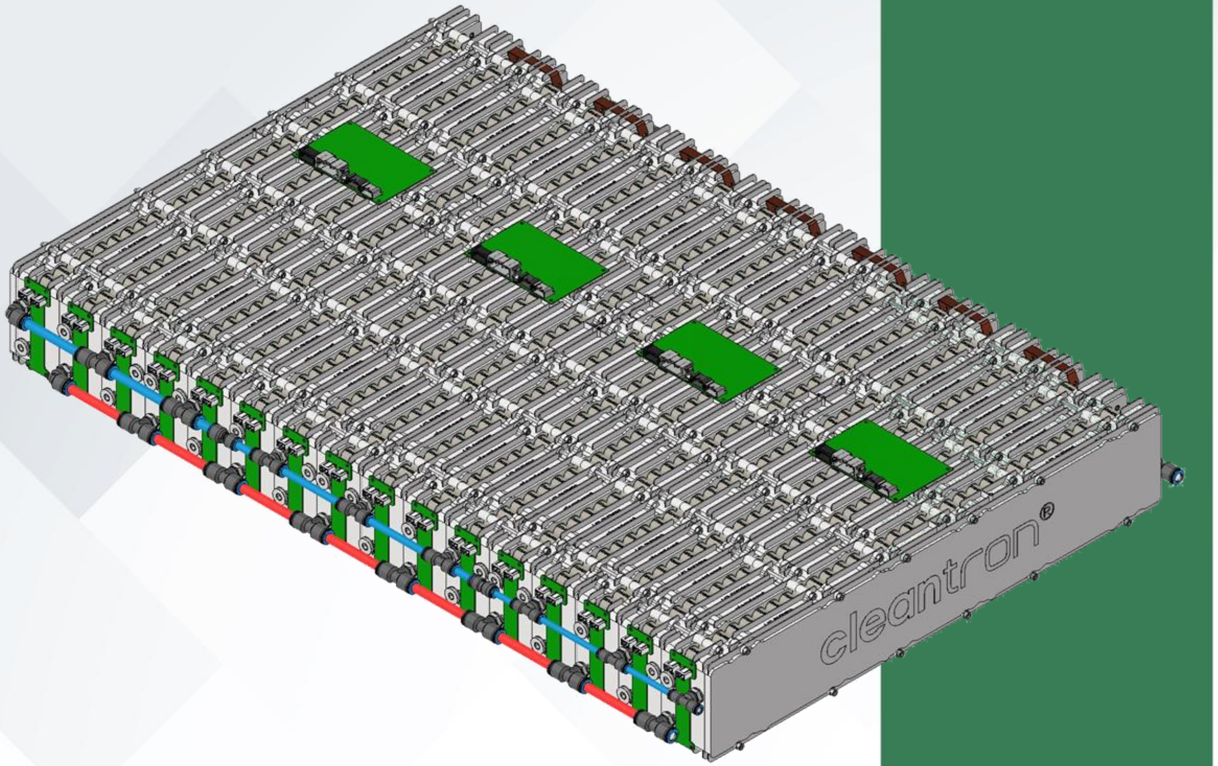
Modular and Scalable Battery Pack Design

Bjorn van de Ven

cleantron
cleantech batteries



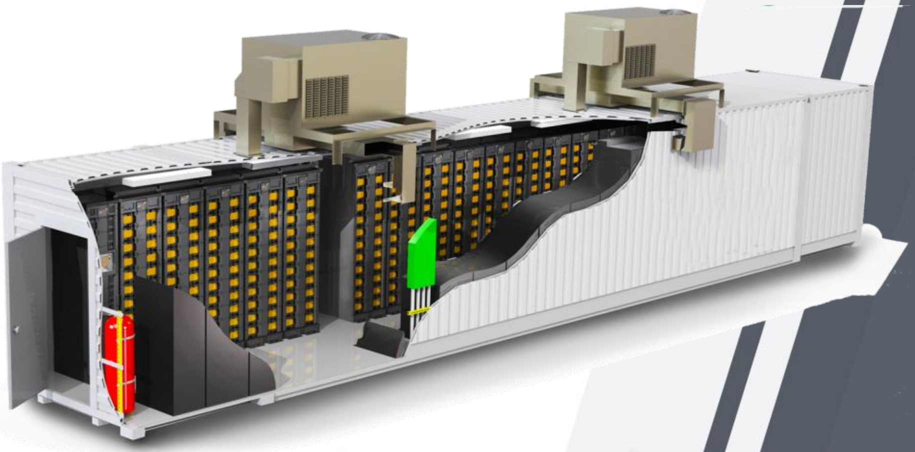
Agenda

- Packaging Space
- Requirement Elicitation
- Concept Development
- Module Design
- Integration Challenges

Packaging Space

How to find the optimal packaging space:

- What is our target vehicle?
- Is there a second life target?



Packaging Space

How to find the optimal packaging space:

- What is our target vehicle? → BMW i3
- Is there a second life target? → Yes, home energy storage

What does this mean for our packaging space?

- Pre-defined volume decided by vehicle chassis and/or Battery Tray
    - Additional volumes within the chassis can be exploited
- Home energy storage would be best to do using small form factor modules

Requirement Elicitation

Besides the packaging space other requirements:

- Thermal Management: Immersion
- Charging Performance: 150kW
- Range: 25% increase
- Energy Density: >200Wh/kg on Pack level

These will help to determine:

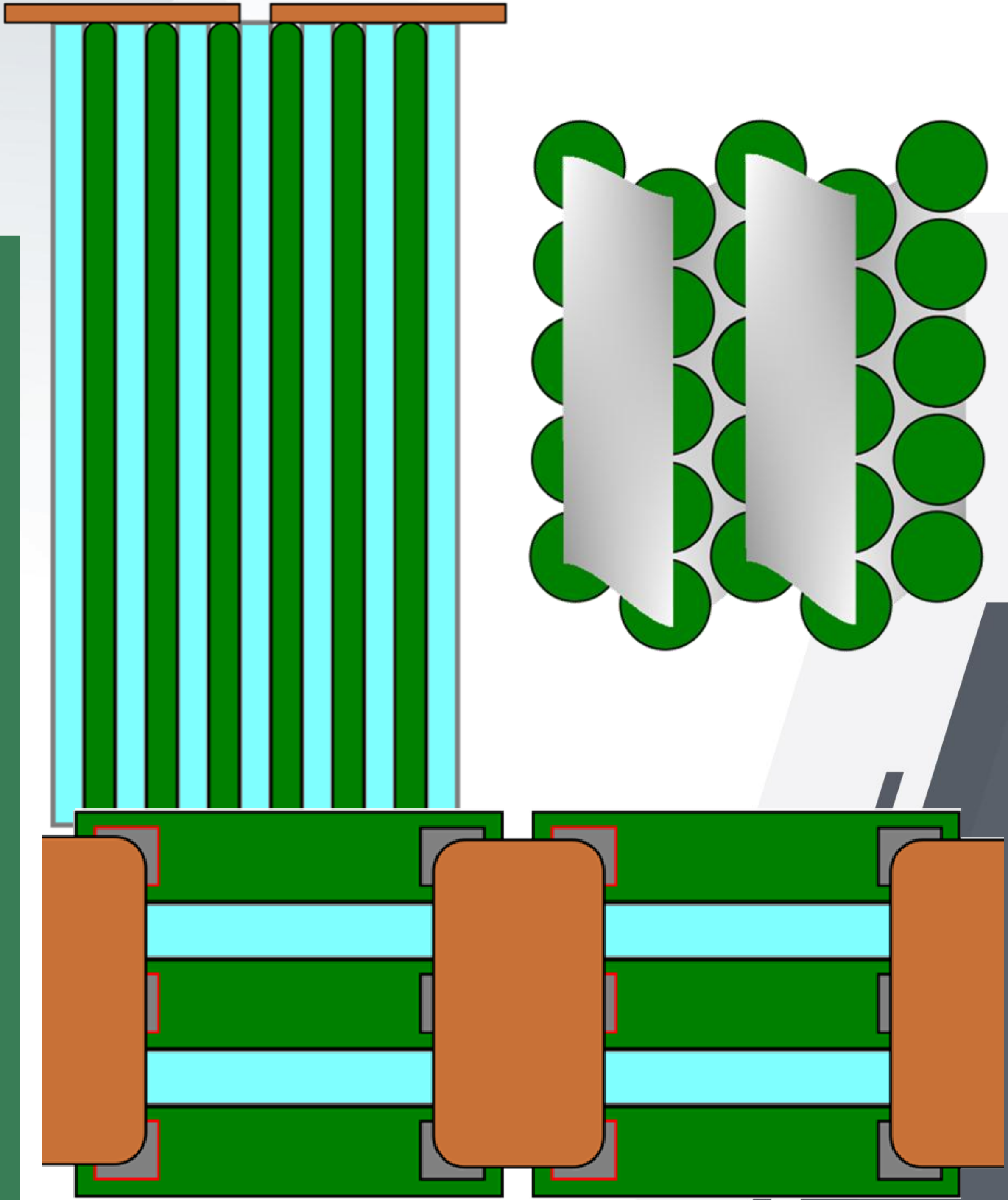
- Cell Type
- Number of Cells
- Sub-division of cells

Module Concept – Cell Type

Three Main Options:
- Cyclindrical
- Prismatic
- Pouch

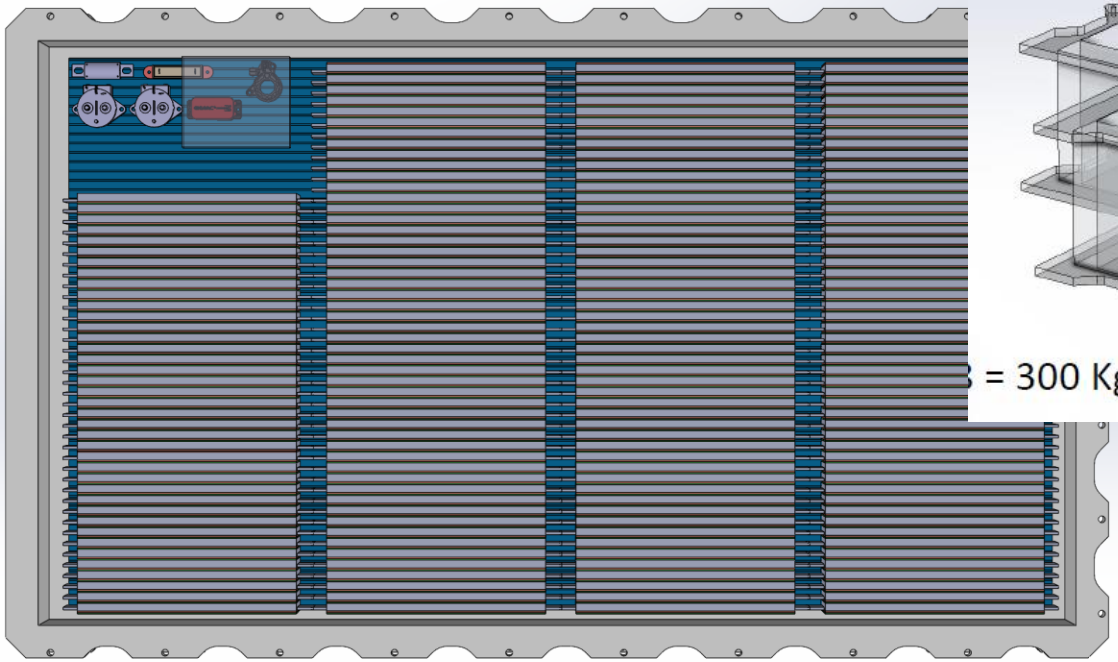
Main choice variables:
- Thermal Design → Immersion Cooling
- Scalability → Small Steps
- Energy Density → Highest possible energy density

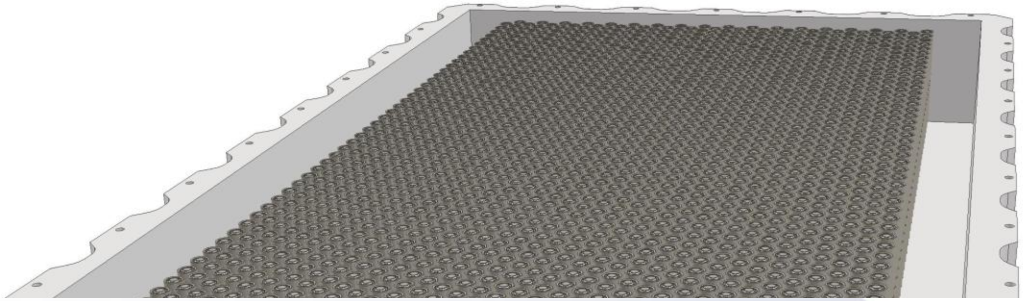
Out of these the cylindrical cells won:
- High energy density
- Compatible with Immersion Cooling
- Scalable

