWh**
- Terra E ym. Saksa: **34 GWh**
- Northvolt, Västerås/Skellefteå: **8 GWh** 2020, **32 GWh** 2023
- SK Innovation, Unkari **7,5 GWh**
- Daimler, Dresden, Saksa: Uusi tehdas tuotannossa
- Tesla ostanut saksalaisen Grohman Engineering 11/2017; In the future, batteries and complete vehicles to be manufactured under one roof in a big way. For the expansion of production, Musk already took Audi's German manager Peter Hochholdiger as production specialists.

US: Tesla, Nevada: **150 GWh** by 2021

LIB akkuvalmistuksen energiatarve 1

(Yuan, Deng, Tonghui, Yan 5/2017: Manufakturens energy analysis of lithium ion battery pack for electric vehicles)

Case : Nissan Leaf LIB battery pack:

- 24 kWh, 192 cells
- Total weight 221 kg of which 166 kg battery cells (+ 8,9 kg cooling system, 8,5 kg BMS, and 37,6 kg packaging)
- Energy consumption in battery cell manufacturing:
  - 13.28 kWh/cell
  - 192 x 13.28 kWh = 2550 kWh
  - 2550 kWh/24 = **106,24 kWh (382 MJ)** manufacturing energy required for 1 kWh battery storage capacity, of which
    - **38 % in the electrode drying process**
    - **43 % dry room facility**

Yuan, Deng, Tonghui, Yan 5/2017: Manufakturens energy analysis of lithium ion battery pack for electric vehicles

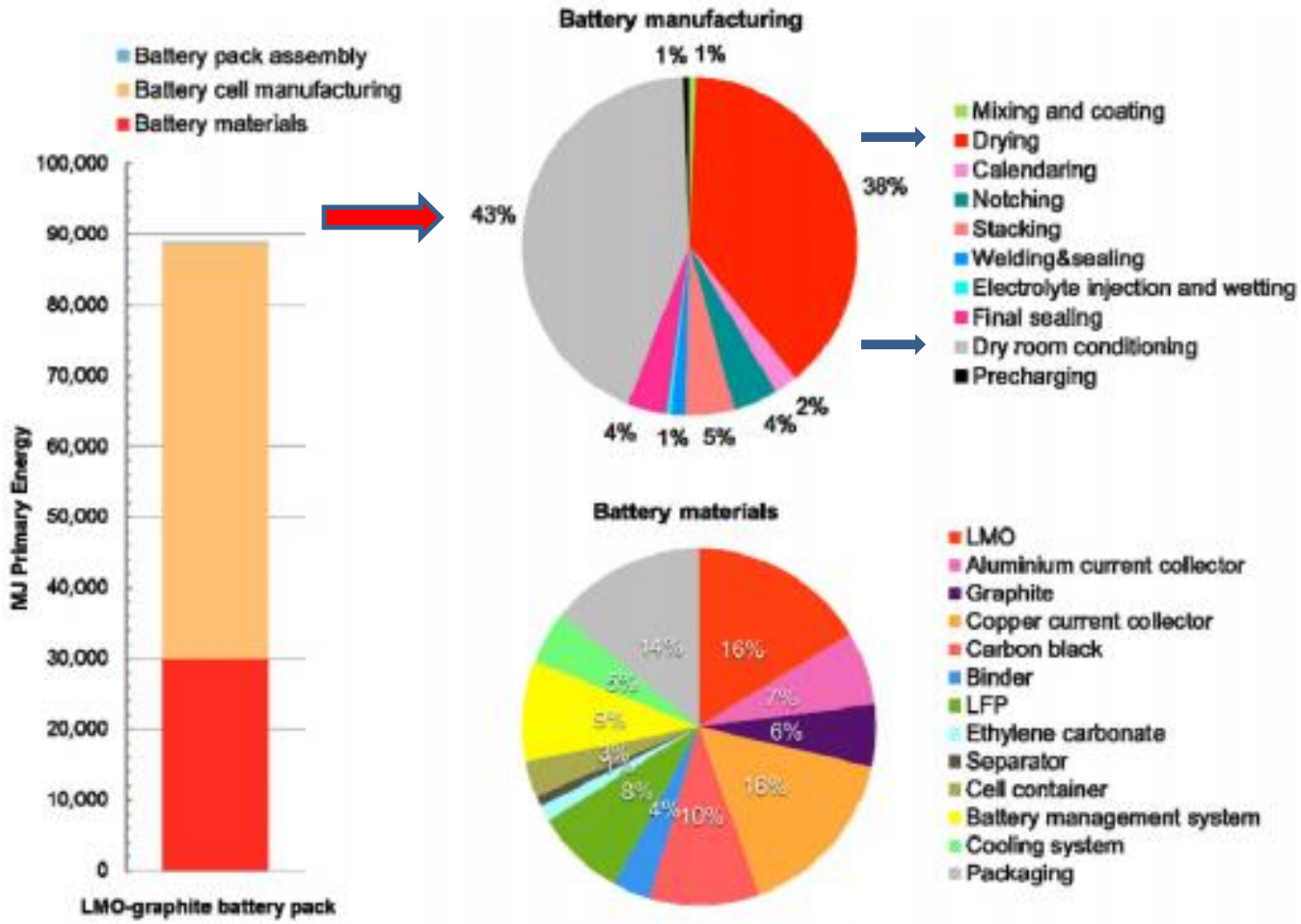


Fig. 3. Primary energy consumption of the LMO-graphite battery pack production.

LIB akkuvalmistuksen energiatarve 2 :

Mia Romare, Lisbeth Dahllöf 2017. The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-Ion Batteries

Table 13: Energy consumption per kWh battery and modelling method presented in five different LCA studies on lithium-ion batteries (Ellingsen, et al., 2016).

Study	Manufacturing energy MJ/kWh	Top-down/Bottom-up
(Ellingsen, et al., 2014)	586	Top-down
(Notter, et al., 2010)	3.1	Bottom-up
(Zackrisson, et al., 2010)	451	Top-down
(Majeau-Bettez, et al., 2011)	371-473	Top-down
(Dunn, et al., 2012)	10.7	Bottom-up

Ellingsen et al (2014) reported 586 MJ/kWh, mainly electricity, for manufacturing based on primary data from a battery manufacturer. The dry rooms contribute to a large extent to the electricity use. This exact value was taken from several months of measurements for cell manufacturing, and the value chosen was from a high production month as this best represent a future full scale production scenario. Since this value is based on a primary data source it makes the results highly relevant for future assessments.

It seems, based on the data found, that the energy use for current battery manufacturing lies between 350 and 650 MJ/kWh.

Vaasan tehtaan energiatarve

- Manufacturing energy required for 1 kWh battery storage capacity: Case Nissan Leaf: **<u>106,24 kWh</u>**
- Production time 24/7 = **<u>8760 h/a</u>**

Koko, tehontarve ja energiantarve:

<u>Vaihe 1 - Akkutuotanto 8 GWh/a :</u>

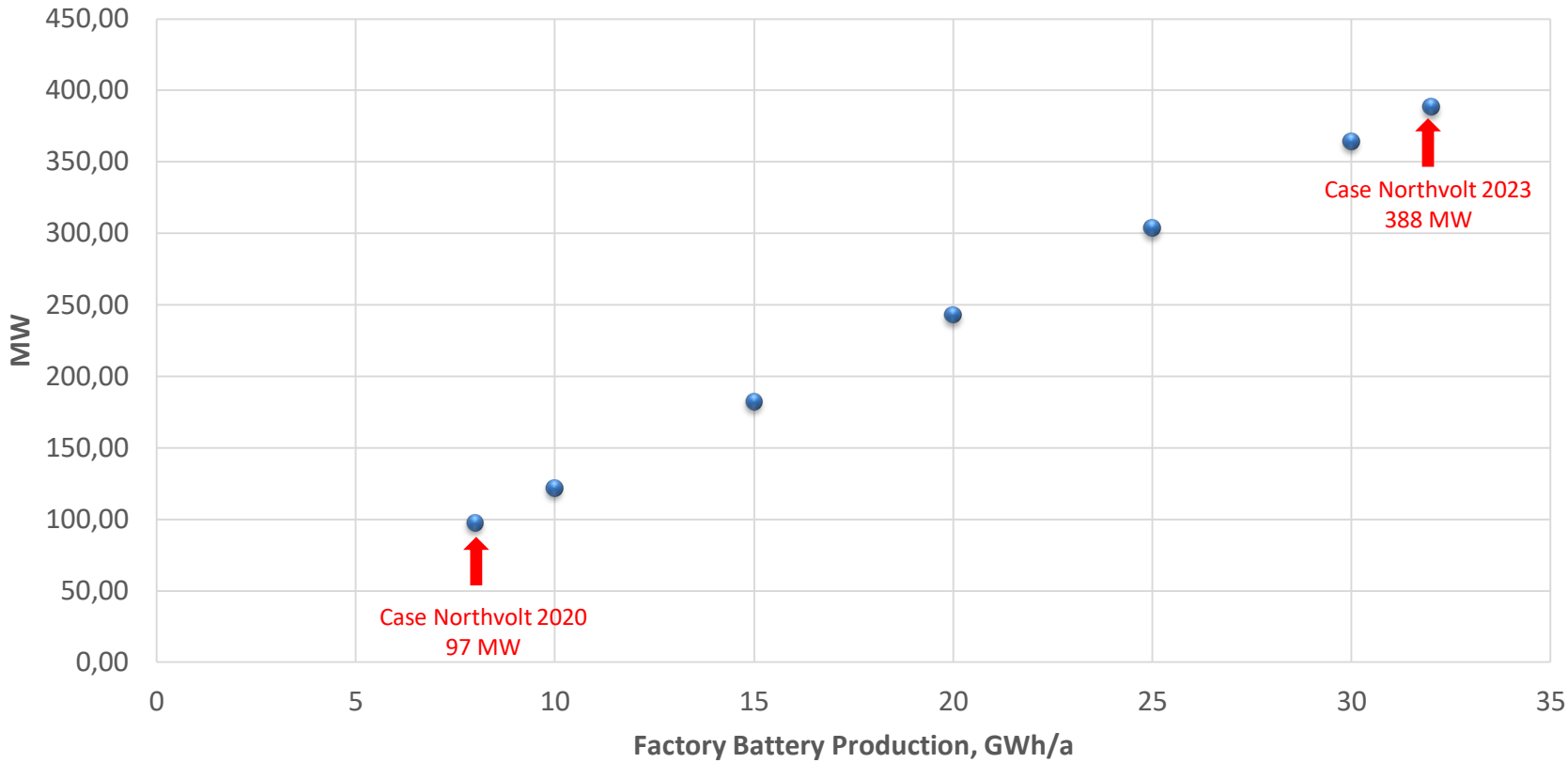
- Tehontarve 96,9 MW
- Energia 849 GWh/a (*106,24 GWh/GWh akkukapasitettia)*

<u>Vaihe 2 – Akkutuotanto 32 GWh/a</u>

- Tehontarve 388 MW
- Energia 3400 GWh/a

Factory Electricity Capacity Demand, MW

According to 106,24 kWh/ 1 kWh battery storage capacity produced and production 24/7



Vaasan tehtaan aurinkosähköpotentiaali

Oletukset Vaasan korkeudella:

- 850 kWh/kWp
- 6 m^2/kWp

Hehtaarin (100m*100m) paneelipinta-alalta saadaan tällöin vuositasolla sähköenergiaa Vaasan korkeudella keskimäärin vuodessa noin 1416 667 kWh eli noin 1417 MWh, (850 kWh/kWp*10000 m^2/(6 m^2/kWp))

Tehtaan omalla katolla tuotettu sähkömäärä edustaisi **noin 0,25 %:n osuutta vuotuisesta tehtaan sähköntarpeesta**.