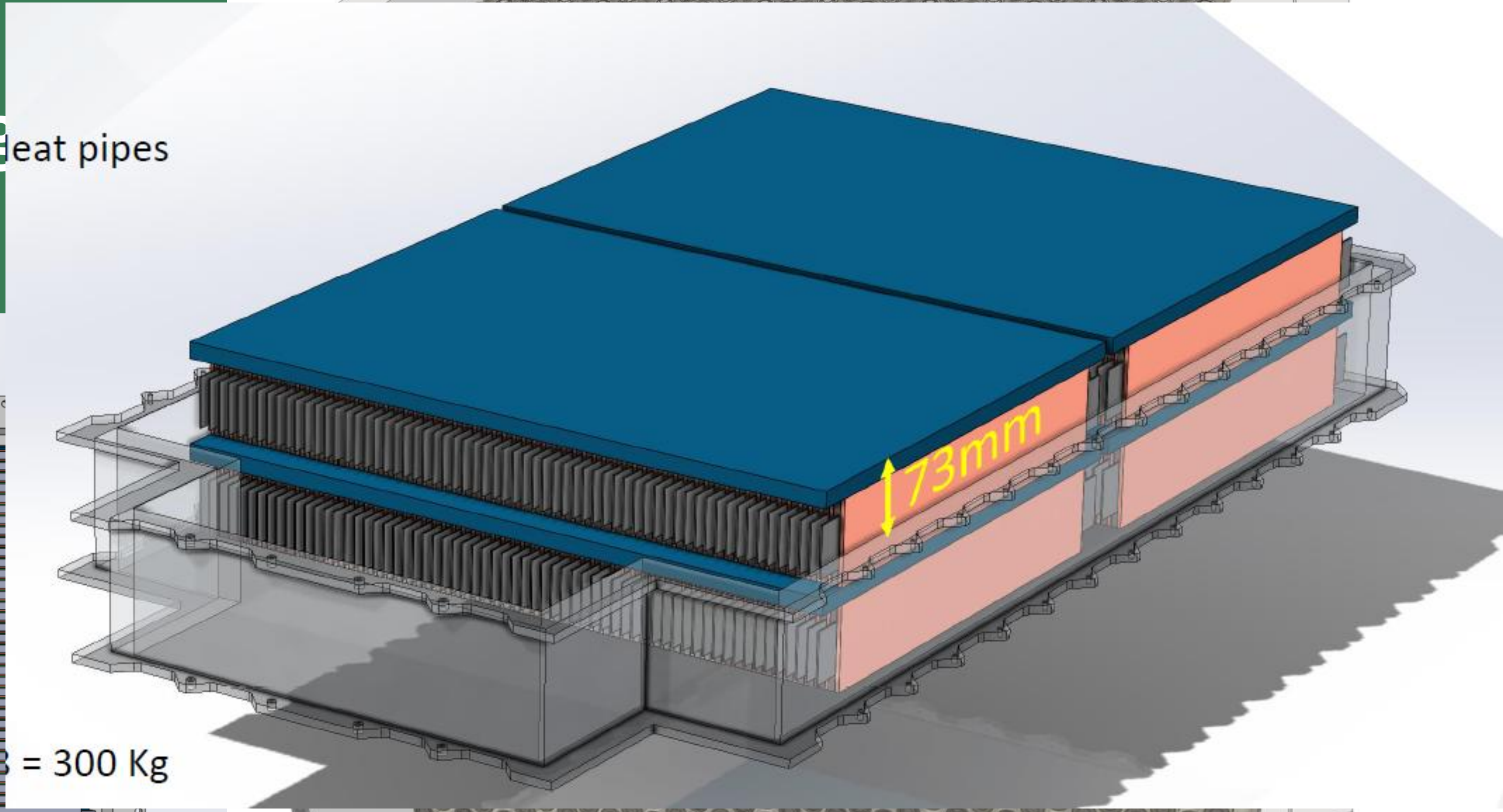


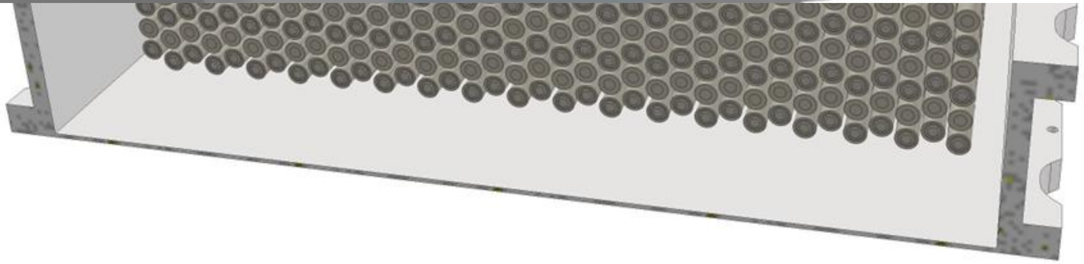
Module Concept – Packag

Various concepts need to be evaluated





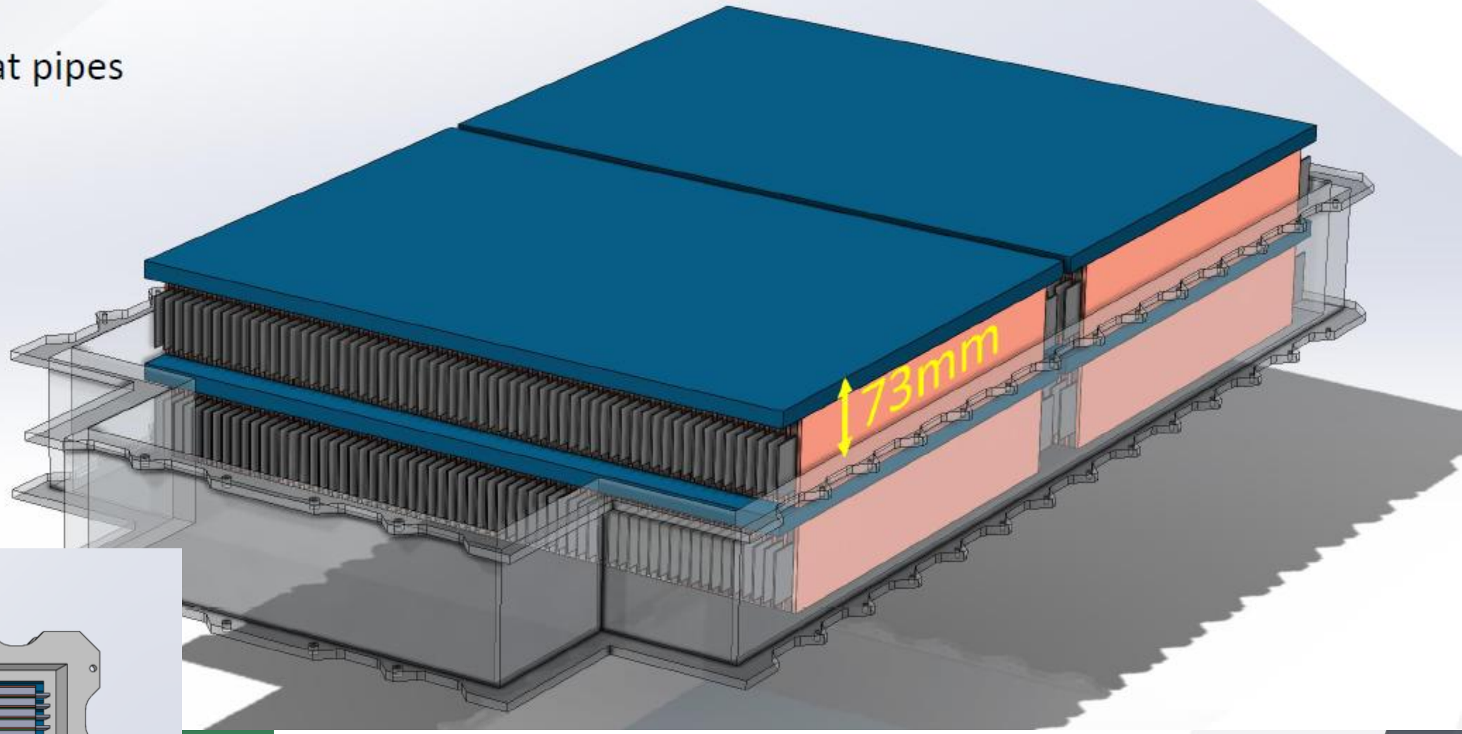


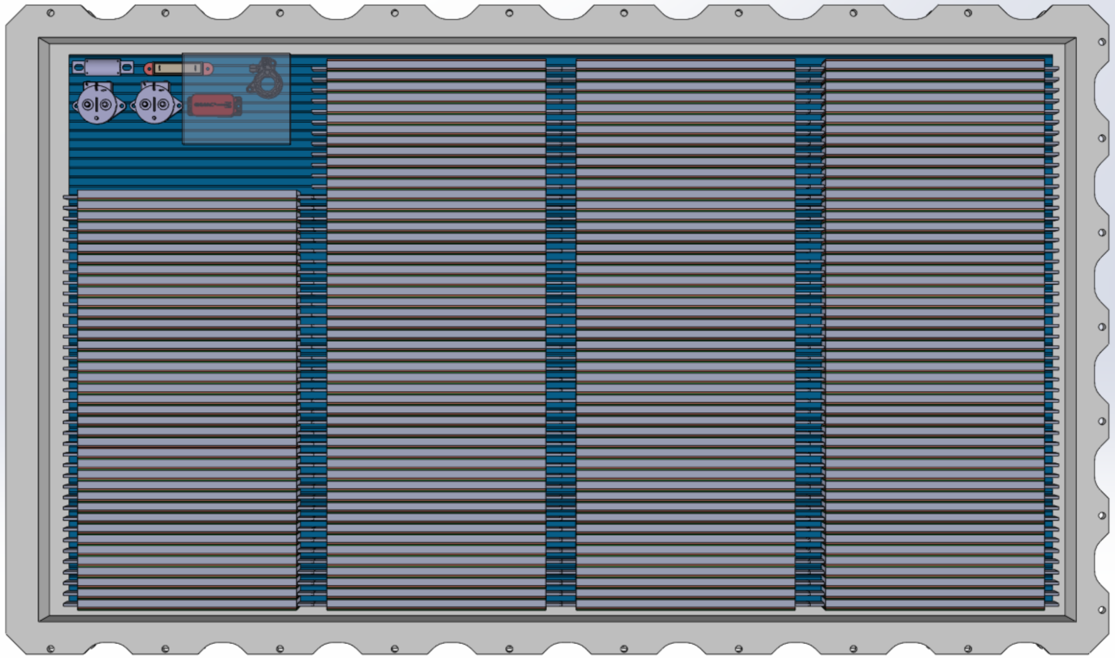


Module Concept – Packag

Various concepts need to be evaluated

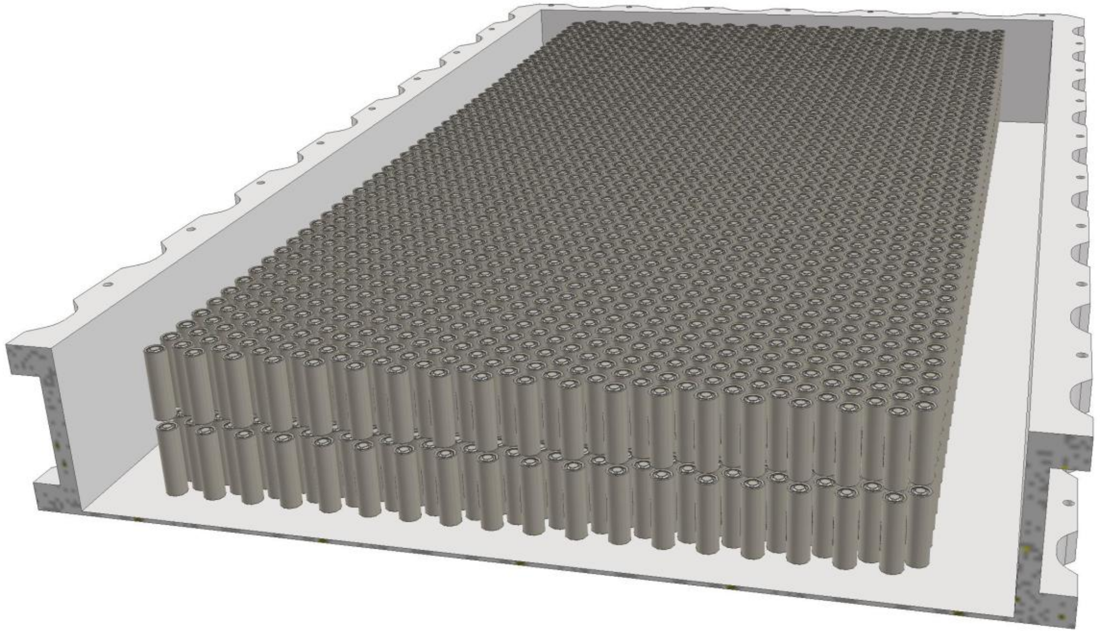
leat pipes

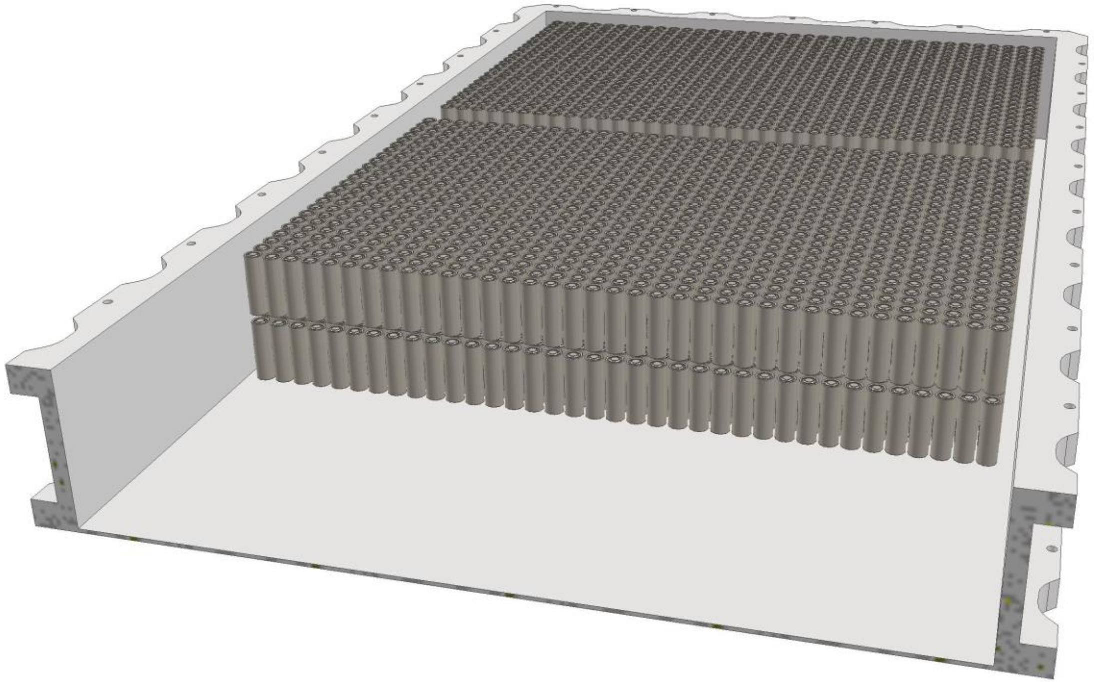


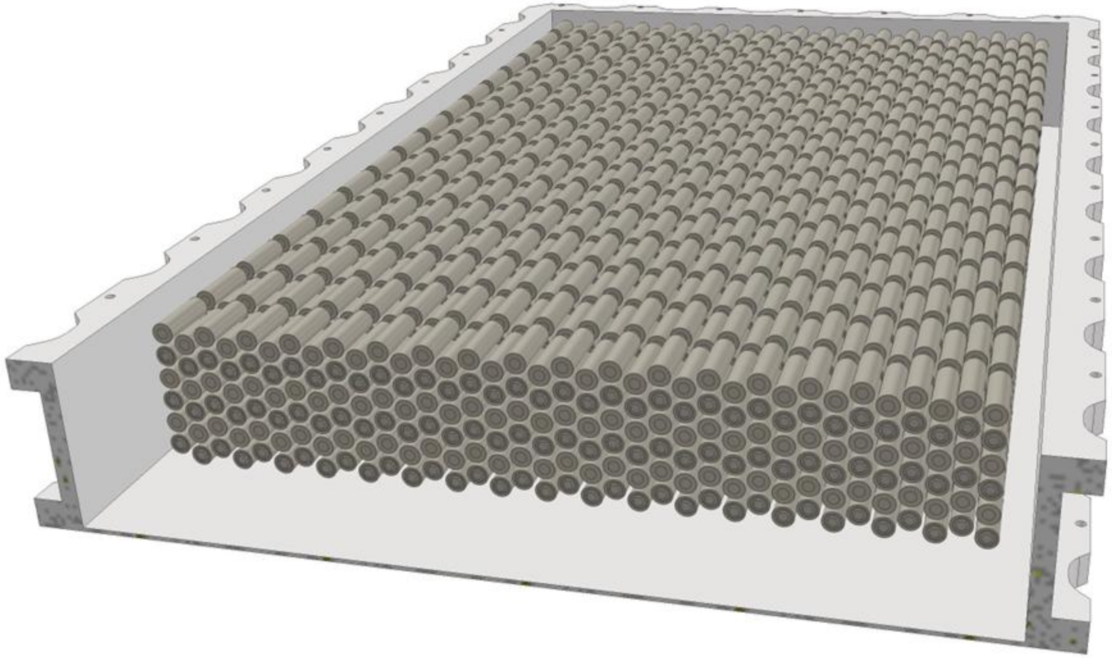


Module Concept – Packaging

Various concepts need to be evaluated







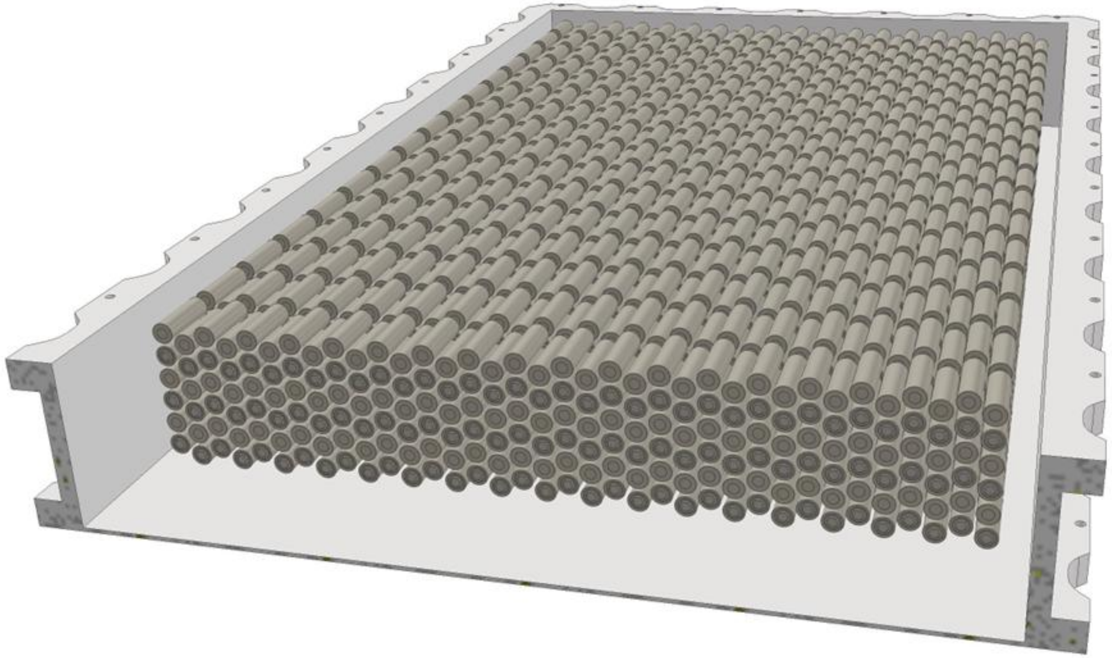
Module Concept – Packaging

Various concepts need to be evaluated

One Remained, in conjuncture with the cell type discussion above!

Horizontal 21700 cells:

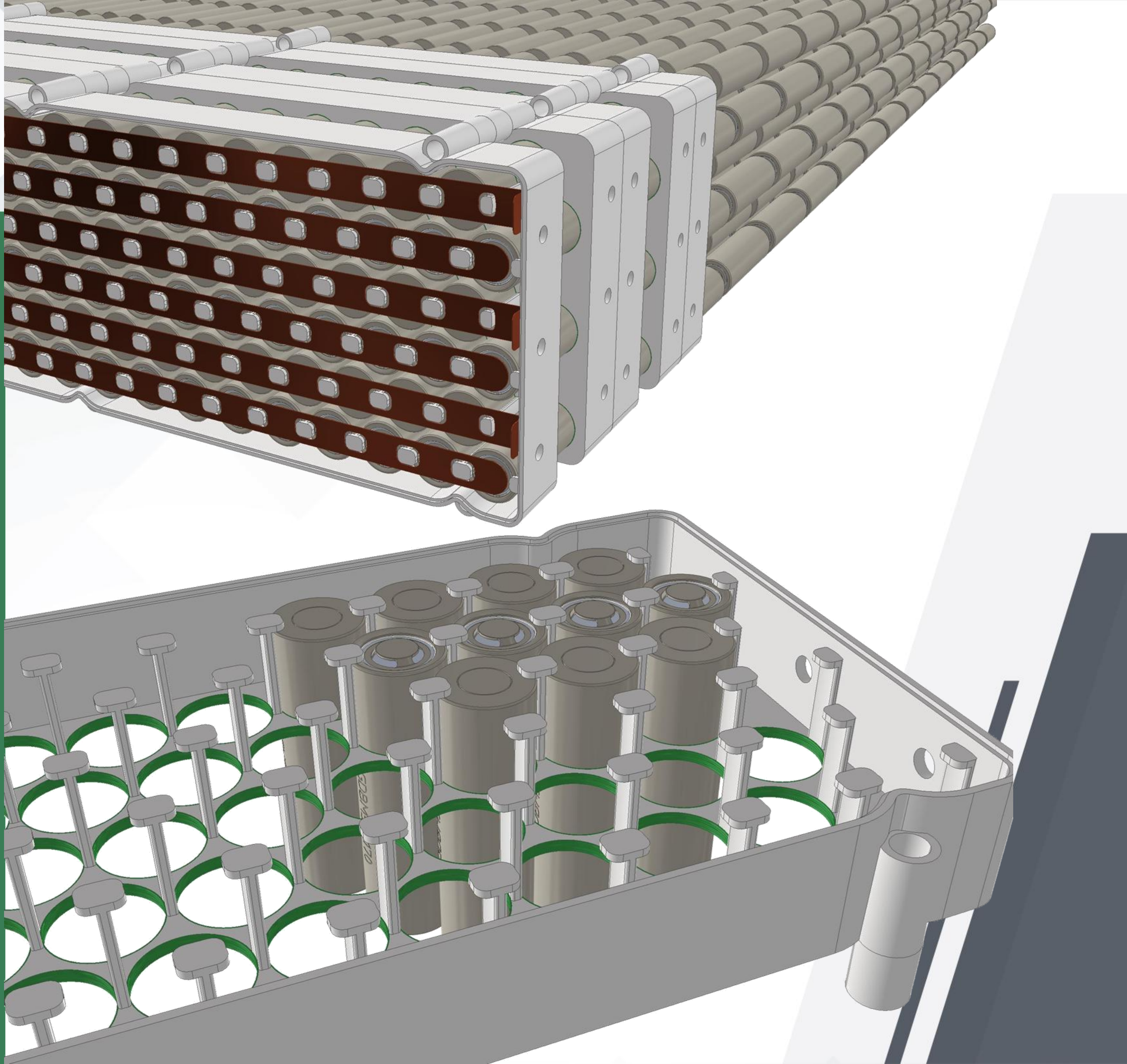
- **High Energy Density**
- **Allows for Fluid Paths**
- **Easily Scalable**



Module Design

After settling on a concept:

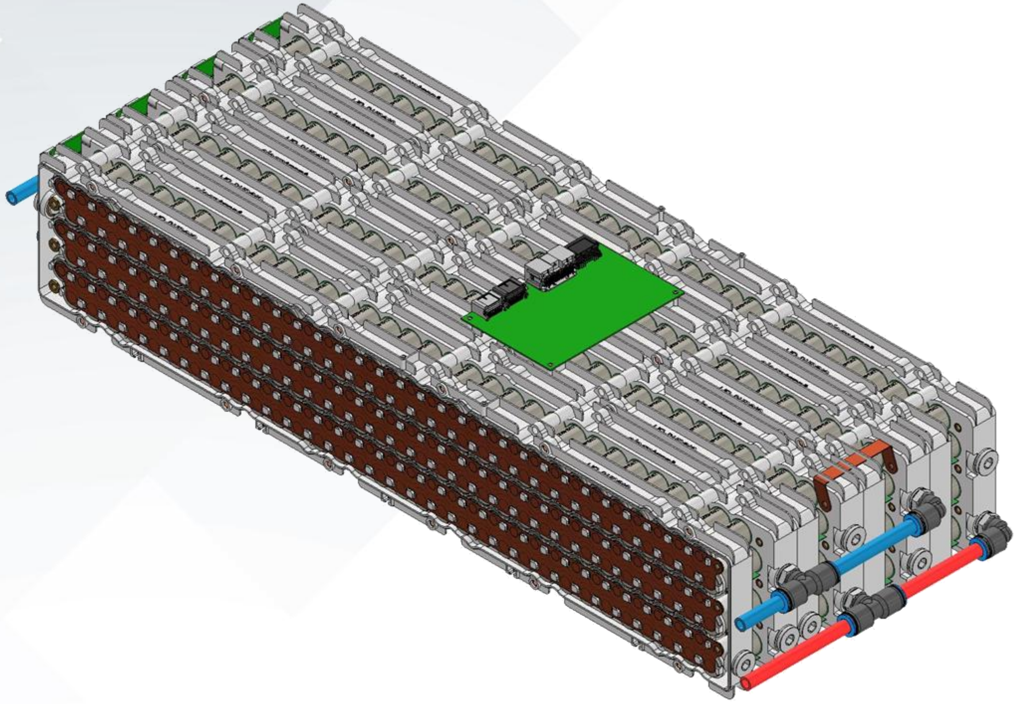
- Start sketching design concepts
- Various thermal design variations

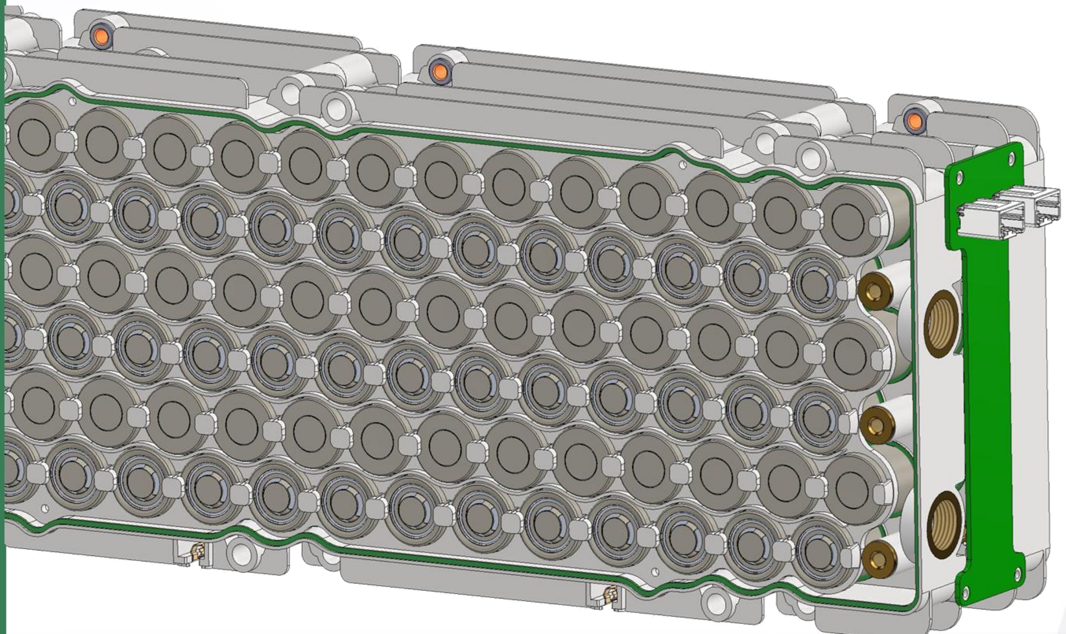


Module Design

After settling on a concept:

- Start sketching design concepts
- Various thermal design variations

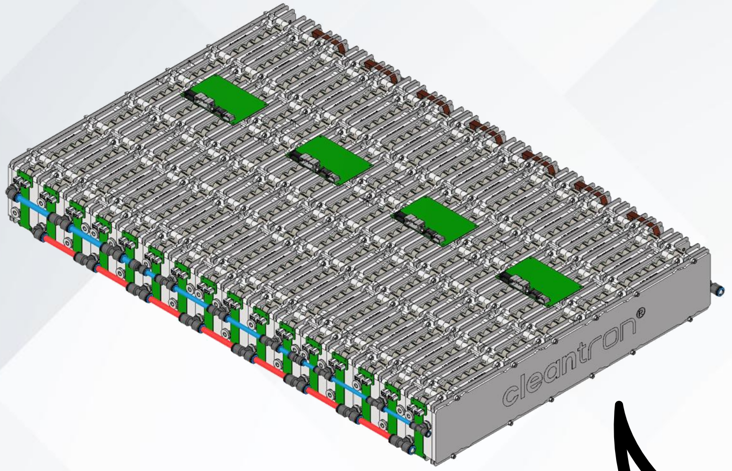




Integration Challenges

- Assembly Order
  - Sealing
  - Welding
  - Connections
- Assembly Cost
- Design for Assembly, Repair, Reuse and Disassembly

Any Questions?



HELIOS Project –

Innovative hybrid modular pack design with HP & HE cells to cope with different driving styles and use cases

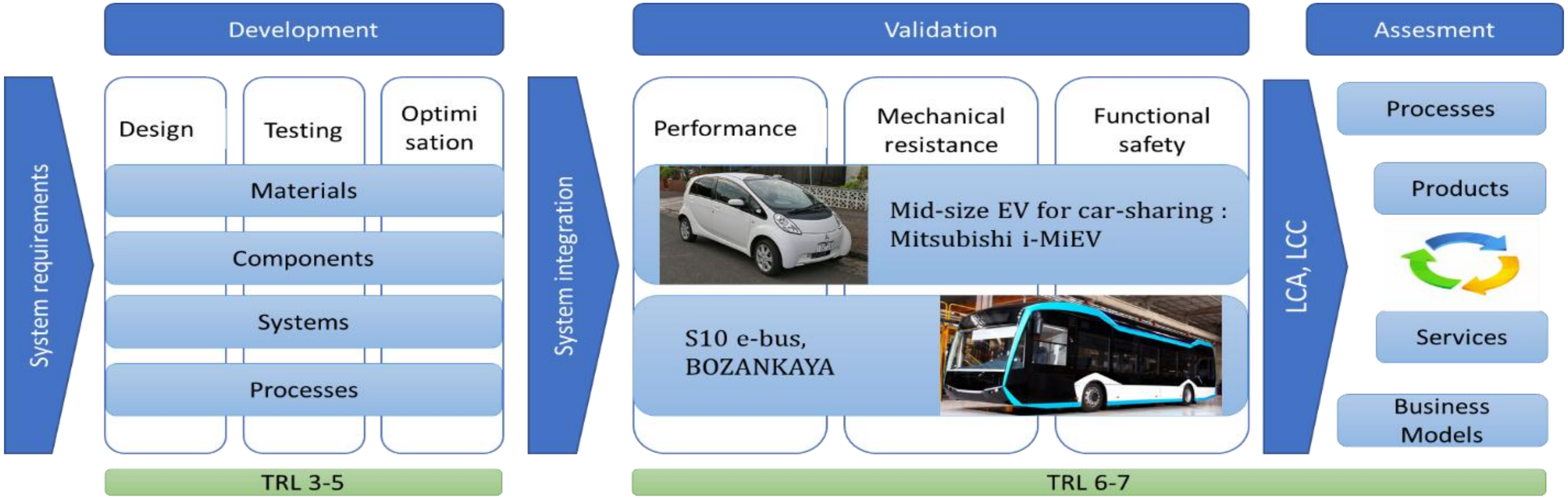
prepared for Collabat Cluster Workshop, 26th Nov 2024 in Barcelona

by Corneliu Barbu, Aarhus university

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 963646

Helios Project Overview

Methodology followed in Helios project



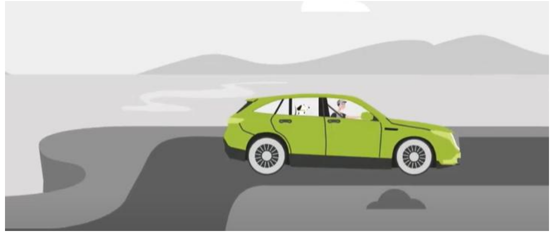
Project specific goals

- 30% reduction of weight and 20% reduction in volume for both EV and e-bus application, corresponding to energy densities of 240 Wh/kg (500 Wh/L) and 500 W/kg (1000W/L) , which represents a 50% improvement compared to current energy density levels provided by TESLA (Model 3)
- Charging of a small EV (~80% SoC) in approx. 6 minutes with superfast-charging at 360kW
- Extend lifetime of Helios battery pack up to 300,000km or 20 years
- Improve circular economy processes within manufacturing, assembling, disassembling and recycling to min 20% Life Cycle Analysis improvement

➢ 2 Prototypes as demonstrators in Mitsubishi city car and Bozankaya E-Bus

Why “hybrid” battery pack with 2 chemistries?

How confident are you that a given EV model meets **YOUR** customer demands?