Lentokentän läheisyydestä johtuen <u>tuulivoimaa ei voida rakentaa</u> alueelle mutta tuulivoimasähköä voi ostaa sähköpörssistä

Vaasan tehtaan ylijäämäenergiapotentiaali.

“Ylijäämäenergia” = 43 % dry room conditioning…

Tehtaan koko ja määrät:

<u>Vaihe 1 - Akkutuotanto 8 GWh/a:</u>

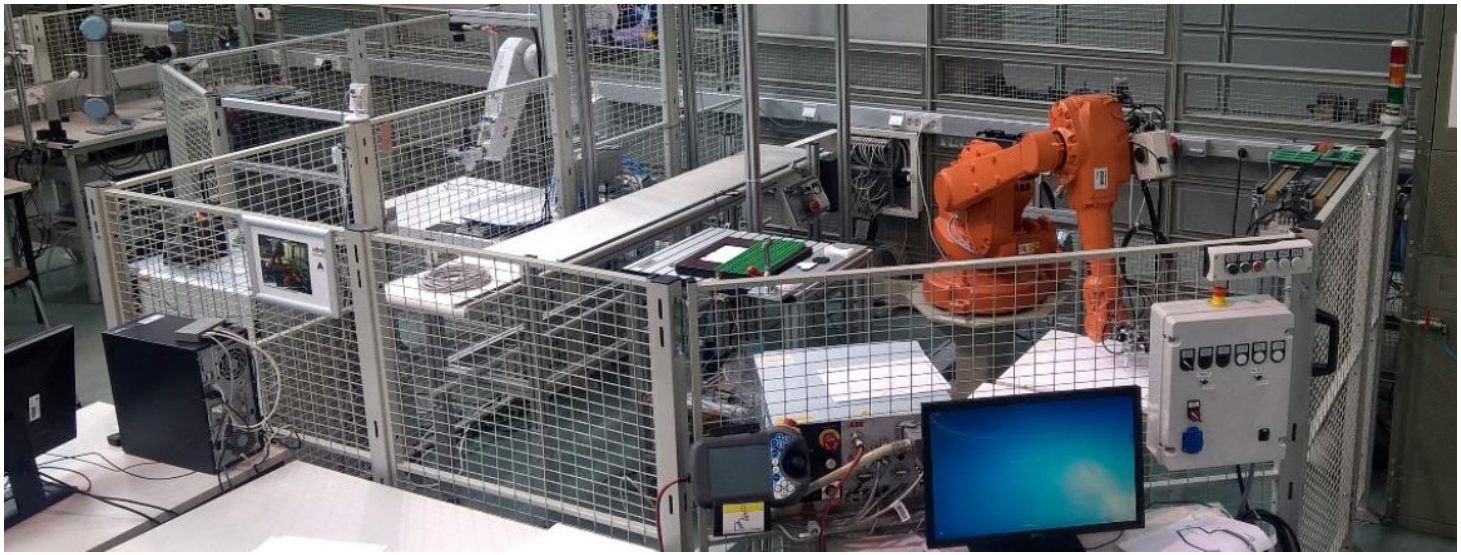
- Tehontarve 96,9 MW ; **41,7 MW ylijäämäenergia**
- Energia 849 GWh/a; 365 GWh/a

<u>Vaihe 2 – Akkutuotanto 32 GWh/a</u>

- Tehontarve 388 MW; **166 MW ylijäämäenergia**
- Energia 3400 GWh/a ; 1462 GWh/a

Akkupaketin kookoonpanosolun kehitys ja valmistus, tausta

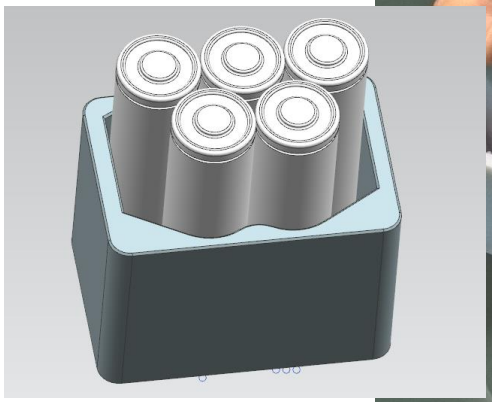
- Tarkoituksena oli luoda teollisuusstandardit täyttävä akkujen kokoonpanosolu, jonka pohjana käytettäisiin olemassa olevaa opetuslaitteistoa.

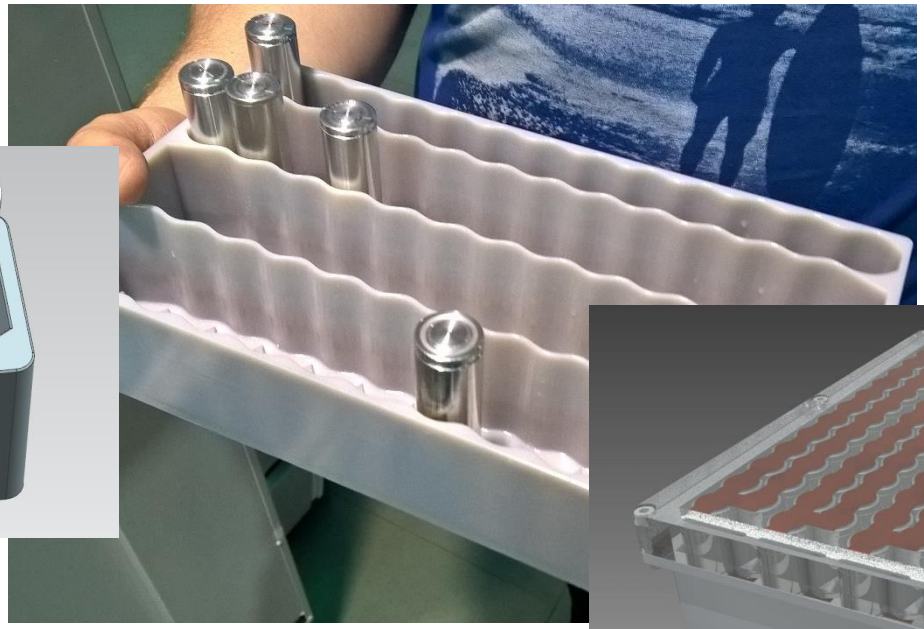


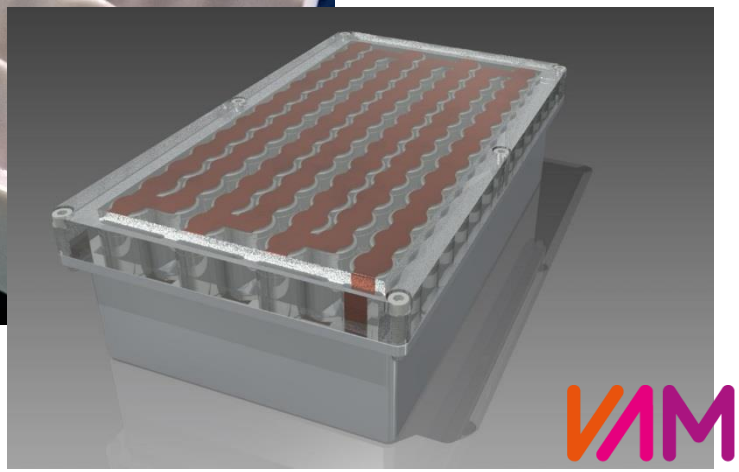
- Robottisolun tulisi kokoonpanna automaattisesti akkupaketti, mikä koostuu kotelosta, paristoista, kytkentälevystä ja kannesta. Valmiit akkupaketit noudetaan mobiilirobotilla (vuokralaite) ja toimitetaan purkupisteeseen. Solu toimisi oppimisympäristönä ja sitä kehitettäisiin jatkossakin.

Kokoonpanosolun suunnittelu

- Suunnittelun lähtökohtana suunniteltiin kokoonpantava tuote, akkupaketti. Akkupaketti koostuu alumiinisista ”akuista” , kotelosta, kannesta ja kytkentälevystä. Kotelo valmistettiin 3D-printtaamalla, kansi ja kytkentälevy leikattiin laserleikkurilla akryylimuovista ja paristot koneistettiin CNC-sorvin avulla.







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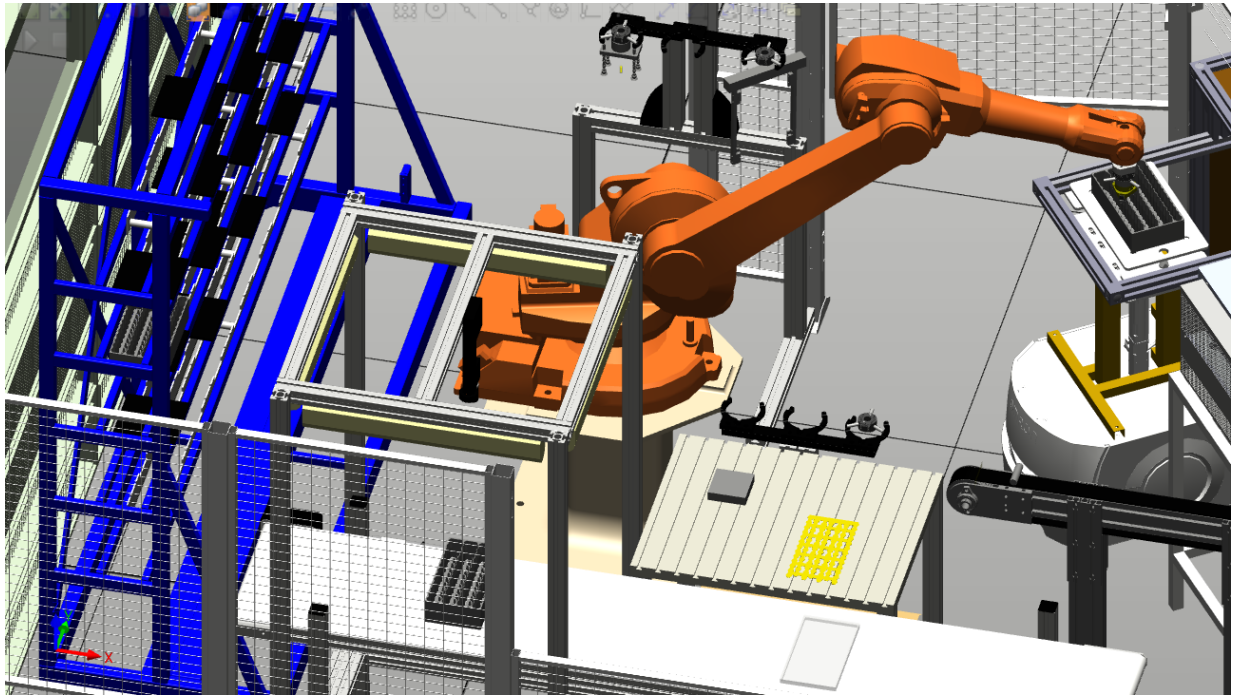
Robottisolun simulointi ja ohjelmointi

- Solun layoutia päästiin suunnittelemaan kun tuote oli valmis. Robottisolun osat mallinnettiin ja tuotiin RobotStudio -etäohjelmointiympäristöön. Layout saatiin suunniteltua ohjelmiston avulla, jonka jälkeen komponentit voitiin sijoittaa robottisoluun paikoilleen. Robotin ohjelmointikin tehtiin suurelta osin RobotStudio-ympäristössä.



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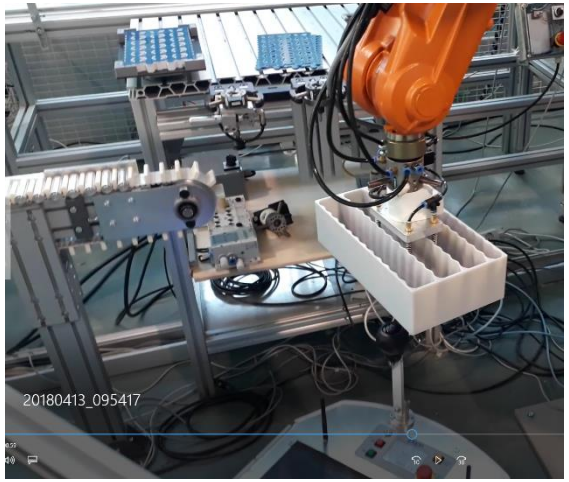
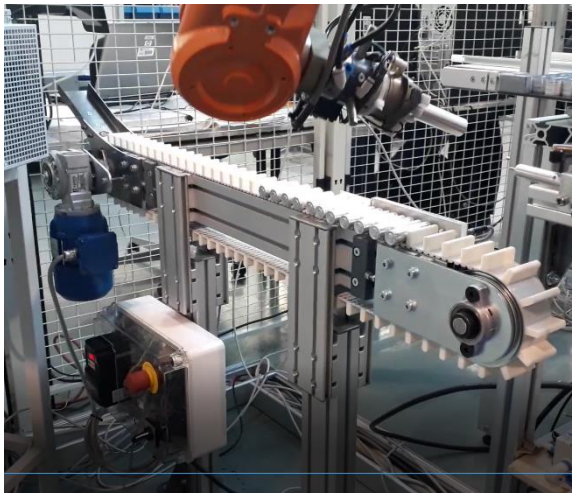
Solun rakentaminen ja testaus

- Solun ohjelmointi tehtiin yhteistyössä CO-Automationin kanssa ja testiajot saatiin onnistuneesti suoritettua juuri hankkeen aikarajoissa.

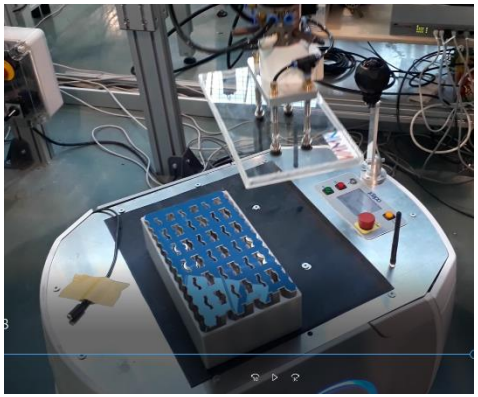


Robotti tuo kotelon kuljetusrobotille

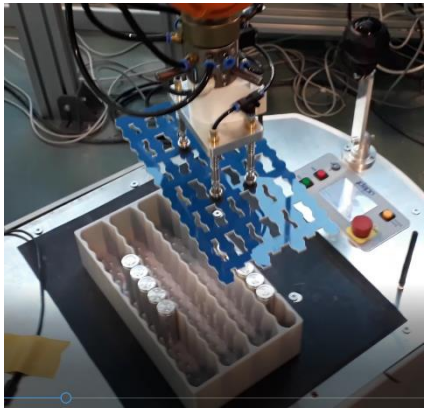


Pariston nouto kuljettimelta

Kannen nouto kameran avulla



Kannen asennus ja tuote on valmis



Kykentälevyn asennus

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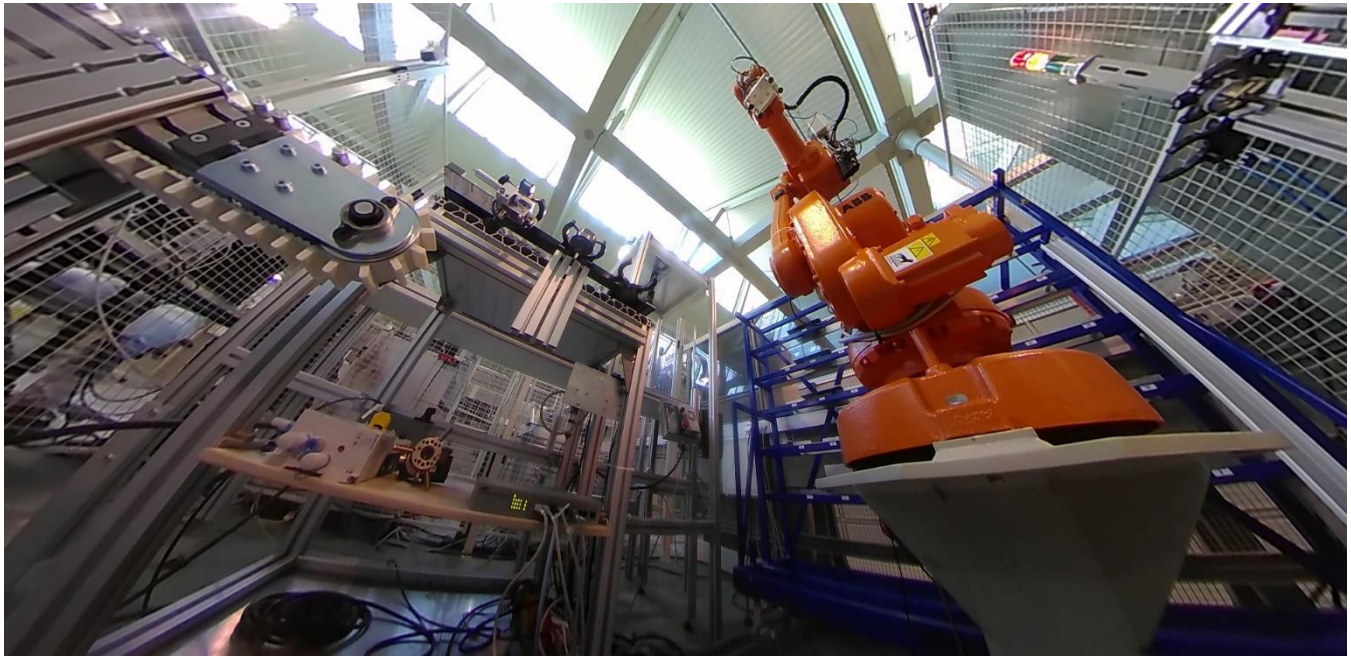
Robottisolun jatkokäyttö ja kehitys

- Robottisolusta saatiin muunnettua toimiva kokoonpanosolu, jota voi käyttää myös muiden tuotteiden kokoonpanoon. Solusta tuli ns. Robo FMS-asema (Flexible Manufacturing Station) palettivaraston, konenäön, sekä työkalun vaihtojärjestelmän ansiosta.
- Hankimme myös oman mobiilirobotin jatkokehittelyitä varten ja tarkoituksena on kehittää solua erilaisten opiskelijaprojektien avulla.



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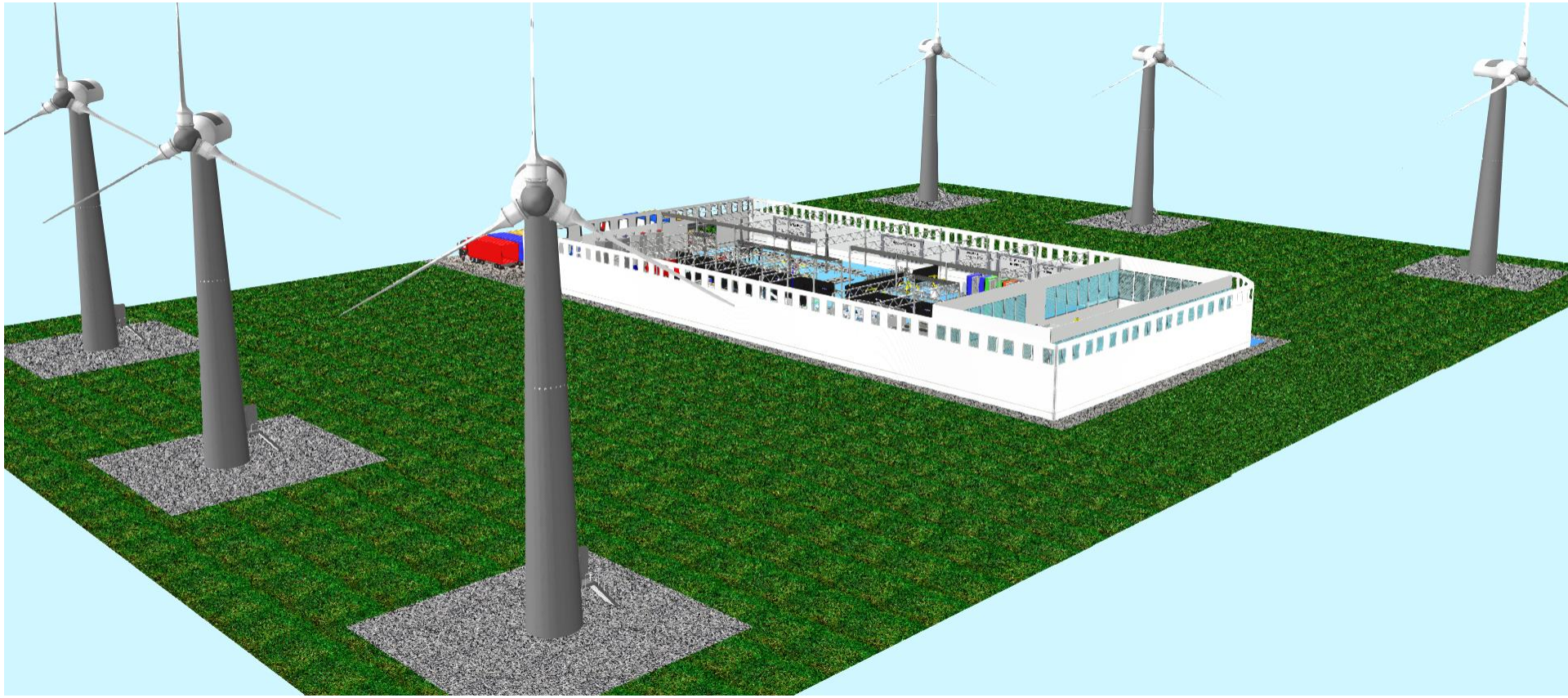
CONCEPT:

To build a **2170** type **Lithium Ion battery** plant with a **35GWh** annual production capacity.