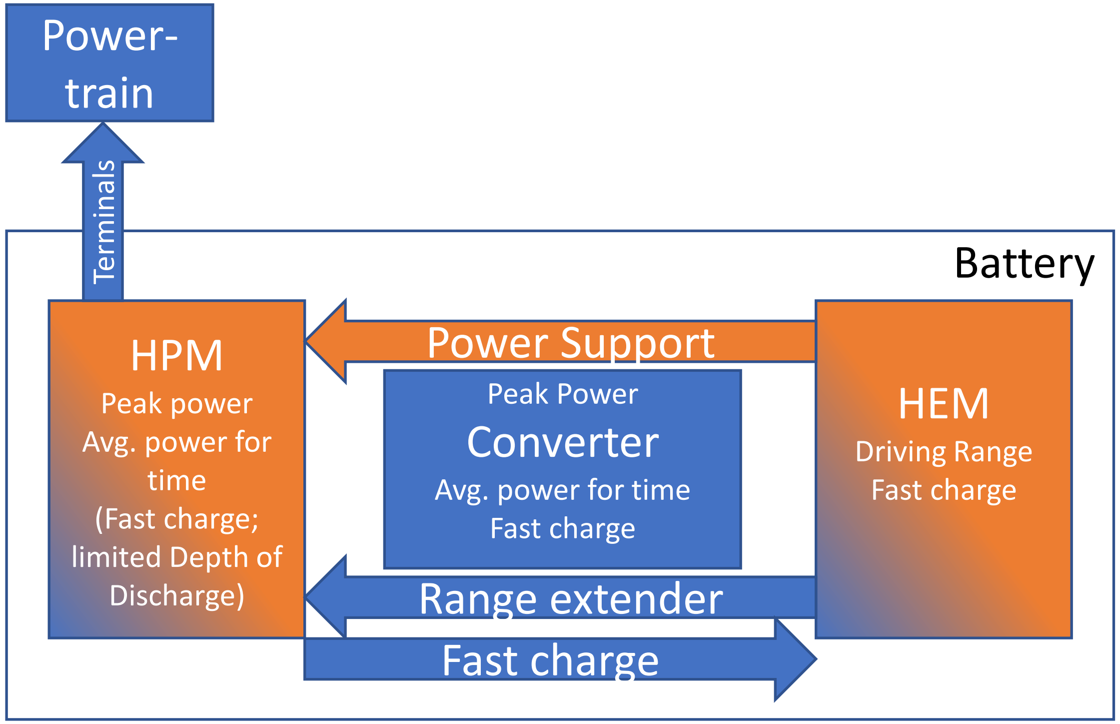
- Are you more a sporty driver, not too long distances, but you want to re-charge your EV battery in < 10 minutes?

- … or a sales rep, travelling long distances per day, but then you stop at your customer site or make an overnight… so need larger driving range, but then have enough time for recharge
- … or…or…or…

- Hence customizing the battery pack already according to the end-use and different driving style needs would be the solution
- Helios hybrid battery pack is addressing this issue

Hybridization Concept

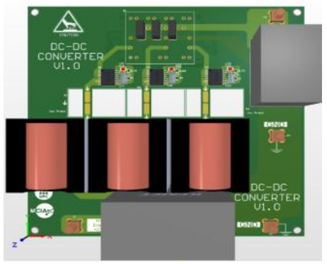
- Combination of **High-Power** LTO cells (**more power & performance in specific cycle conditions**) with **High-Energy** NMC cells (**more range**) cells allows broad application in many use cases and BEVs
- Helios concept with variable configuration of HP & HE modules in series and parallel = highly flexible and scalable



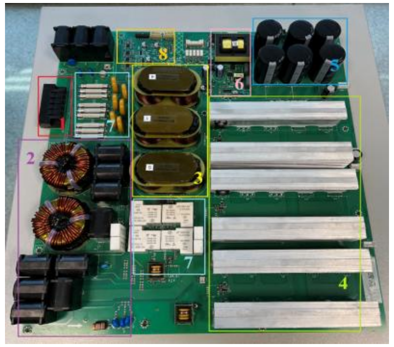
Helios power electronics innovation

To shift load between the two sides of the Helios battery pack and guarantee an effective balancing of power, we need additional power electronics architecture

- To avoid cell degradation and extend battery lifetime

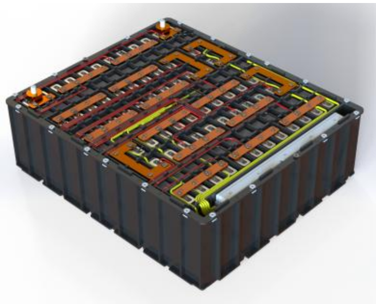


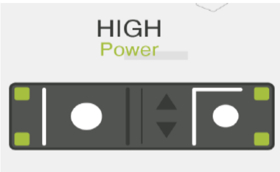
- Specific power converters to enable superfast-charging up to 360kW (demonstrating in Helios prototype) = enable to recharge a small EV in less than 10 minutes

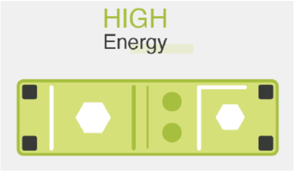


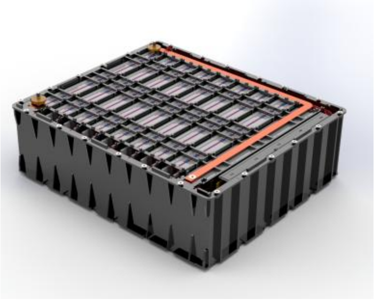

Hybrid Modular Concept

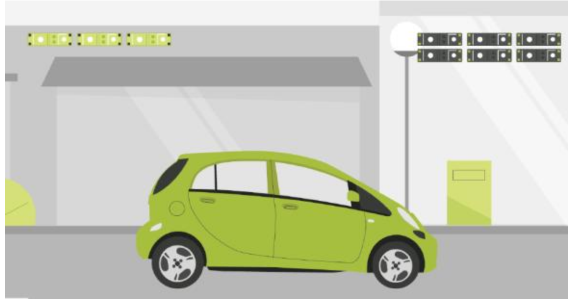
- The High-Power and the High-Energy modules have the same size and shape, so easy to (re)configurate and assemble in a defined Helios battery pack

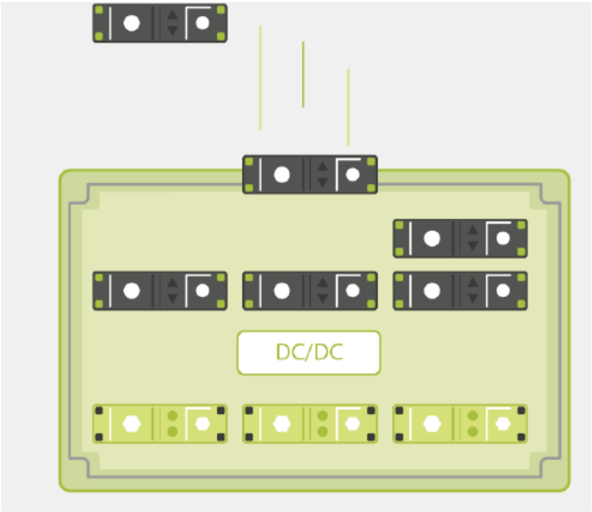




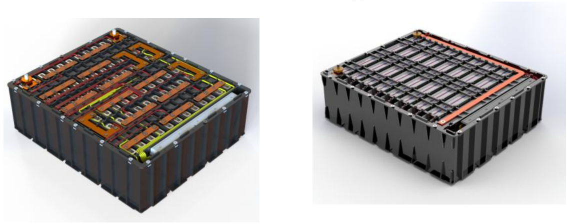




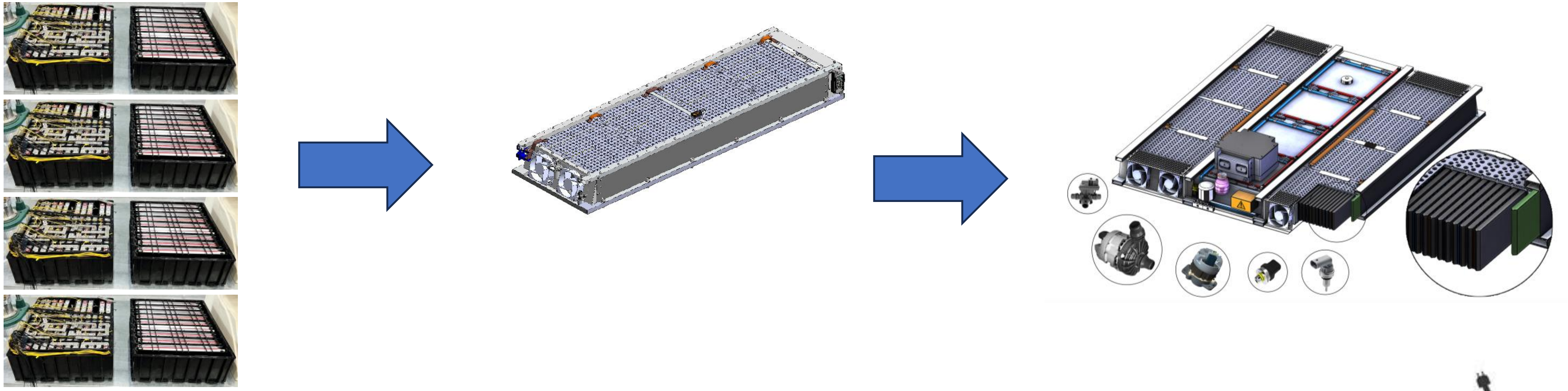




Sub-packs



- As the Helios modules, both High Power as well as High Energy module have same size and shape, these can be easily produced in scale-up production (using plastic molding of several hundreds to thousand pieces per year).
- Always 4 same type modules (HE or HP) will go into 1 “Subpack” with its thermal mng circuit
- For the small passenger car, we wil have 3 “subpacks” with the DC/DC and wireless BMS, etc



Outlook

- In the final validation of the Helios hybrid modular battery concept, we will show our results in two use-case towards end of 2024, on the extreme ends of needs and driving styles
- A small EV (Mitsubishi iMiEV) and a fullsize E-Bus from Bozankaya

THANK YOU!

Lightweight design for safer and efficient cell-to-pack

Eduardo Miguel (Ikerlan S. Coop)

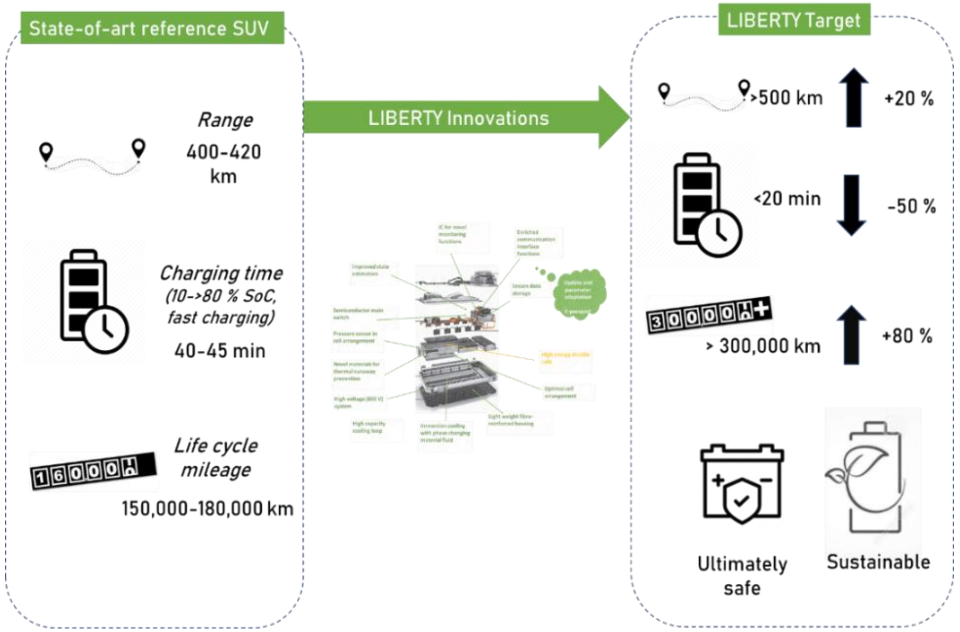
Lightweight Battery System for Extended Range at Improved Safety

LIBERTY has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 963522.
The document reflects only the author's view, the Agency is not responsible for any use that may be made of the information it contains.

LIBERTY – Project Overview

- O1: To achieve a range of 500 km on a fully charged battery pack
- O2: To achieve a short charging time
- O3: To achieve an ultimately safe battery system
- O4: To achieve a long battery lifetime
- O5: To achieve sustainability over the battery pack entire life cycle

Parameter	Benchmark: EQC 2019	Target: LIBERTY EQC
Battery system capacity [kWh]	80	96
Battery system weight based on 80 kWh battery capacity [kg]	650	520
Max. charging power [kW]	110	350
Charging window 10-80% SoC [min]	40	18
Range (WLTP) [km]	417	500
Battery life (no. of cycles to 80% DoD)	500	1000
Mileage [km]	160,000	>300,000



LIBERTY – Why a cell to pack?

- O1: 500 km range
- O2: 18min charging time
- O3: Safe battery system
- O4: Long battery lifetime

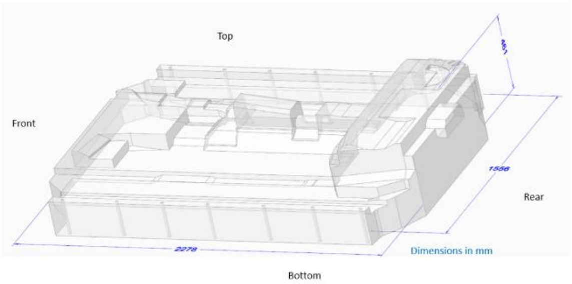
- O1: High energy density
  - Efficient space utilization & Lightweight materials
- O2: Effective cooling
- O3: TR reinforced measures
- O4: Propper temperature control

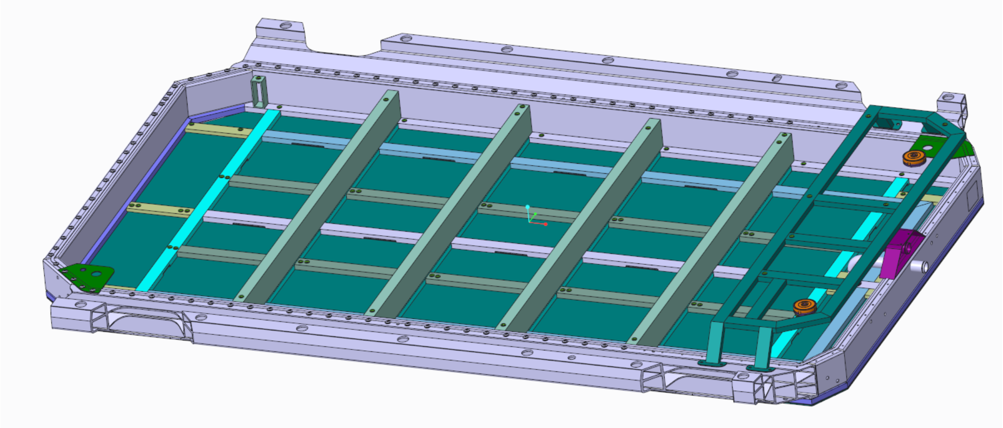
Parameter	Benchmark: EQC 2019	Target: LIBERTY EQC
Battery system capacity [kWh]	80	96
Battery system weight based on 80 kWh battery capacity [kg]	650	520
Max. charging power [kW]	110	350
Charging window 10-80% SoC [min]	40	18
Range (WLTP) [km]	417	500
Battery life (no. of cycles to 80% DoD)	500	1000
Mileage [km]	160,000	>300,000

LIBERTY – Why a cell to pack?

- Efficient space utilization & Lightweight materials
- Effective cooling
- TR reinforced measurements
- Propper temperature control

How much energy could fit in the existing EQC frame?





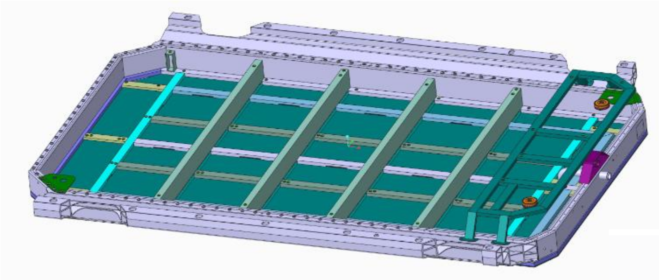
LIBERTY – Why a cell to pack?