Site Overview



Estimated space Required

Electrode manufacturing + raw material storage130m*70m=**9100 m2**
Assembly estimate: 120m*40m= **4800 m2**
Formation and testing: 55m*50m= **2700 m2**
Packing: 45m*50m= **2250 m2**

Total space required: **19 000 m2**

Factory overview

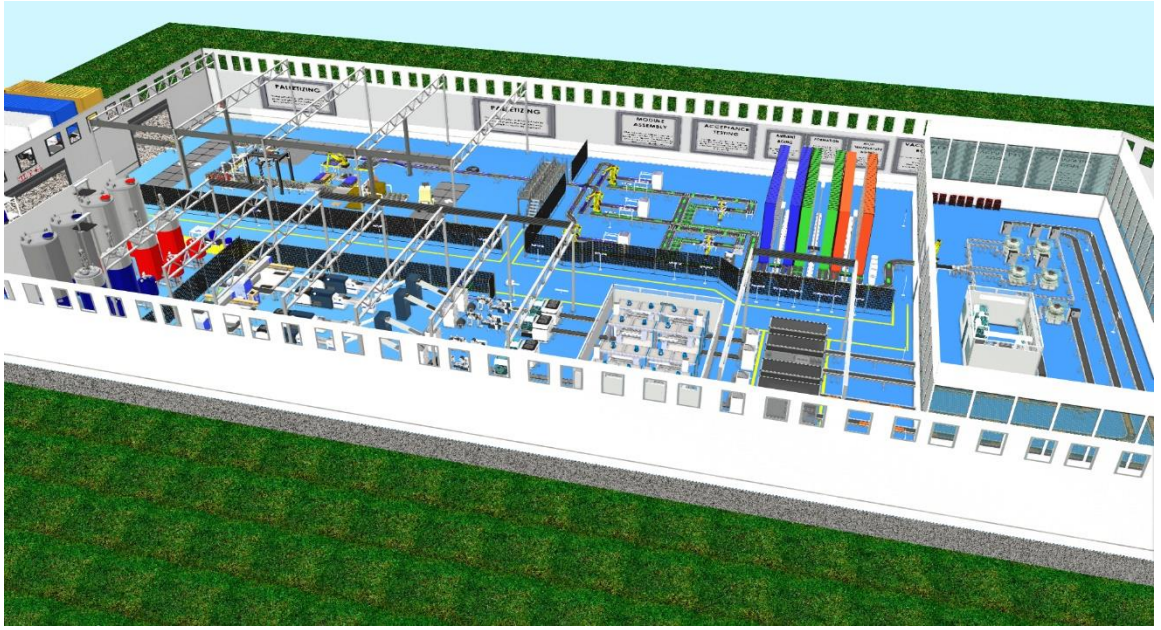
Made up of the following steps and sub sections

STEP_1: ELECTRODE PRODUCTION
Mixing
Electrode Coating
Electrode Calendaring
Electrode Slitting
Cell rolling and Winding

STEP_2 CELL ASSEMBLY
Cell case/cover production
Casing & covering
Cell assembly
Electrolyte producing
Cell filling
Cap sealing and welding

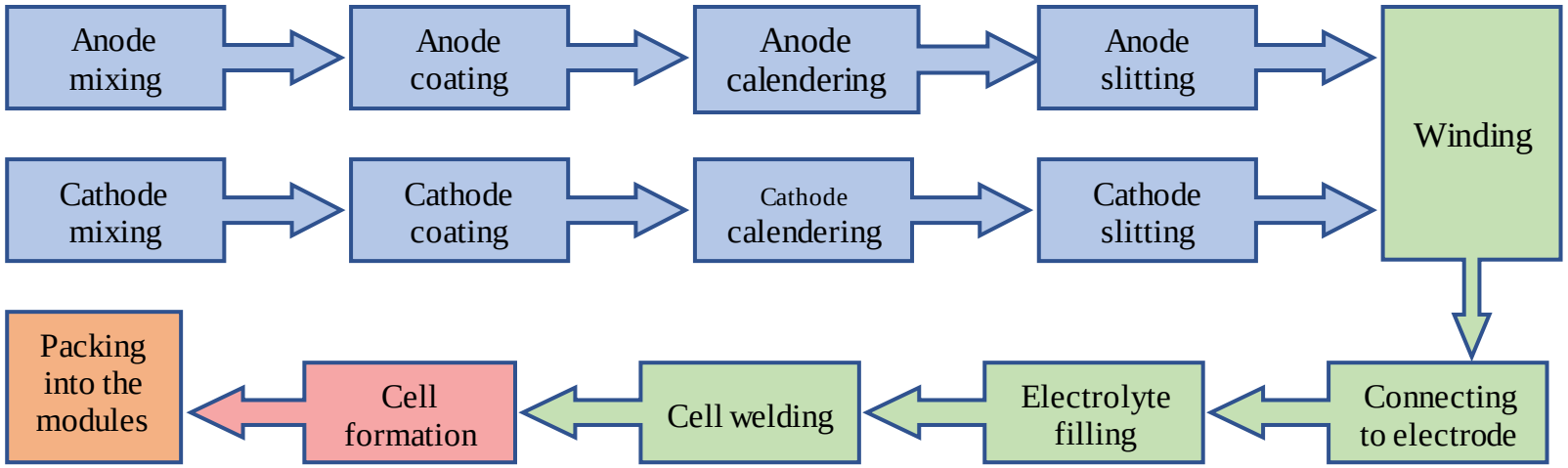
STEP:4 BATTERY PACK ASSEMBLY
Cell packing for modules
Module welding
Final testing
Palletizing

STEP_3 FORMATION
Aging process
Vacuum and heat drying
Tab welding (bottom+top)
Formation & charge retention
Cell testing
Empty cell module production.



LithiumIon battery production process

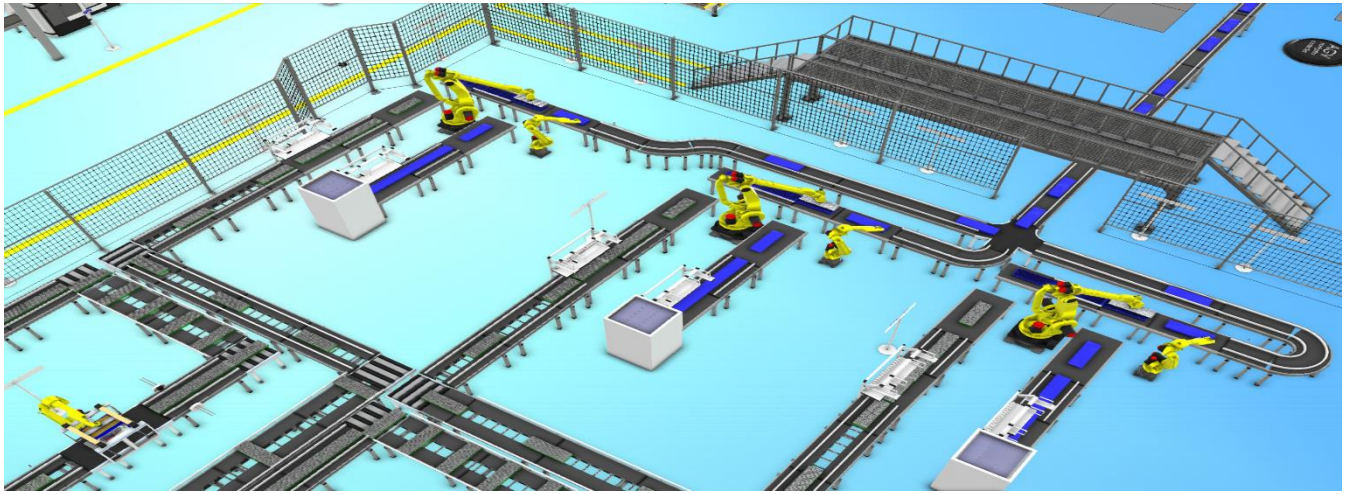
- Production process starts with the preparation of the anode and cathod.
- By mixing, coating, calendaring and slitting both aluminum and copper electrodes with the required solvents.
- Both electrodes (positive and negative) are wound together with an insulator and filled with electrolyte.
- Formation process through aging and charge retention follows.
- Final process of sealing and terminal welding concludes the process



Requirement for the 1,4 billion cells per annum target.

Electrode production	
Mixing	8
Electrode coating	6
Solvent recovery	2
Electrode calend.	10
Electrode slitting	4
Cell rolling & winding	14

Cell assembly	
Cell case production	18
Cell cover production	12
Caseing & covering	23
Cell assembly	23
Electrolyte producing	4
Cell filling	9

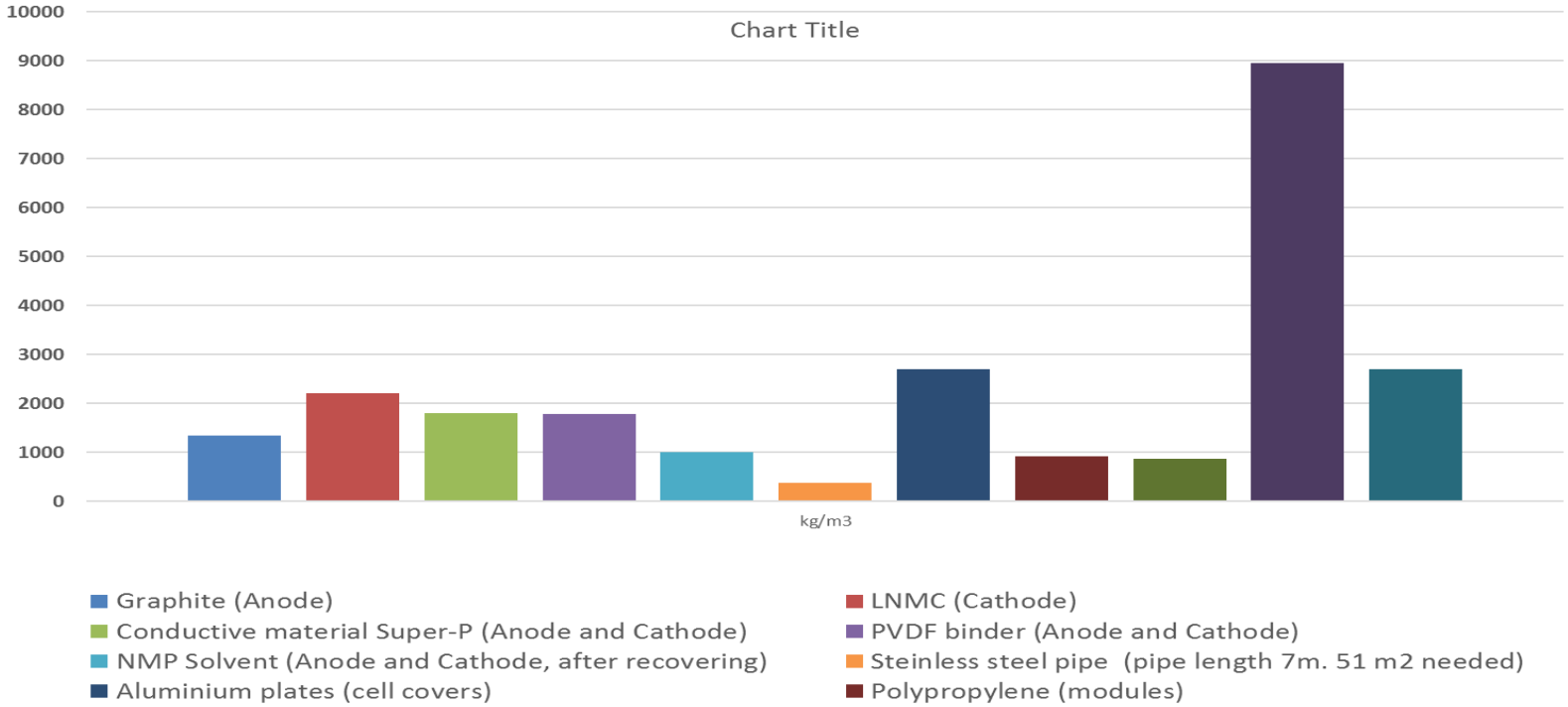


Equipments and quantities cont.

Formation	Shelves
Aging	384
Vacuum and heat drying	192
Tab weldings (bottom+top)	89
Formation & chg. retention	422
Cell testing	5

Battery pack assembly	
Cell packing for modules	7
Module welding	90
Final testing	1
Palletizing	2
Empty cell module prodn.	3

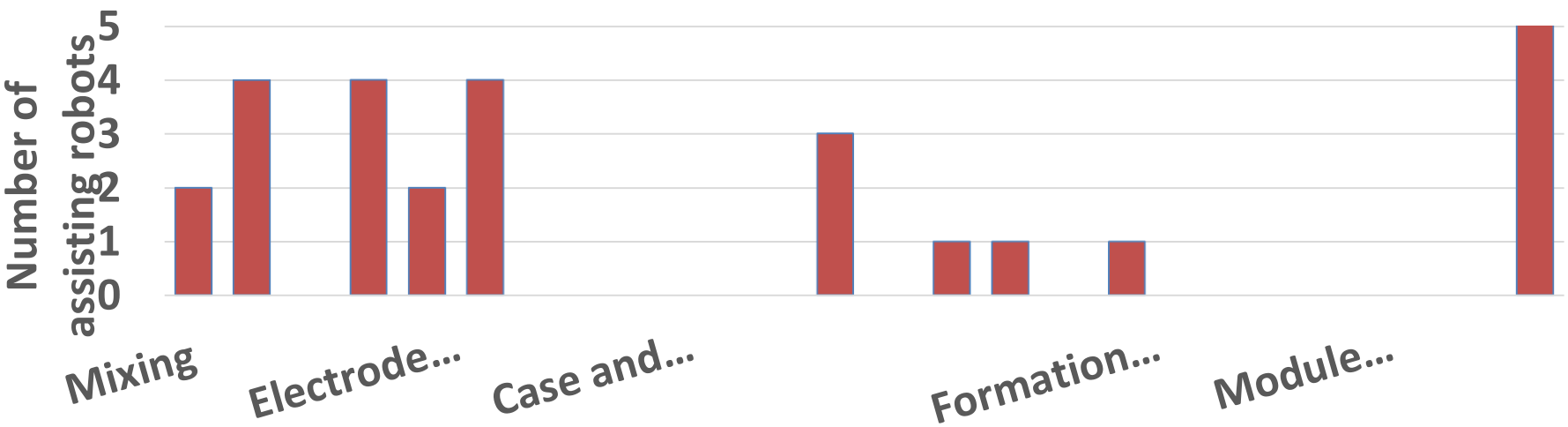
Raw material requirements



Requirement for 35GWh annual energy production rate

- Each cell has a capacity ~ **25Wh**
- This implies, produce **1,4 billion** (2170 type cells) annually.
- Implying **2664cells** per minute and in an hour:**159817cells**
- A module consists: **385 cells**
- An eco-friendly car has 10 battery modules.
- Totalling 10 X 385 = 3850 cells amounting to 80KWh

Required numbers of assisting robots



Power consumption estimates

For **each cell**;

- Machines, mixing and charging consumes: **65Wh**
- Robots, forklifts etc.: **32Wh**
- Total consumption: 97Wh = ~100Wh

Total Consumption for all 1,4 billion cells in a year,

=100Wh*1 400 000 000=**140GWh**

Videos:

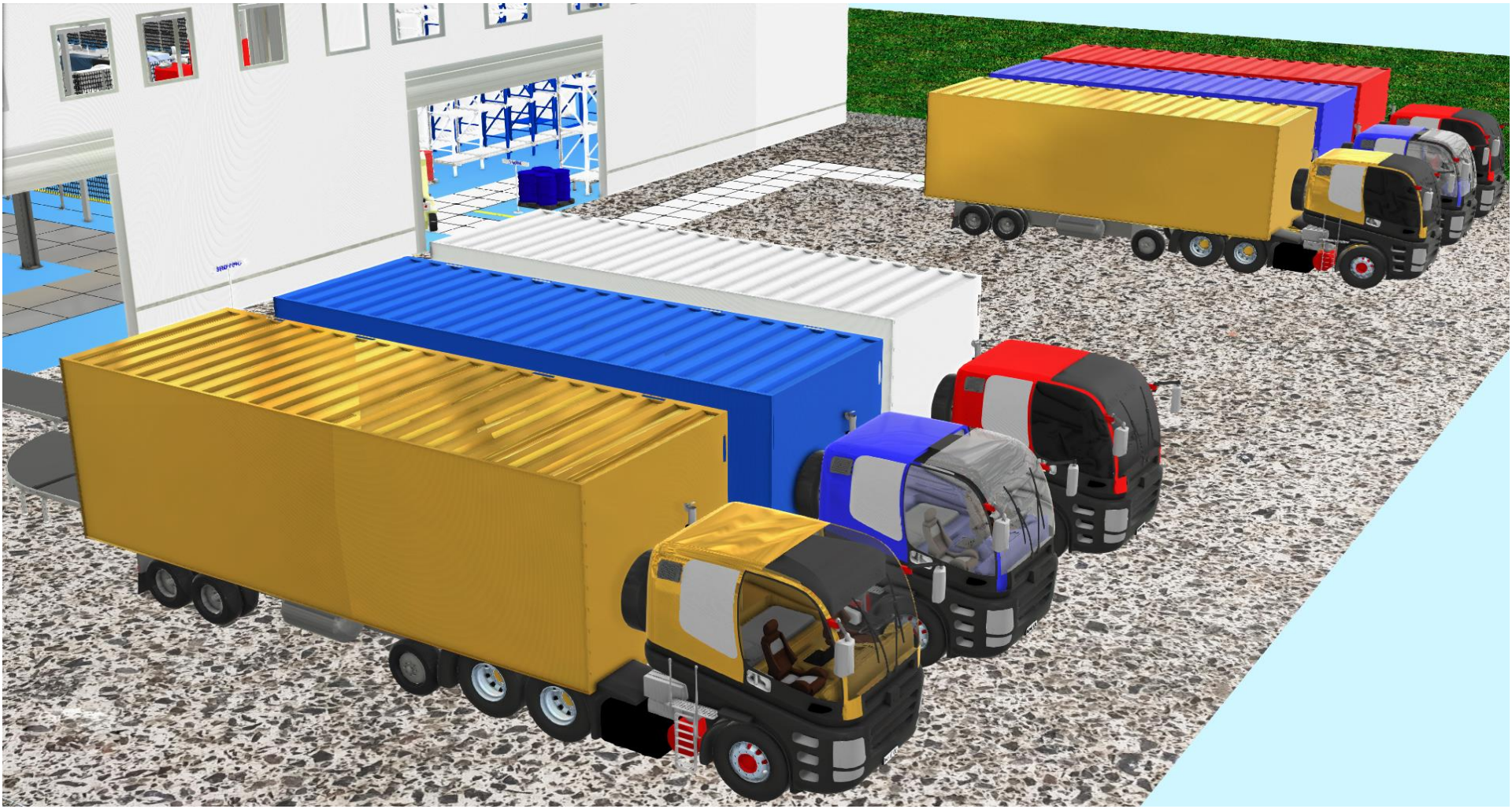
Trailer: duration 3.06 minutes

- **https://www.youtube.com/watch?v=136BOyyW43Q**

Full version: duration 16.13 minutes

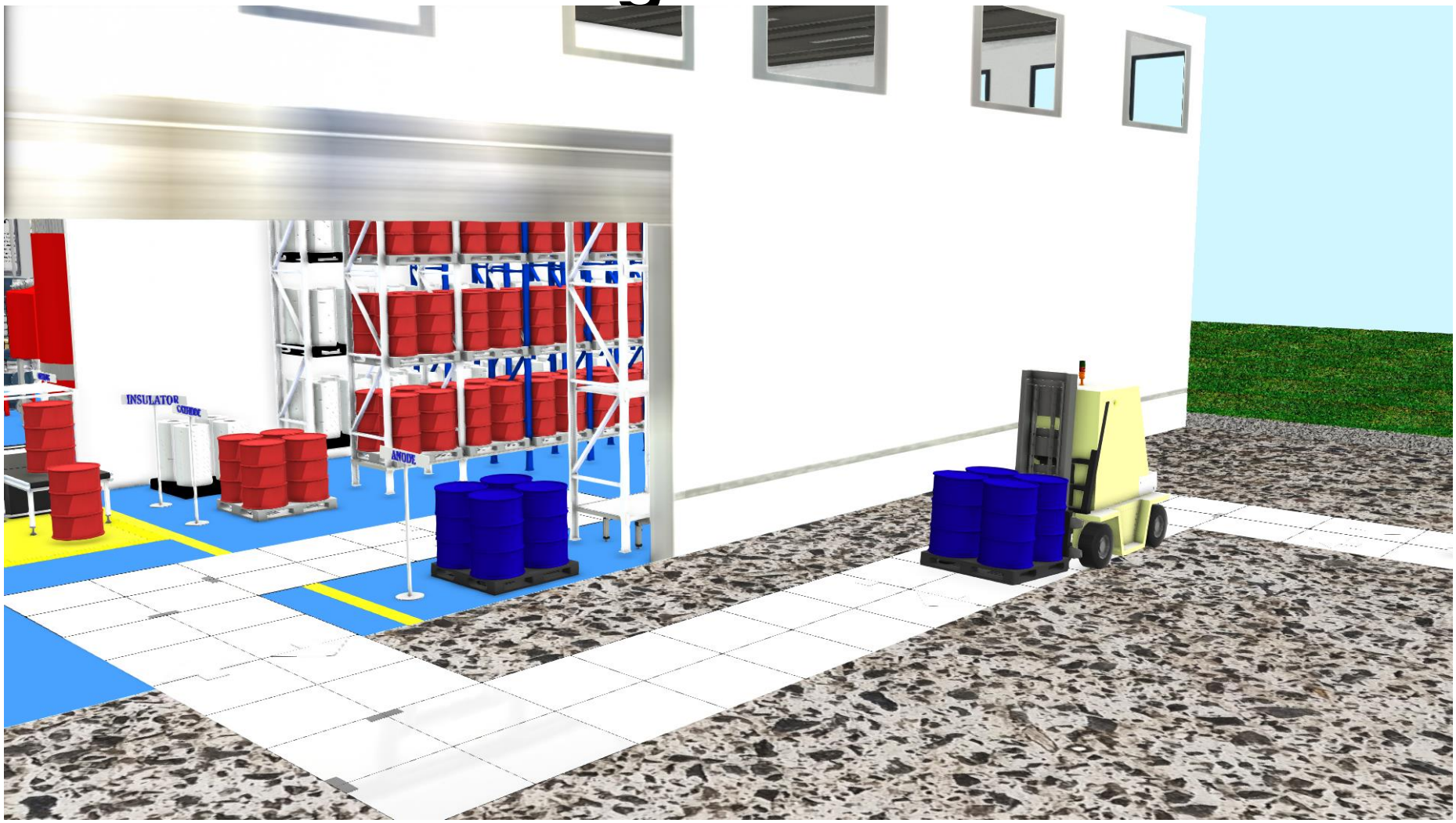
- **https://www.youtube.com/watch?v=lybC1Rr67pk**