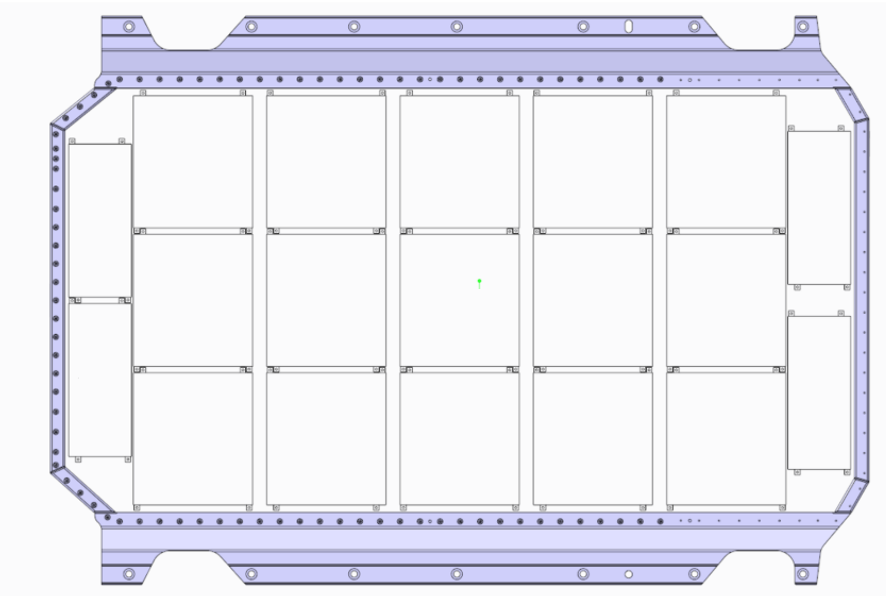
- Efficient space utilization & Lightweight materials
- Effective cooling
- TR reinforced measurements
- Propper temperature control

A cell to pack is the more energy dense solution!

86,7KWh/800V system

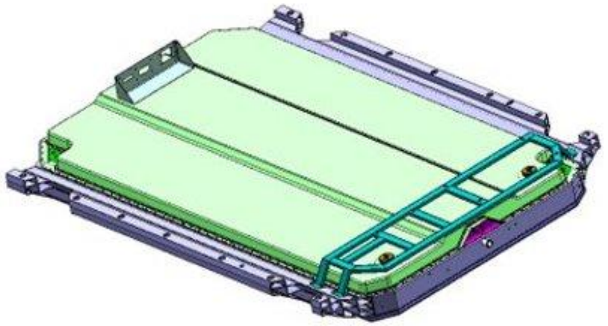
What else can we do?

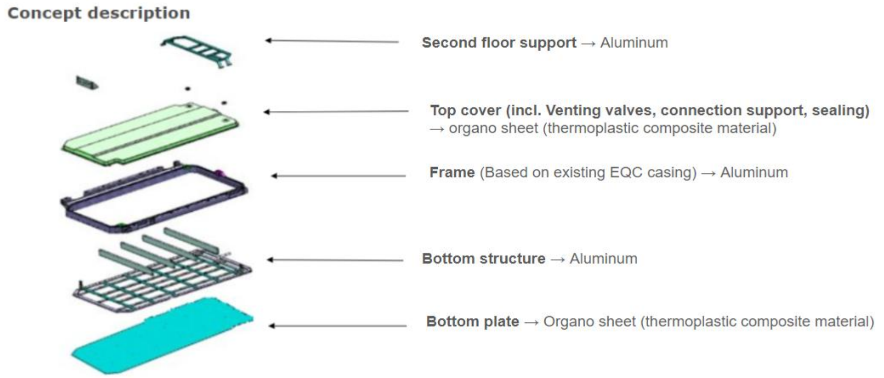




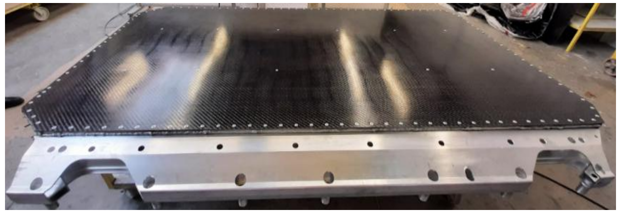
LIBERTY – Lightweight materials

- Efficient space utilization & Lightweight materials
- Effective cooling
- TR reinforced measurements
- Propper temperature control





- State-of-the-art aluminium battery casing large parts replaced by composite parts
  - Reduction in weight and environmental footprint

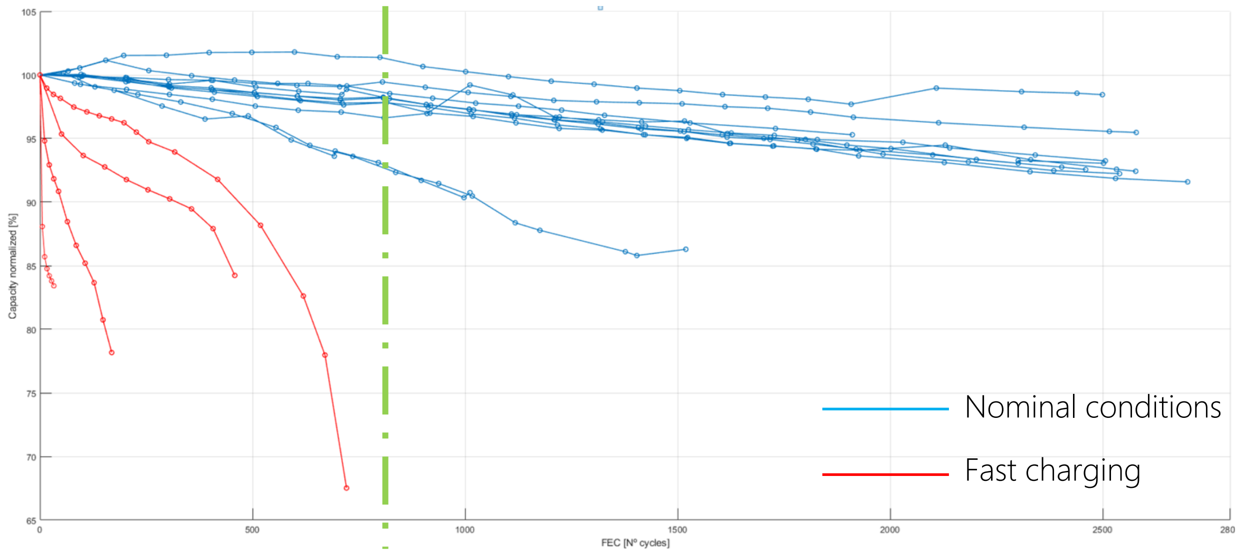


LIBERTY – Efficient cooling

- Efficient space utilization & Lightweight materials
- Effective cooling
- TR reinforced measurements
- Propper temperature control

- Remember that…
  - 18min charging time
  - Safe battery system
  - Long battery lifetime

So how we make cooling effectively?



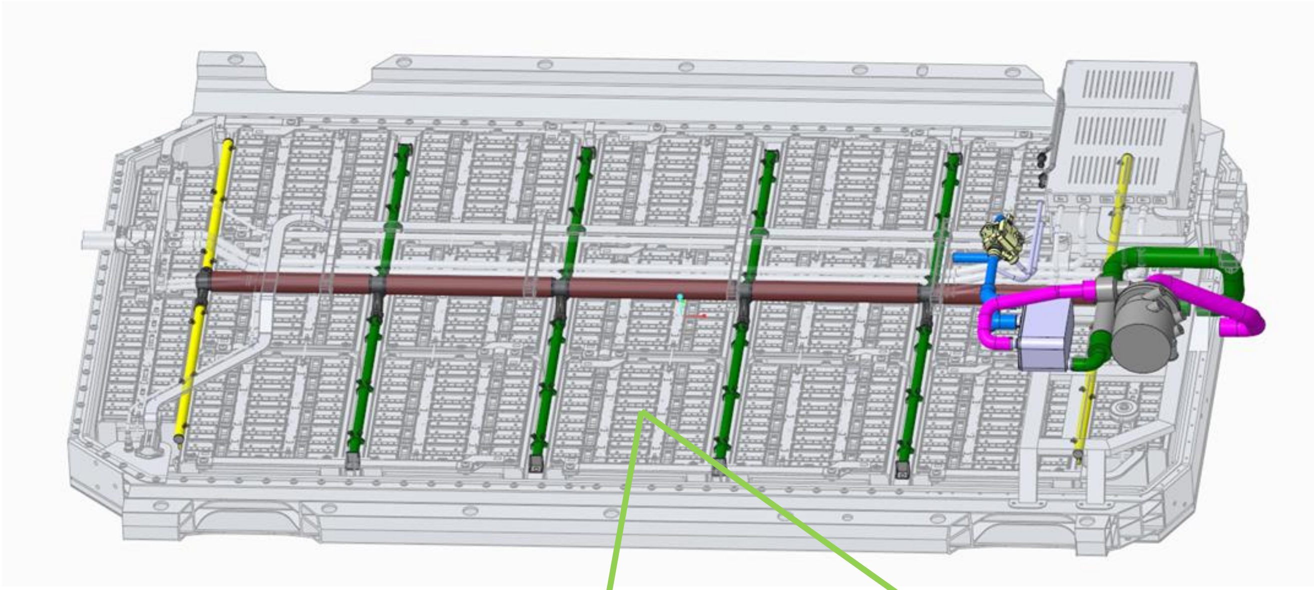
En of first life

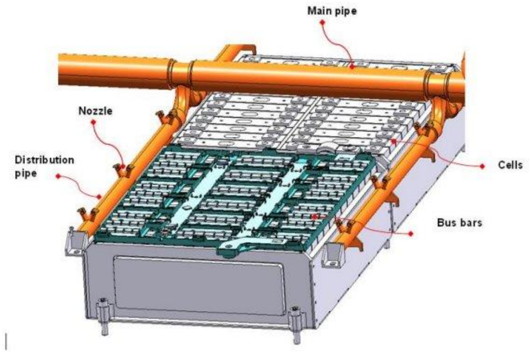
LIBERTY – Semi-immersed spray cooling system

- Efficient space utilization & Lightweight materials
- Effective cooling
- TR reinforced measurements
- Propper temperature control

So how we make cooling effectively in a cell to pack concept?

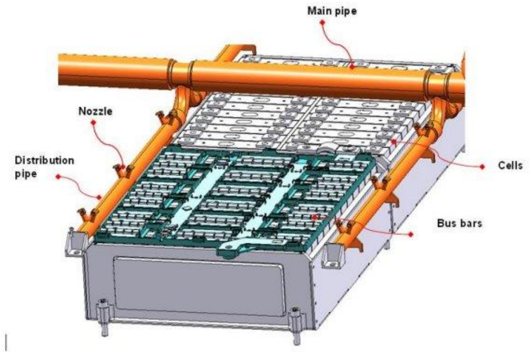
- Semi-immersed spray cooling system
  - Propper temperature control
  - Aid TR propagation containment

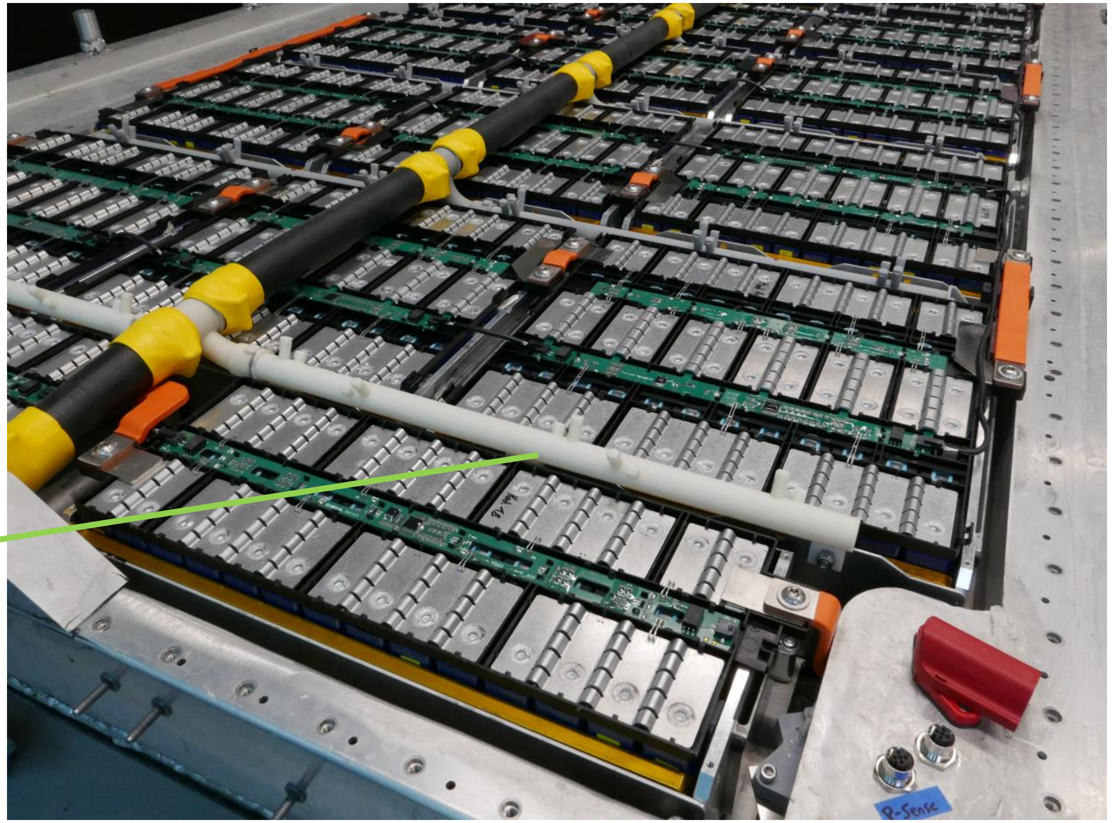




LIBERTY – Semi-immersed spray cooling system

- Tubing
- Spray nozzels
- Semi – Inmersed cells



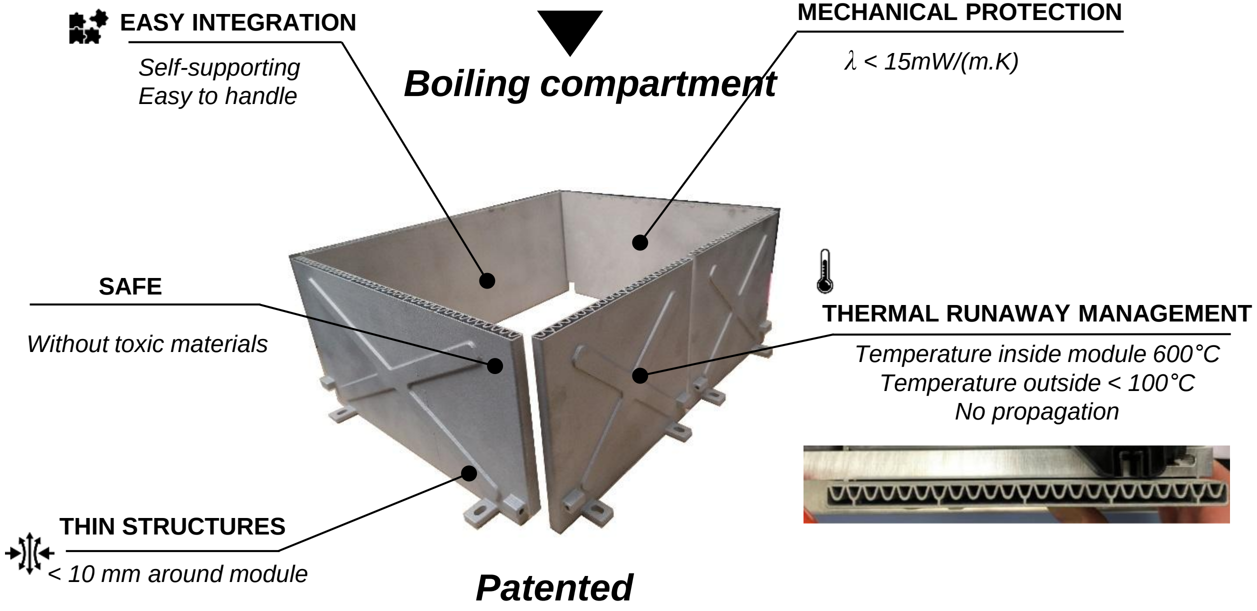


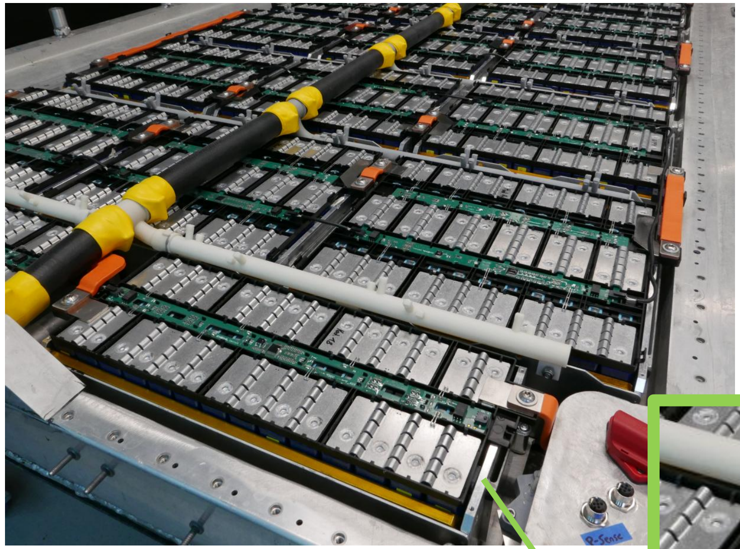
Assembled battery pack with electrical subsystem installed