Raw materials arrival



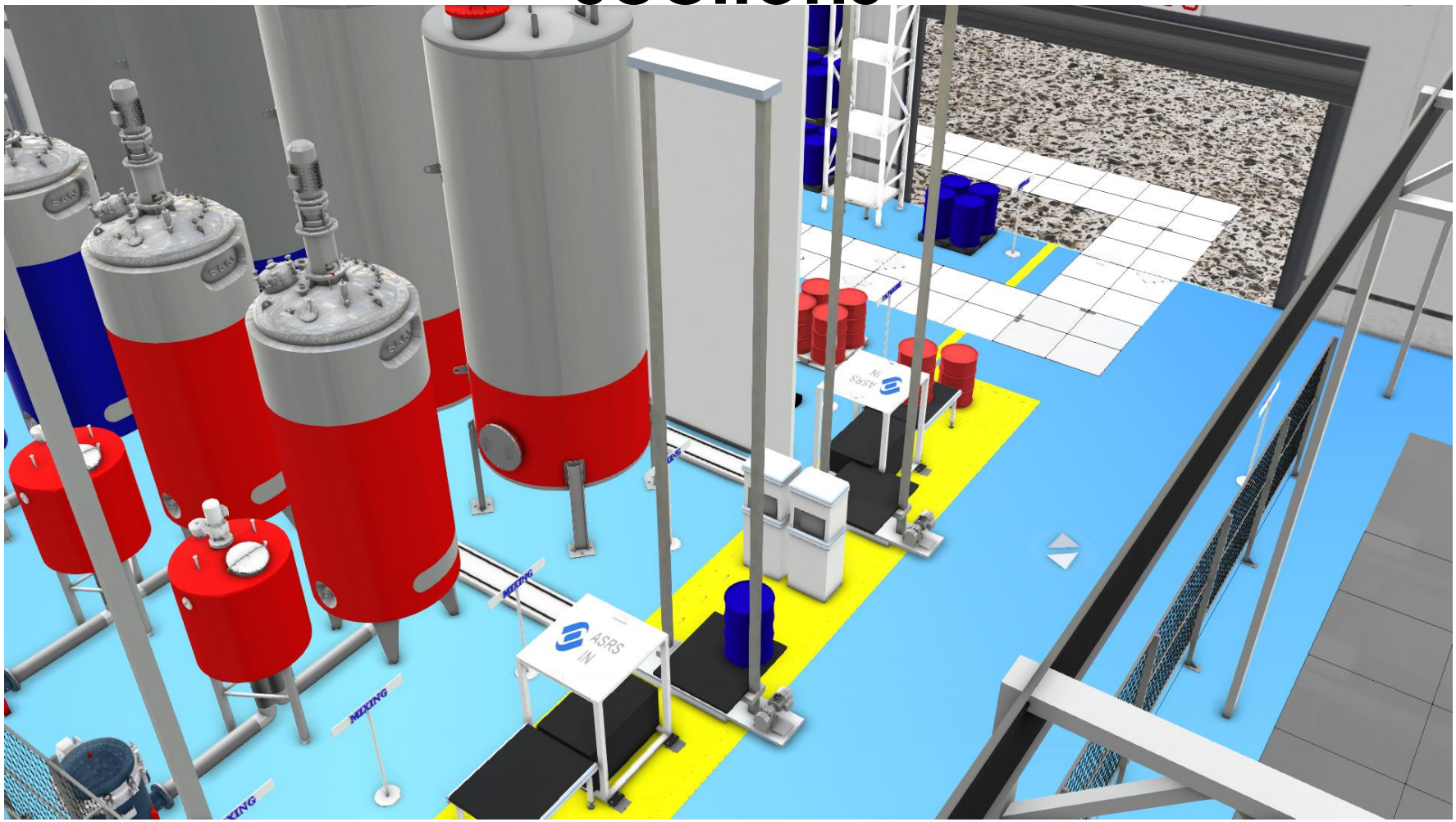
- Total quantity of materials needed/day: **400 tons**
- Truck capacity: **35 tons**
- Approximate number of trucks arriving daily: **12**

AGV carries raw materials to storage section.



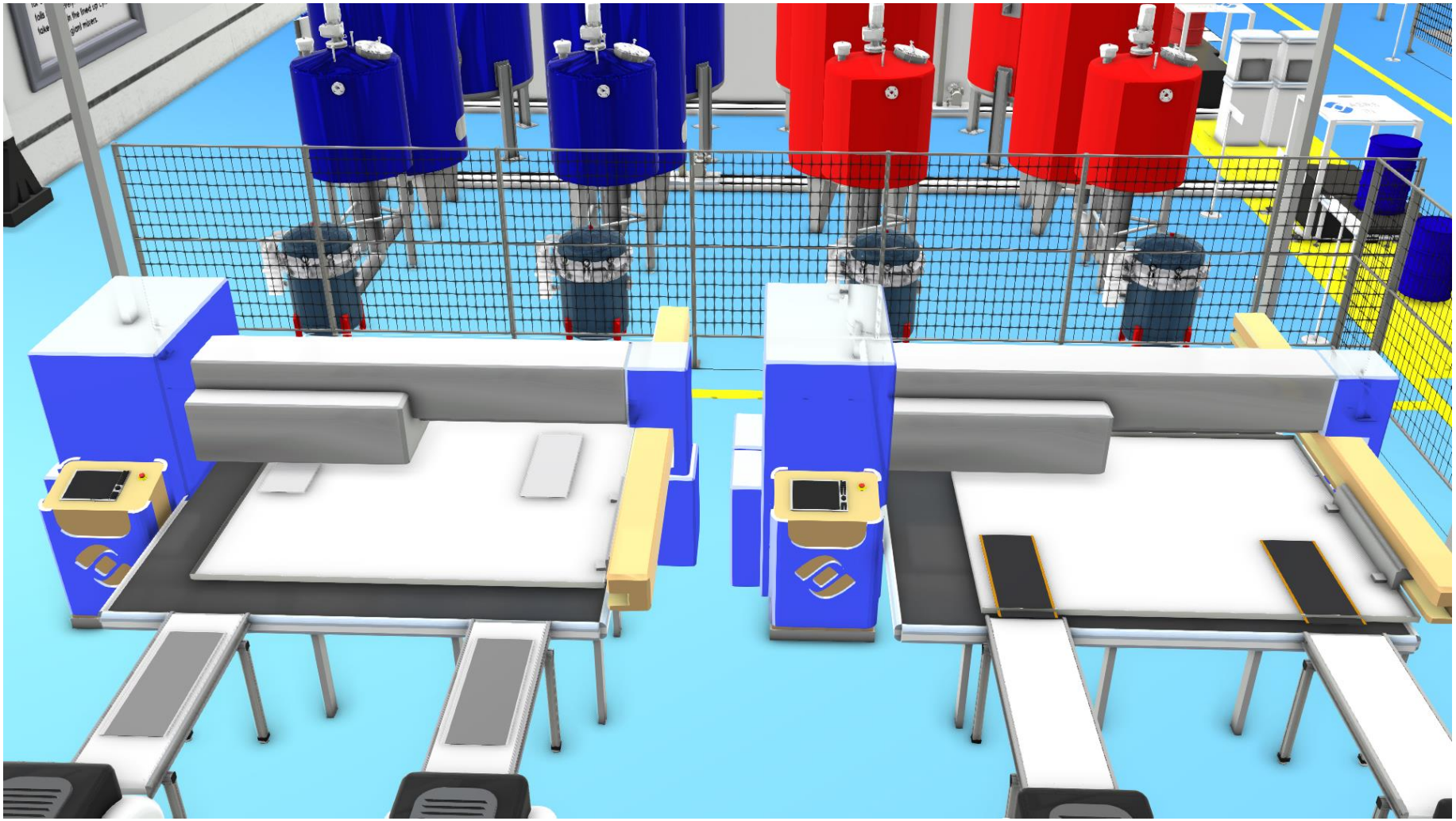
- Rolls of copper and aluminum are 130 meters and can produce 2676 cells.

Material storage and solvent mixing sections



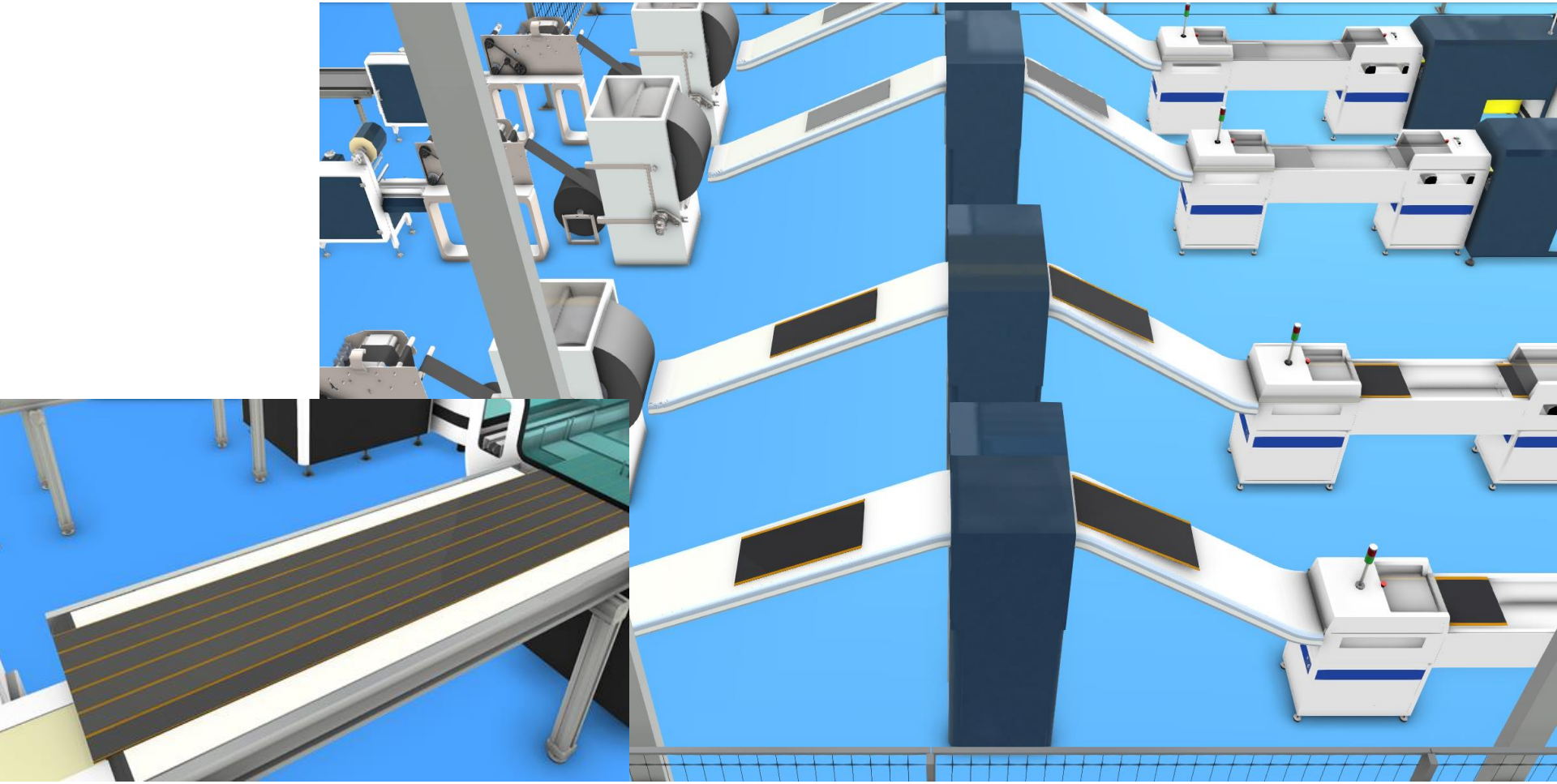
- **Mixing Cycle time: 160 minutes /batch.**
- **Energy consumtion for mixing: 375KWh (Anode) + 750KWh (Cathode)**

Copper and aluminum foils coating



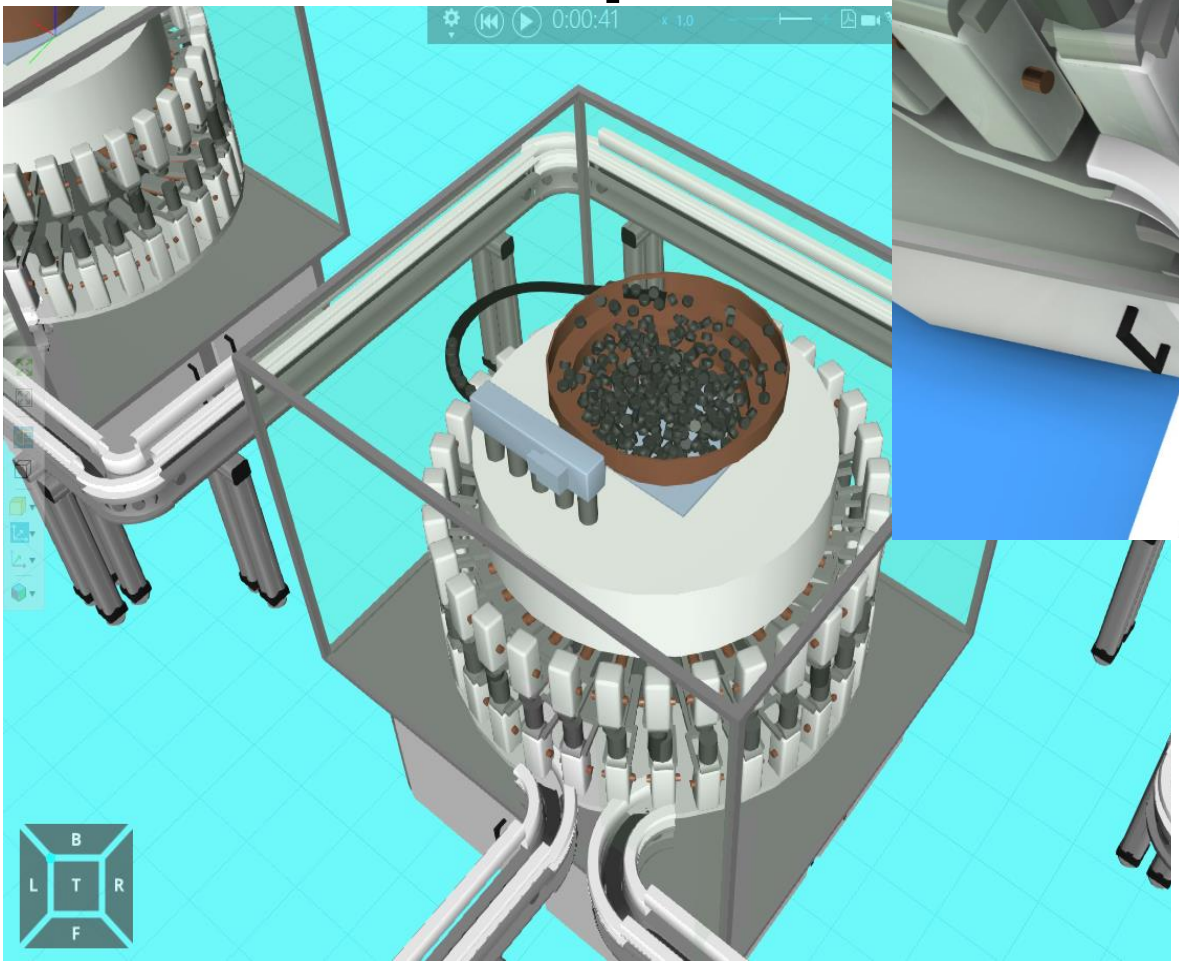
- **Coating and first drying cycle time: 2.2 min/batch.**
- **Heat drying cycle time: 180min/batch.**
- **Energy consumption for 6 coating machines: 6*50KWh**

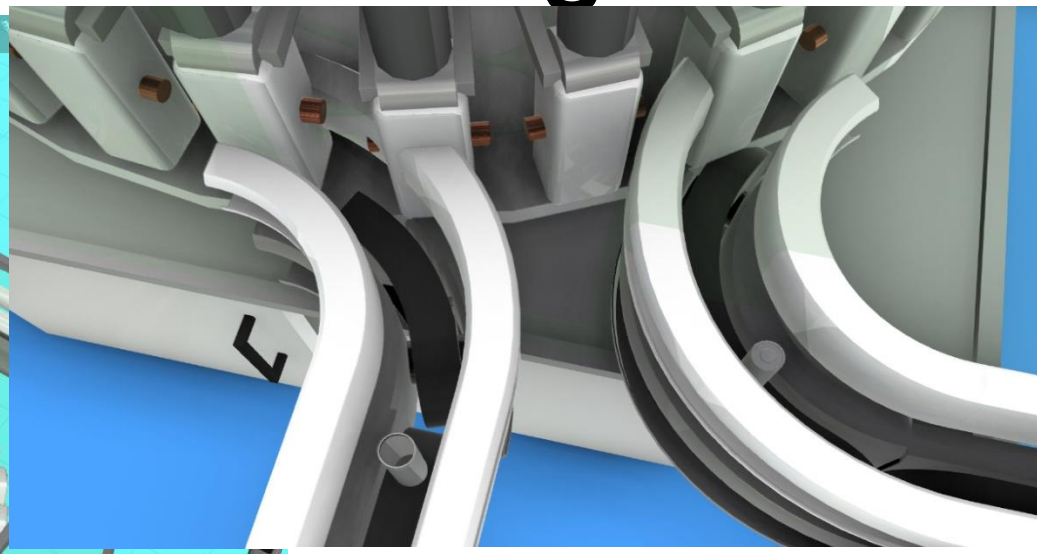
Electrode winding and Calendaring sections



- Electrode calendaring cycle time**: 4,3 min/batch.**
- Electrode slitting cycle time: **1.3 min/batch,**
- Slitting energy consumption: **4*15KWh**
- Energy consumption**: 10*30KWh**