LIBERTY – Active safety system

- Efficient space utilization & Lightweight materials
- Effective cooling
- TR reinforced measurements
- Propper temperature control

ACTIVE SAFETY SYSTEM



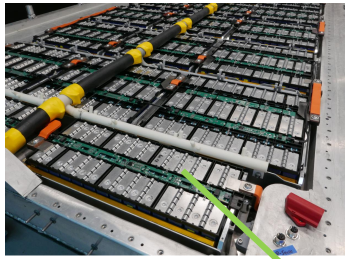


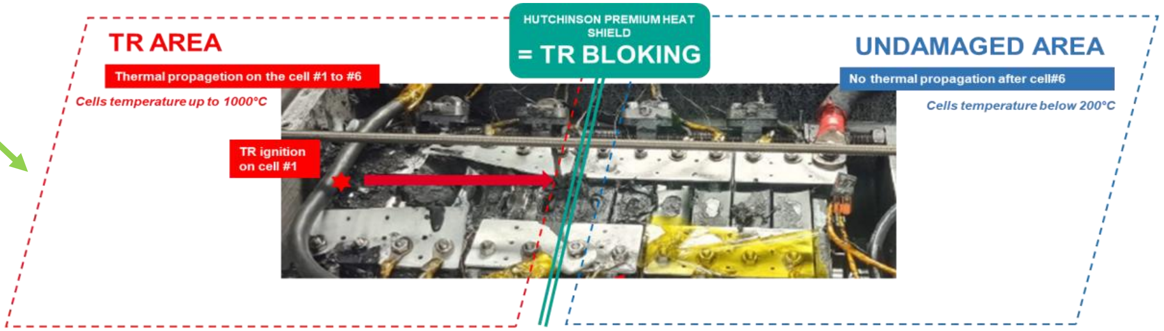
HUTCHINSON®

LIBERTY
LIGHTWEIGHT BATTERY SYSTEM
FOR EXTENDED RANGE AT IMPROVED SAFETY

LIBERTY – Passive safety system

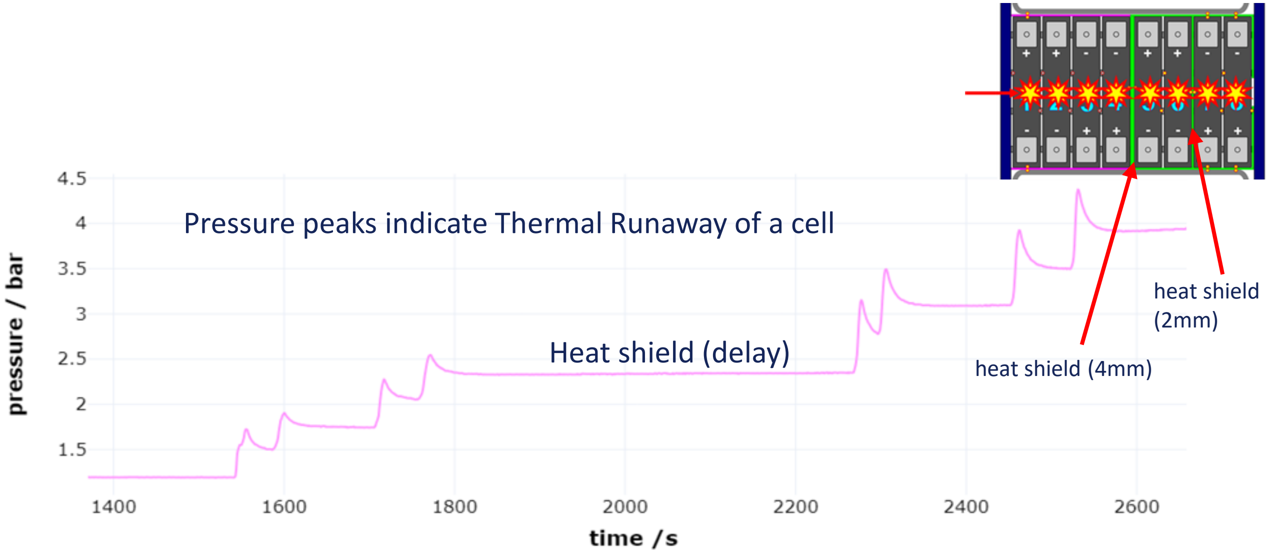
- Efficient space utilization & Lightweight materials
- Effective cooling
- TR reinforced measurements
- Propper temperature control





PASSIVE SAFETY SYSTEM (HEAT SHIELD)

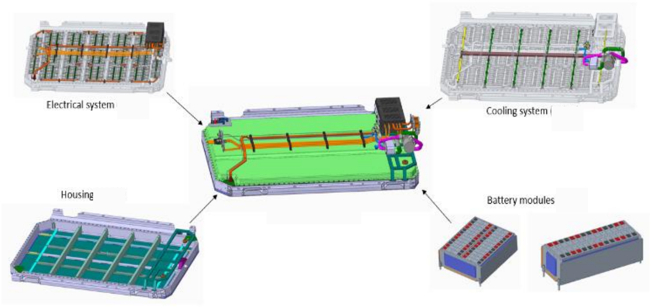
- **Delay thermal propagation from:**
  - One cell to the other
  - One module to the other
  - The cells to the encloser
- **Lightweight**
- **Enable cell compressible & breathing**
- **Electrical & Thermal Insulation**
- **Non-flammable**
- **Integration:** self adhesive & customized design



LIBERTY – Battery pack

This is our battery concept

Want to know more?



LIBERTY final event

LIBERTY
LIGHTWEIGHT BATTERY SYSTEM

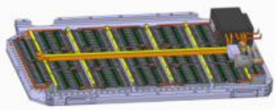
KEY INNOVATIONS

O1. To achieve a range of 500 km on a fully charged battery pack.
O2. To achieve a short charging time.
O3. To achieve an ultimately safe battery system.
O4. To achieve a long battery lifetime.
O5. To achieve sustainability over the battery pack's entire life cycle.

PROJECT GOALS

LIBERTY will develop a new battery system through smart combinations and implemen-tation of innovations including.

- A compact and safe battery pack based on high energy density cells and light-weight materials housing which is crash resistant.
- A versatile battery management system resulting in optimal performance and safety over the system's total lifetime (first and second life).
- High accuracy state estimators allowing fast charging, enhancing range and lifetime, and guaranteeing ultimate safety diagnostics.
- An innovative thermal management system ensuring safety and preventing battery degradation during fast charging.
- Design a (semi) automated battery dis-mantling procedure thereby reducing costs for recycling and reuse.
- Developing of future-proof testing protocols for standardised EV safety as well as performance testing.



PROJECT PARTNERS

Liberty Battery Pack presentation, Design and Innovation.

MEETING INFORMATION

LOCATION: Mercedes Headquarters II Stutgart, Germany.

DATA / TIME: 2024-12-06, 9:30 - 16:00.

AGENDA

Description	Start/Duration
Welcome	9:30 - 10:00
Project technical overview	10:00 - 11:00
Coffee break	11:00 - 11:15
LIBERTY battery display	11:15 - 11:45
Roundtable discussion & Q&A	11:45 - 12:35
Showroom & lunch	12:35 - 14:00
Visit to Mercedes museum	14:30 - 16:00

REGISTER HERE

www.libertyproject.eu

Thank you!

Lightweight Battery System for Extended Range at Improved Safety

LIBERTY has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 963522.
The document reflects only the author’s view, the Agency is not responsible for any use that may be made of the information it contains.

MARBEL

Manufacturing and assembly of modular and reusable EV battery for environment-friendly and lightweight mobility

COLLABAT
Circular design in high performance Battery Packs

PRESENTER NAME: Violeta Vargas (EURECAT)
EMAIL: violeta.vargas@eurecat.org

DATE: November 26th, 2024

The Urgency for Sustainable Innovation in EV Batteries

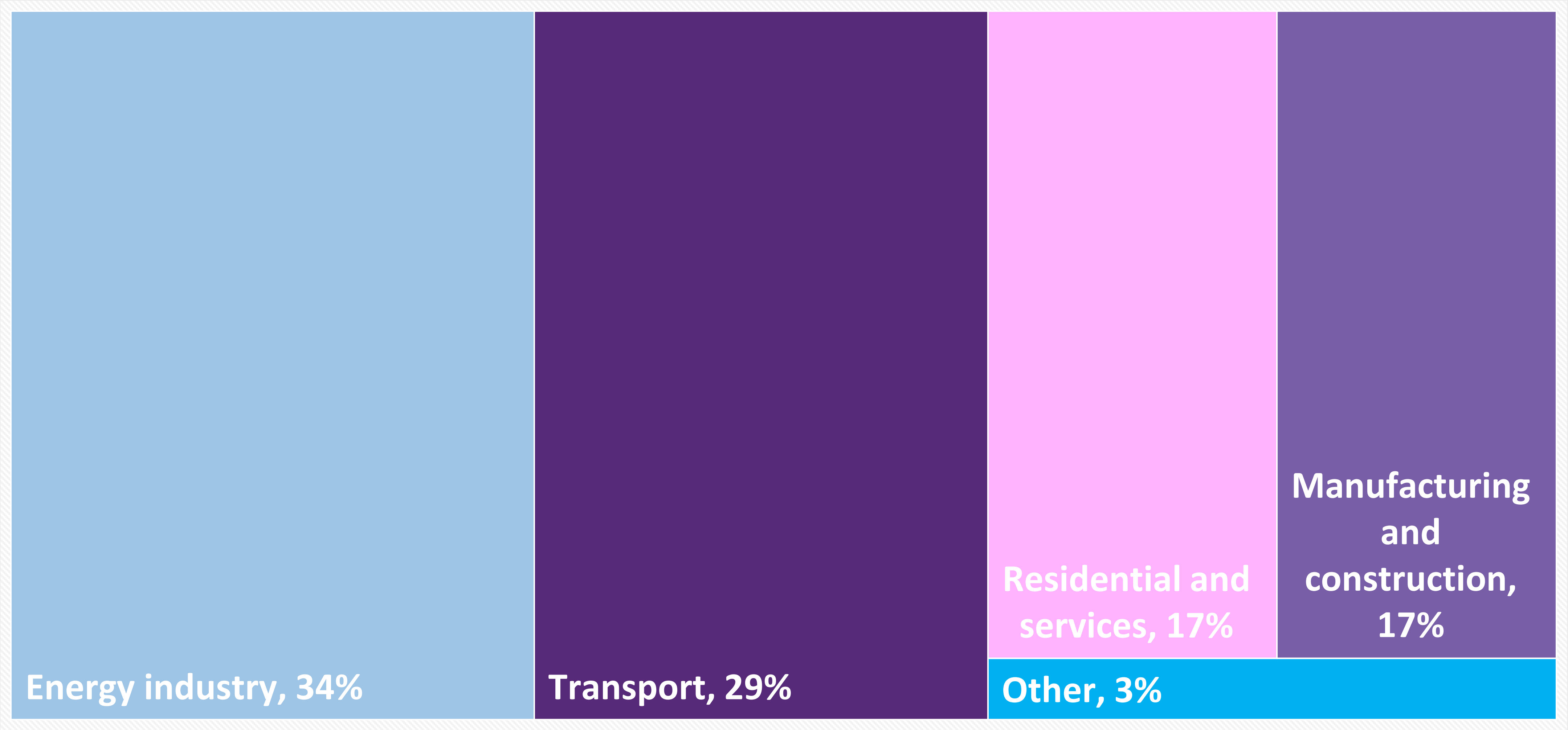
Strategy
Climate neutrality
by 2050

European Climate Law
Cut net greenhouse gas
emissions by at least 55% by
2030,

Commitment
To stay below 1.5 °C of global warming
50% emission reduction by 2030
Zero CO2 emissions by 2050

images: Flaticon.com' and Canva. These covers has been designed using resources from Flaticon.com and canva.com

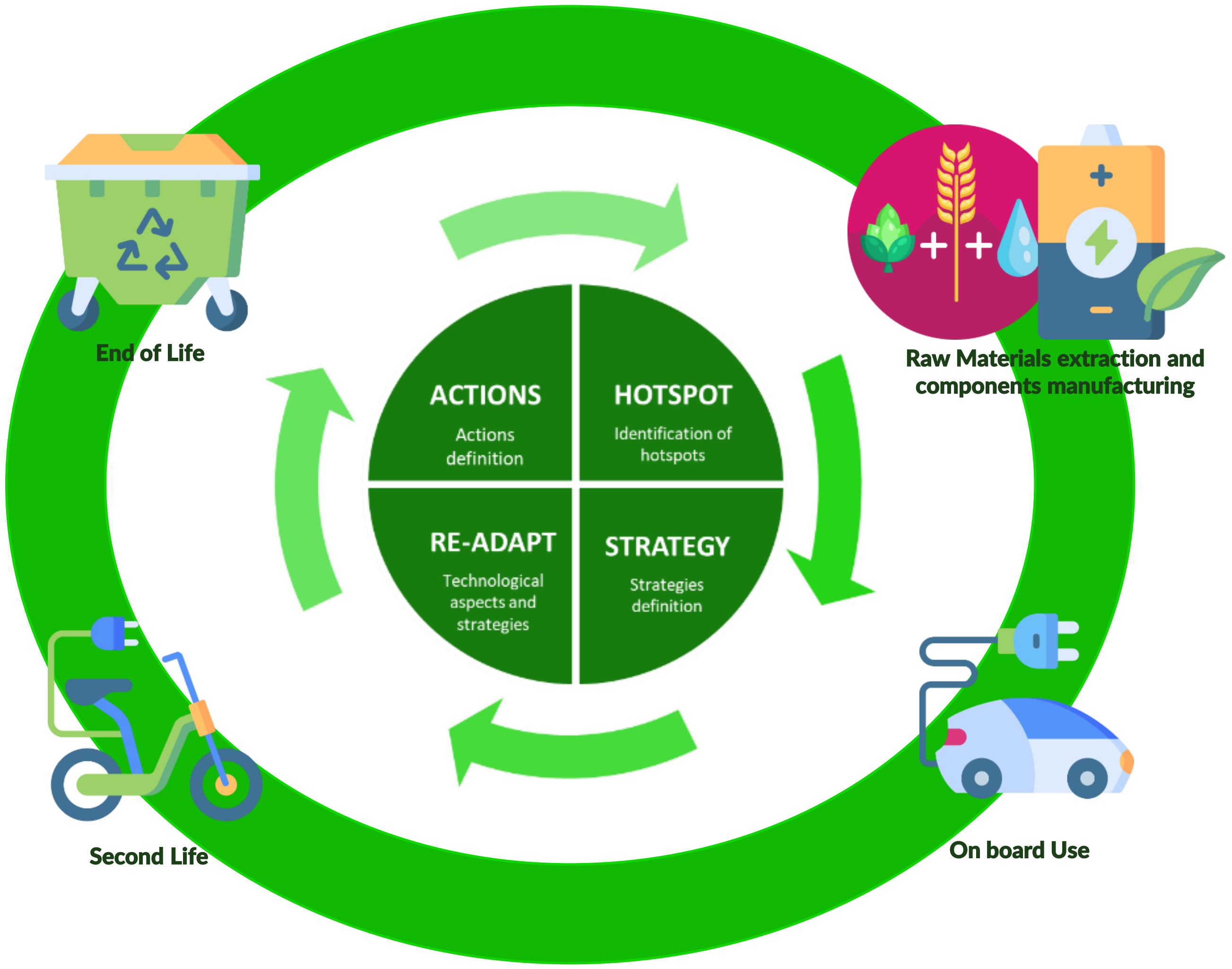
The Urgency for Sustainable Innovation in EV Batteries