Cup seal and welding

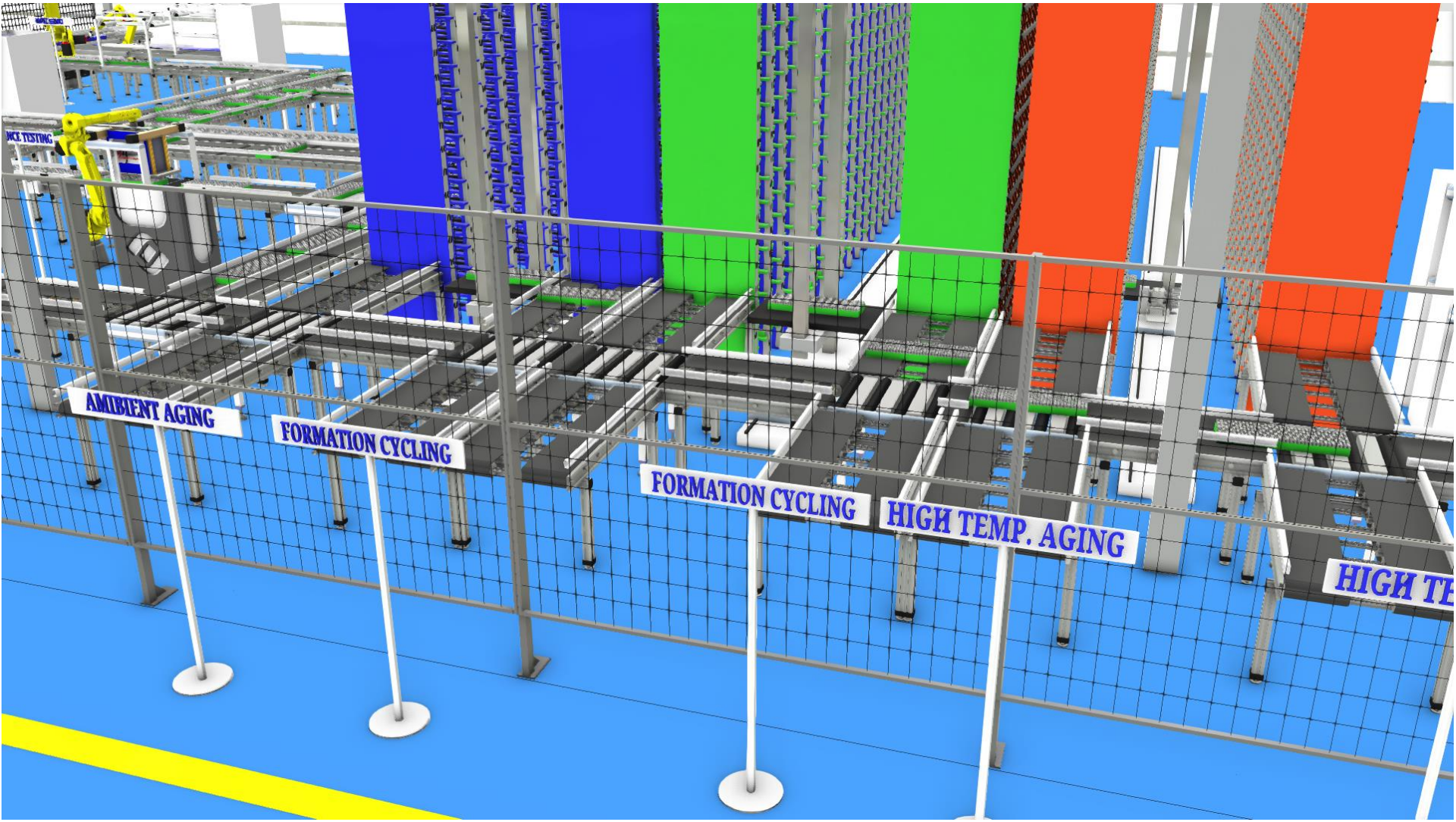




- Cell electrolyte filling cycle time: 0.9 min/batch

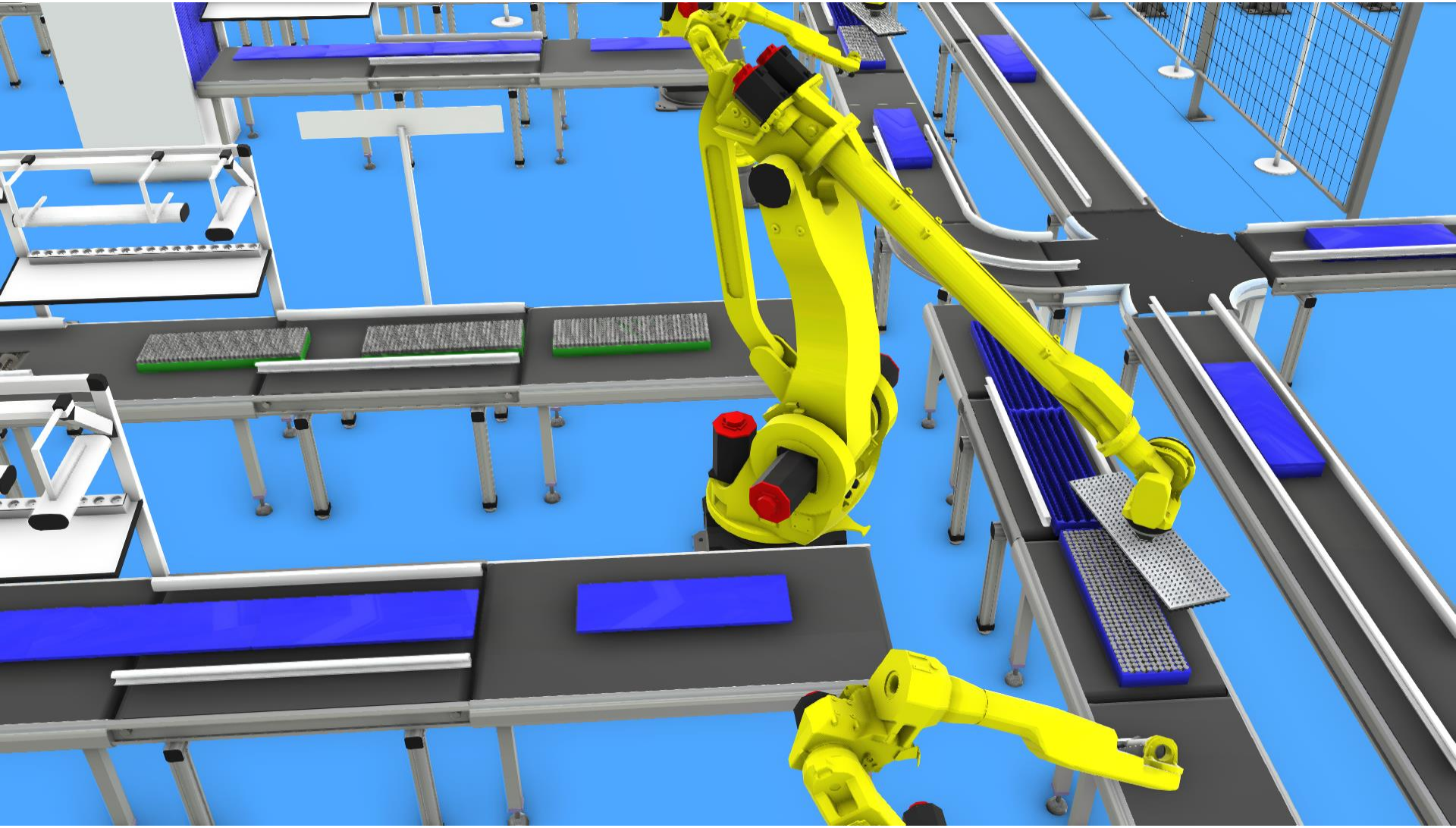
- Cap welding and sealing cycle time: 41.7 min/batch
- Cell electrolyte filling cycle time: 0.9 min/batch
- Cell case sawing energy consumption: 18*4KWh
- Cell case welding consumption: 2*45*3,6KWh

High temp. Aging, Formation cycling and Ambient Aging processes.



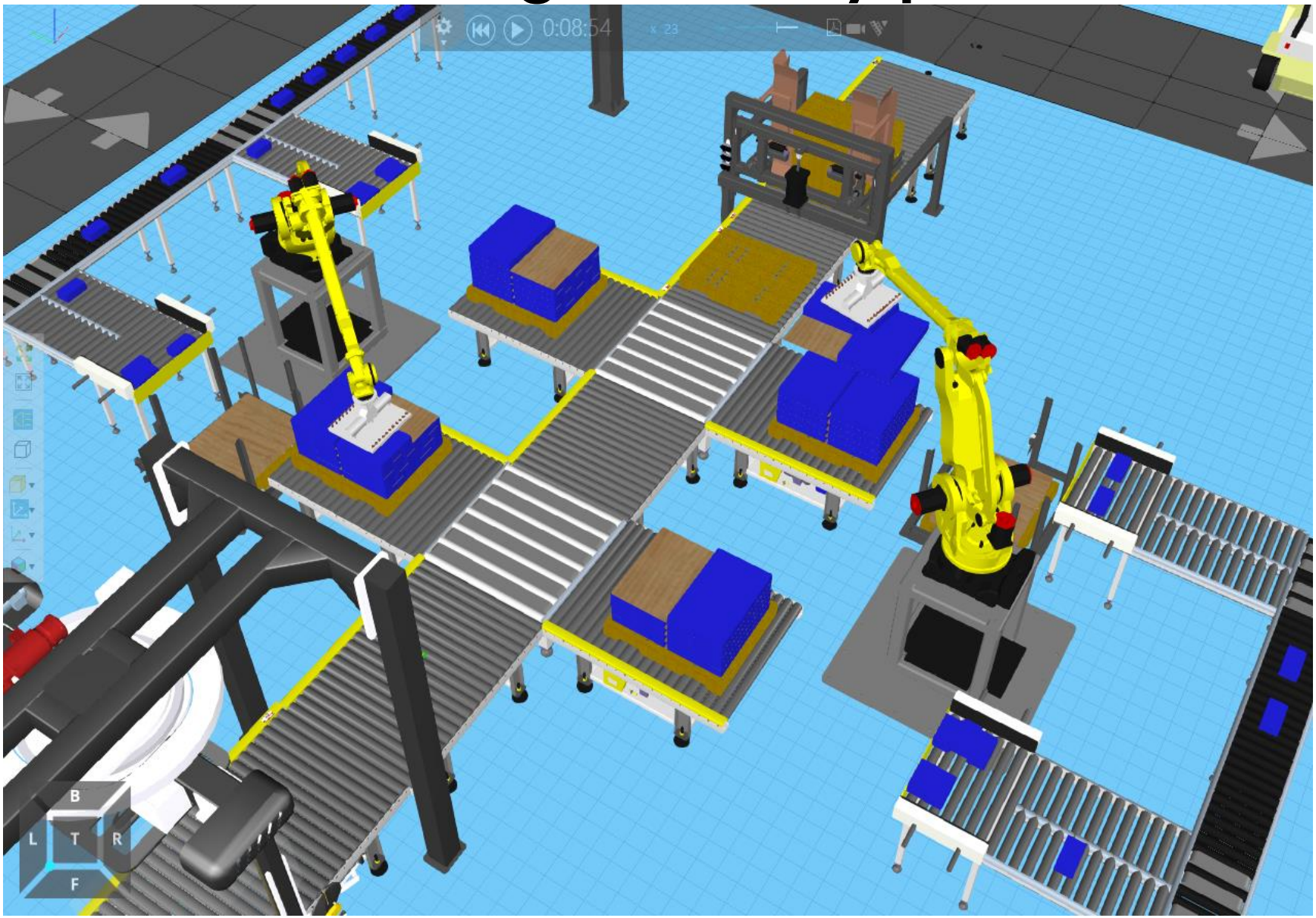
- Formation cycling/charging energy consumption: 21Wh+9Wh+5Wh=35Wh

Module assembly of 35 by 11 cells



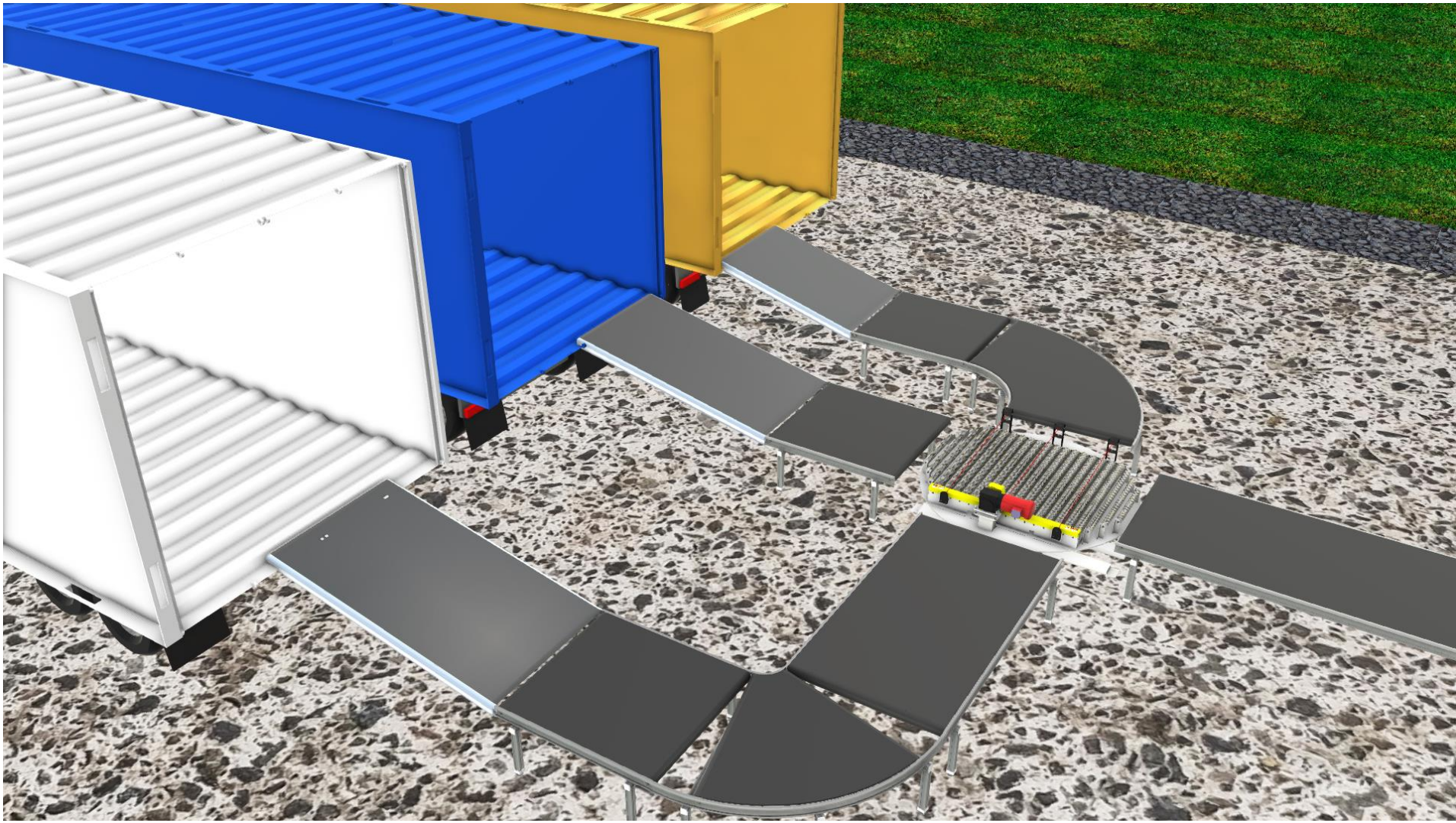
- **Module assembly and welding cycle time: 13.7 min/batch**

Palletizing of battery parks



- **Palletizing & wrapping cycle time: 6.2 min/batch**.

Automatic loading for shipment



Finished battery modules (daily outbound)

- (Modules*module weight)/truck capasity
  = 996*300kg/35 000kg=**8,5 trucks**