Breakdown by source of GHG emissions in the EU-27 between 1990 and 2021
Source: UNFCCC

MARBEL

Methodology



images: Flaticon.com'. These covers has been designed using resources from Flaticon.com

Methodology

STEP 1

- Hotspots and main issues

STEP 1: Identification of Hotspots and Life Cycle Stages

STEP 2: Establishment of the most properly

Based on a benchmark analysis for conventional products/stages/materials…

With the application of the LCA/LCC in a prospective manner at the beginning of the project/action/task

RAW MATERIALS EXTRACTION AND COMPONENTS MANUFACTURING

IMPACT RANGE 30% - 50%

HOTSPOTS & MAIN ISSUES

- The contribution coming from the **production of structural parts (steel)** (Messagie et al)
- Presence of metals on the **wirinig System (copper),** and their upstream extration process (Messagie et al)
- Regarding GW **whole and th** **mainly**, achie impacts in r conventional (Hawkings et al

REFERENCES

- Messagie M., Boureima F., Matheys J., Sergeant N., Turcksin L., Macharis C, Van Mierllo J
- Troy R Hawkins, Bhawa Stingh, Guillaume Majeau-Bettez and Anders Hammer Stromman
- Rinne, M., Elomaa, H., Porvali, A., Lundström, M., (2021). Sikulation-based life cycle asses and Recycling, 170, 105506
- Xion Shu, Yingfu Guo, Wenxian Yang, Kexiang Wei, Guanghui Zhu. Life-cycle assessment
- Fan, E., Li, L., Wang, Z., Lin, J., Yao, Y., Chen, R., Wu, F., 2020. Sustainable recycling Tech

ON BOARD USE

IMPACT RANGE 50% - 80%

HOTSPOTS & MAIN ISSUES

- Energy consumption is directly related to weight (Del Pero et al.)
- The environmental performance of EVs relies on electricity mix in the same way than it does on energy use and vehicle lifetime (Hawkings et al)
- Vehicle lifetime is governed by use and has a very important effect on whole EV life cycle (Hawkings et al)
- Battery weight has as well effects in other important aspects, such as tire and brake abrasion (Messagie et al)
- Increasing the internal battery efficiency implies a reduction on the impact of the internal efficiency losses of the battery (Zacrkrisson et al.)

REFERENCES

- Messagie M., Boureima F., Matheys J., Sergeant N., Turcksin L., Macharis C, Va
- Francesco del Pero, Lorenzo Berzo, Andrea Antonacci, Massimo Delogu. Auton Machines, 8, 51
- Troy R Hawkins, Bhawa Stingh, Guillaume Majeau-Bettez and Anders Hammer
- Marques, P., Garcia, R., Kulay, L., Freire, F., 2019. Comparative life cycle assess 229, 787-794.
- Zackrosson, M., Avellán, L., Orlenius, J., 2010, Life cycle assessment of lithium- 1529.

SECOND LIFE

IMPACT RANGE

HOTSPOTS & MAIN ISSUES

- **Peak shaving application** of batteries (e.g. for a residential dwelling) entails environmental benefits thanks to avoiding battery manufacturing efforts (Bobba et al.[1])
- Replacing a **fresh** LMO battery **by a repurposed** EV battery can **improve** up to **93%**, mainly on production stages (Bobba et al.[2]).
- The ber EV **des** (Lo

REFERENCES

- [1]Sustainability assessment of second life application of Automotive bateries (SASLAB). JRC Technical report. Franco DI CUSENZA Umberto EYNARD Fabrice MATHIEUX Andreas PFRANG
- [2] Silvia Bobba, Fabrice Mathieux, Fulvio Ardente, Gian Andrea Blengini, Maria Anna Cusenza, Andreas Podias, Andreas bateries: an adapted method based on modelling energy flows. Journal of energy storage, 19(2018) 213-235.
- Life Cycle assessment of a lithium Iron Phosphate (LFP) Electric vehicle batteru in second life application scenarios. Sust

END OF LIFE

IMPACT RANGE 15% - 20%

HOTSPOTS & MAIN ISSUES

- **Battery recycling** allows to decrease impacts due to **Li and Co recovery** (Messagie et al.)
- The **recovery of products counterbalance** the drawbacks associated to an increase in **energy consumption** due to these operations (Aichberger et al)
- The **recycling of the cathode material** is the main point related to improve environmental performance

REFERENCES

- Messagie M., Boureima F., Matheys J., Sergeant N., Turcksin L., Macharis C, Van Mierllo J.Life Cycle Assessment of conventional and alternative passenger vehicles in Belgium
- Environmental Life Cycle Impacts of Automotive batteries based on a literature review. Energies.
- Dai, Q.; Kelly, J.C.; Gaines, L.; Wang, M. Life Cycle Analysis of Lithium-Ion Batteries for Automotive Applications. Batteries 2019, 5, 48

MARBEL

Methodology

STEP 2

- Strategies and set-up

STEP 1: Identification of Hotspots and Life Cycle Stages

STEP 2: Establishment of the most properly eco-design strategies based on STEP 1

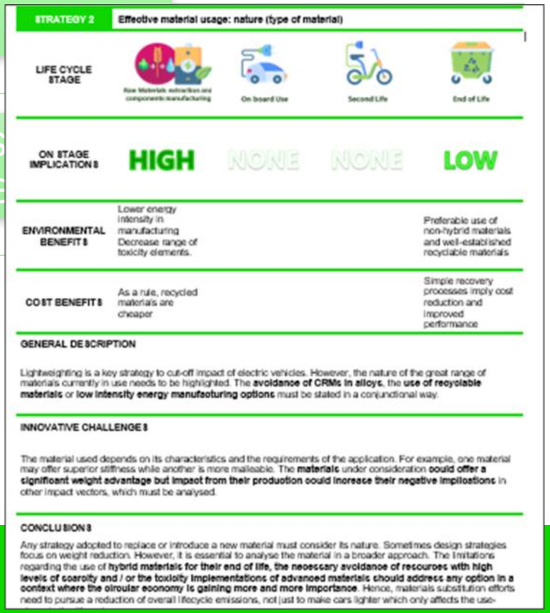
STEP 3: Alignment of technological procedures to the selected strategies

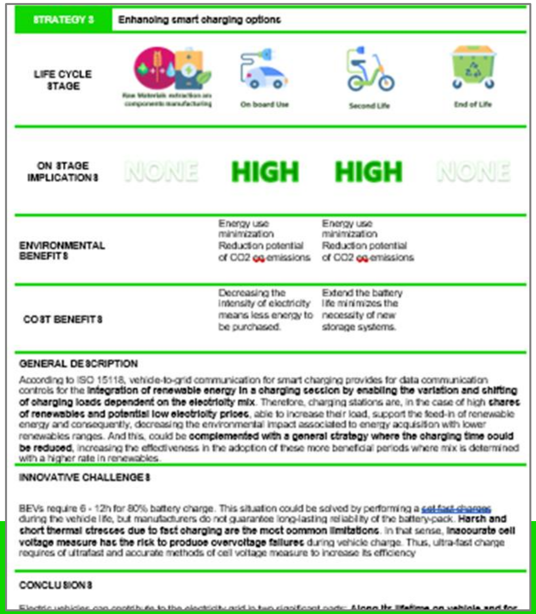
STEP 4: Selection of concrete eco-des actions and Battery Conceptualized De

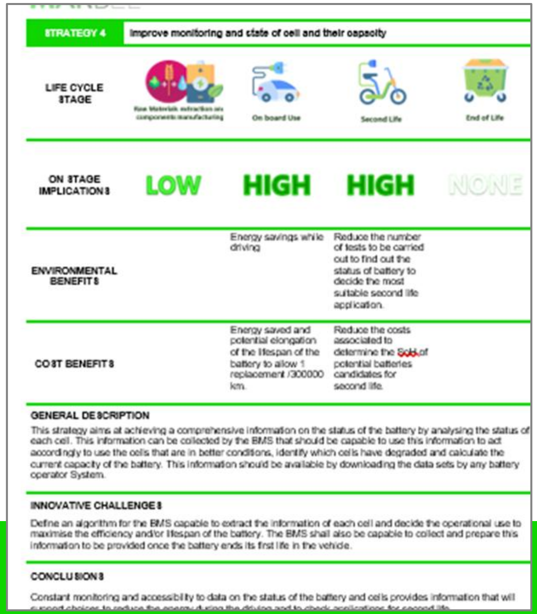
Focused and aligned with the objectives of the study and coupled to technical actions:

- Design for maintainability
- Lifetime extension
- Use of CRM's substitutes
- Considering second-market resources
- …

Creating a repository of strategies in datasheet format







Methodology

STEP 3

- Re-adapt to feasibility

STEP 1: Identification of Hotspots and Life Cycle Stages

STEP 2: Establishment of the most properly eco-design strategies based on STEP 1

STEP 3: Alignment of technological procedures to the selected strategies

STEP 4: Selection of concrete eco-design actions and Battery Conceptualized Design

To procure adapt the technical perspective to the environmental sphere (and vice versa)

HOW? Workshop where all parties involved begin to be familiarized with eco-design concepts

ECODESIGN STRATEGIES

- S1 Effective material usage: lightweighting
- S2 Effective material usage: nature
- S3 Enhancing smart charging options
- S4: Improve monitoring and state of cell and their capacity
- S5: Optimization of the driving conditions
- S6: Enhancing of the battery efficiency
- S7: Promotion of the second life from initial design
- S8: Design for EoL (End of life)
- S9: General structure optimization
- S10: Promote a design to allow repairing and refurbishment to enable reuse

Methodology

STEP 4

- Specific actions

STEP 1: Identification of Hotspots and Life Cycle Stages

STEP 2: Establishment of the most properly eco-design strategies based on STEP 1

STEP 3: Alignment of technological procedures to the selected strategies

STEP 4: Selection of concrete eco-design actions and Battery Conceptualized Design

From the strategy to action, in other words: define clearly what technical specific activities are proposed and "translate it" into the environmental sphere

Action 1: Use of recycled and recyclable materials, for example, in the extrusion of Aluminium profiles.

Action 2: Reduction of copper material needed for electronic components (cables, wirings, etc.)

Action 3: Adopt a "design for reuse, dismantling and recycling" approach by using easy recoverable and recyclable materials instead hybrid ones.

Action 4: Topological optimization of profiles to be used in the BP housing. This simulation will calculate the minimum material necessary to comply with the mechanical requirements.

Action 5: Reduce the quantities of soldering parts of the battery to minimize use of resources and facilitate end of use and second life operations.

Action 6: Use joining elements that can easily be removed to facilitate disassembly, as screws instead of glues to seal the battery pack /modules case.

Action 7: To define and include a protocol for the disassembly operations to assure safety conditions.

Action 8: Introduce a weldless connection to the cells to support disassembly, repairing, etc, options.

Action 9: Reduce whole weight of the battery by using lightweight materials in the casing elements (Al, Mg alloys,) and by choosing a high gravimetric energy chemistry in the electrodes composition that reduces the mass and keeps the energy capacity of the battery.

Action 10: An enhanced BMS that provides advanced degradation rate estimations to optimize battery usage in terms of an extended lifespan.

Action 11: Design a BMS with a multipurpose approach for both primary and second life options of the battery.

Action 12: To create a cloud connecting environment where data associated to the battery could be downloaded at any time during its lifetime and 2nd life extension.

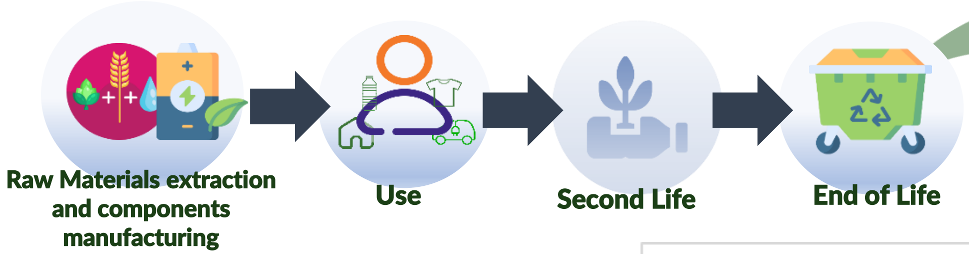
Action 13: Develop a BMS able to respond second life applications by connecting to 200 modules.

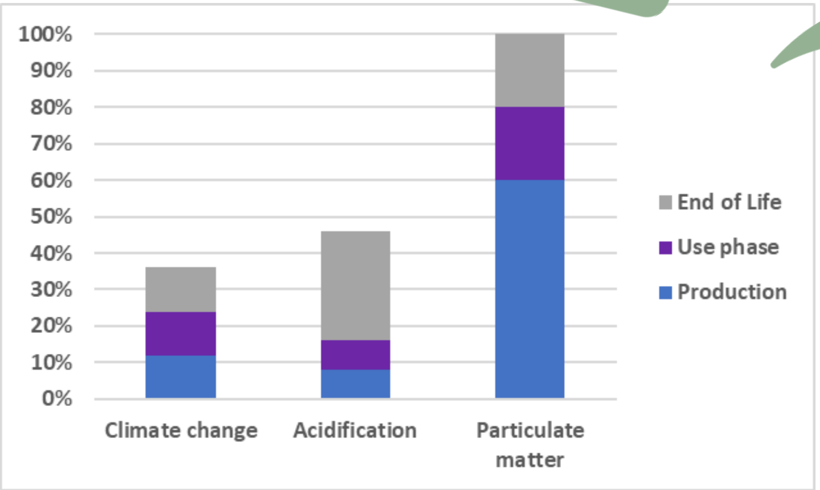
Action 14: Adopt a battery pack design able to be easily repaired, refurbished, and reused with limited interventions.

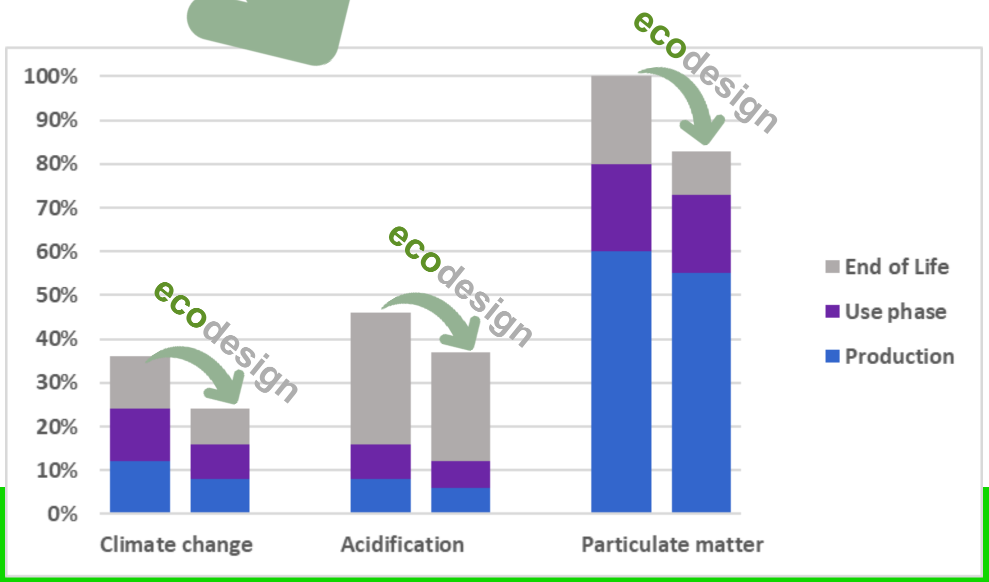
Following steps

How to measure it?

Life Cycle Assessment



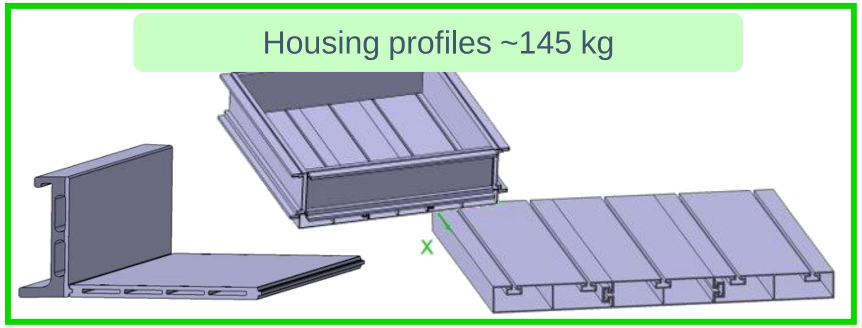


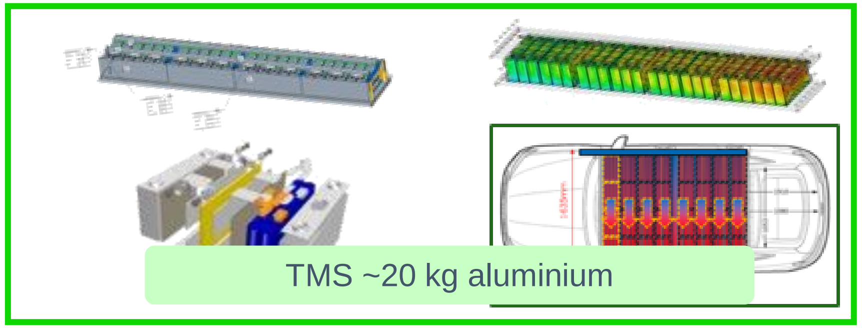


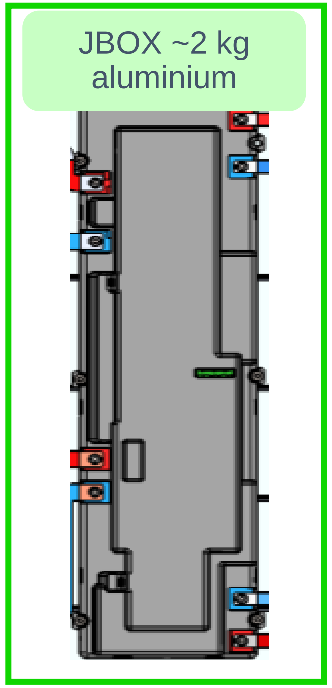
MARBEL

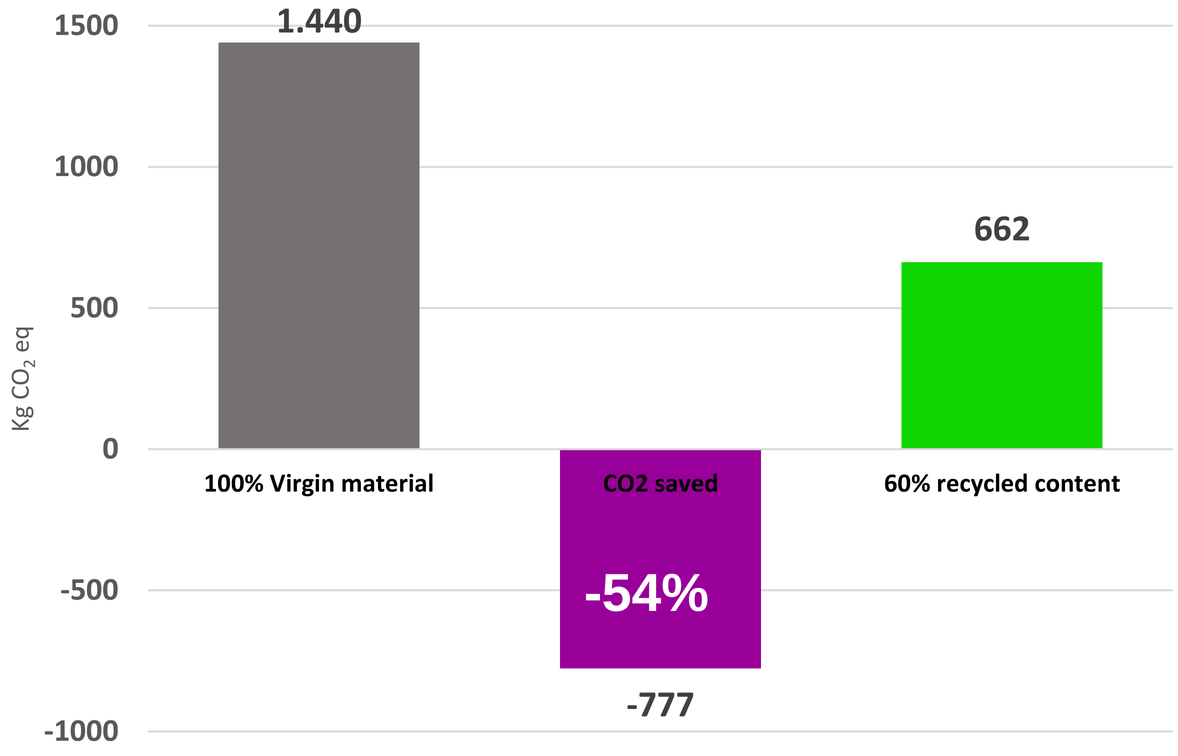
A step forward

Action 1: Use of recycled and recyclable materials









Carbon footprint

Virgin aluminium → 9,9kg CO_2 eq/kg

Recycled aluminium 0,99kg CO_2 eq/kg

Aluminium 60% recycled content

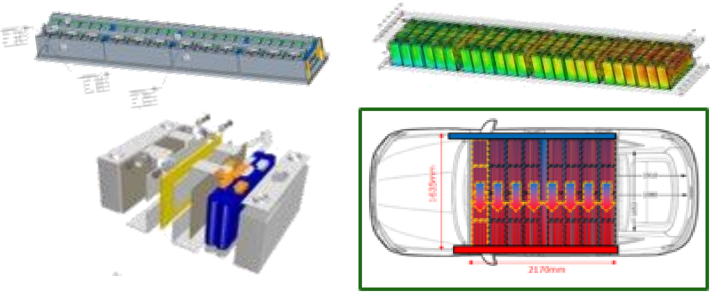
777 kg CO_2 SAVED

MARBEL

A step forward

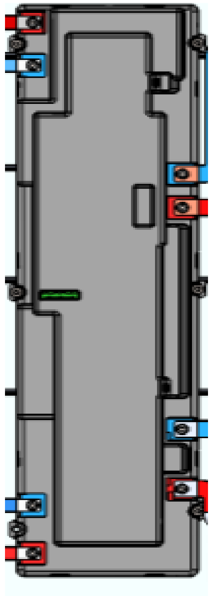
Action 2: Reduction of copper material needed for electronic components (cables, wirings, etc.)

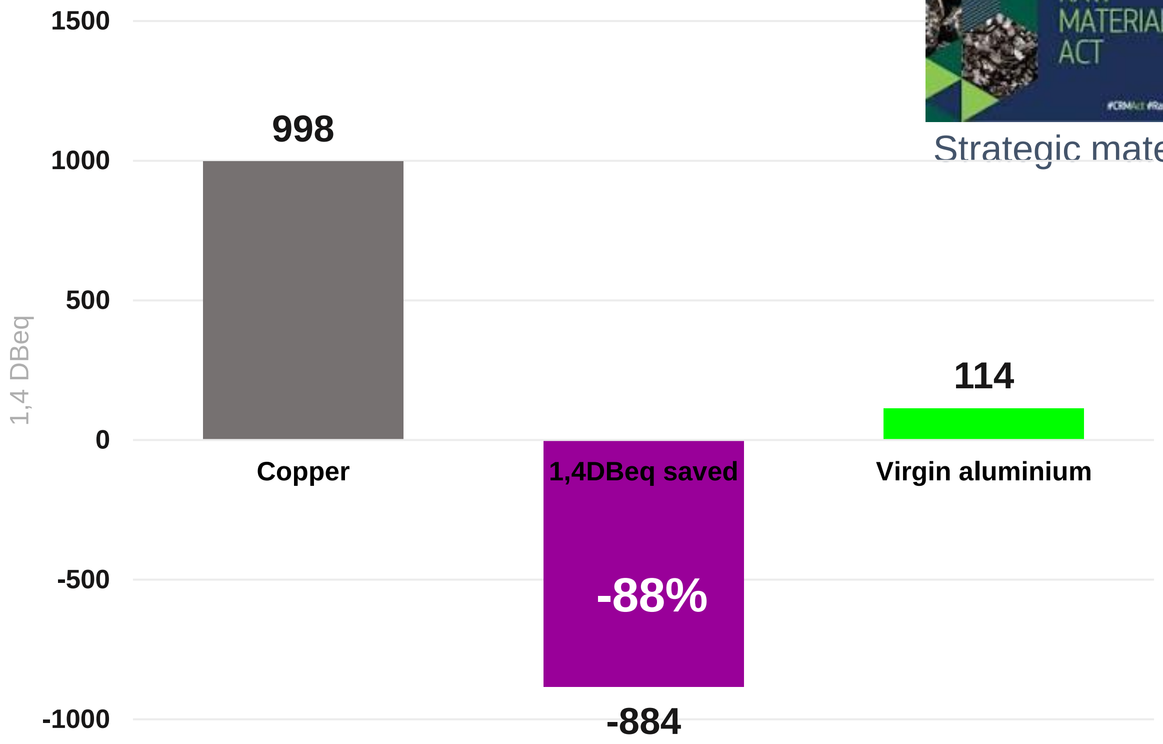
TMS ~9,5 kg cooling fins



Electrical system ~11 kg copper busbars

JBOX ~5 kg copper busbars





Strategic material

Human Toxicity

Virgin aluminium → 24 kg 1,4DBeq/kg

Copper
105 kg 1,4DBeq/kg

Copper vs Virgin Aluminium

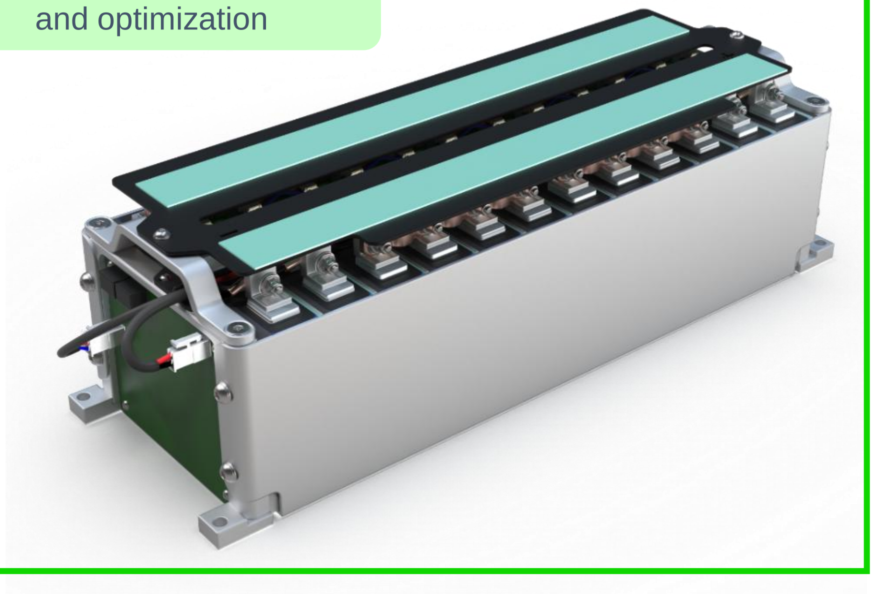
884 kg 1,4DBeq saved

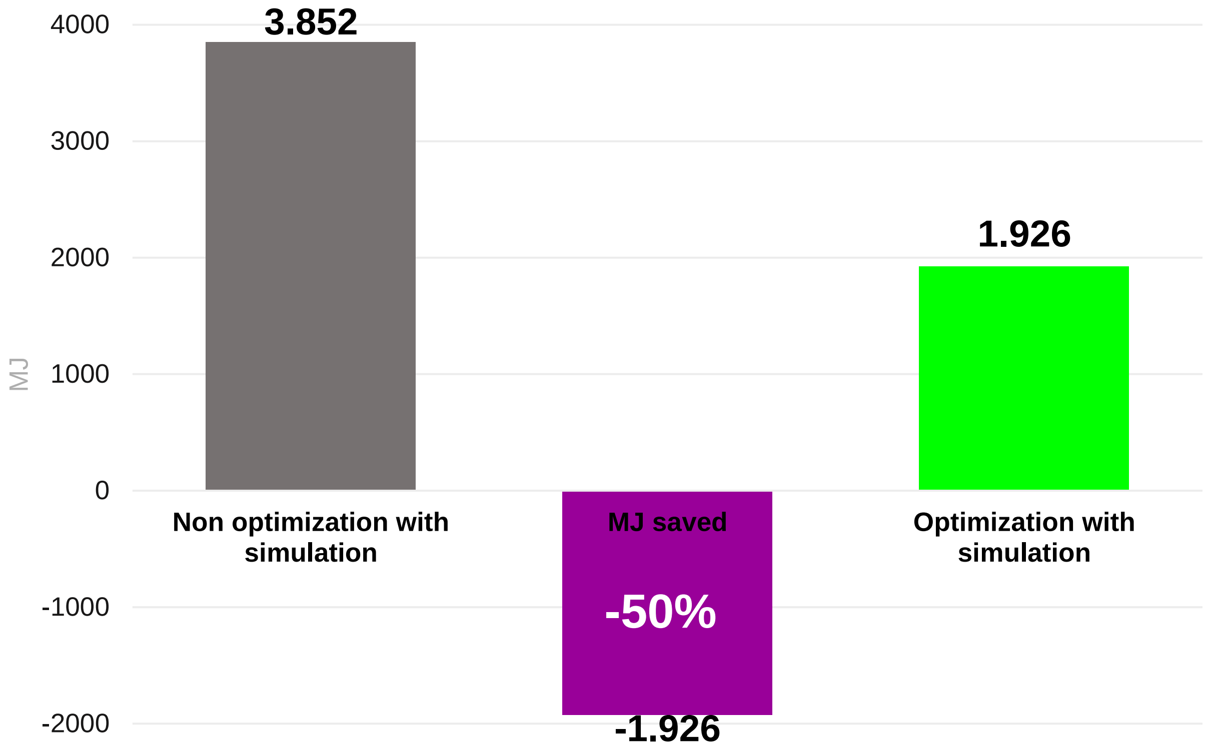
MARBEL

A step forward

Action 4: Topological optimization of profiles to be used in the BP housing. This simulation will calculate the minimum material necessary to comply with the mechanical requirements.

Module Endplates simulation and optimization





Energy consumption

Virgin aluminium → 107 MJ/kg

50% weight reduction 53 MJ/kg

Non optimization vs Optimization with simulation

1.926 MJ saved

Conclusions

Practical Integration of Ecodesign Methodology

- 10 generic ecodesign strategies and 14 specific actions, addressing material efficiency, impact reduction, and recycling pathways.
- Outcomes highlight the importance of integrating simulation tools and recycled materials into design decisions for high-performance battery packs.

Demonstrated Benefits of Ecodesign

- Action 1: Adoption of recycled and recyclable materials in housing profiles saves 777 kg CO_2 reducing climate change impacts by 54%.
- Action 2: Reduction of copper in electronic components mitigates 8834 kg 1,4DBeq in human toxicity impact, reducing it in 88%.
- Action 4: Topological optimization of battery pack housing profiles decreases energy consumption by 1926 MJ, achieving a 50% reduction in energy use.

Implementation and Future Outlook

- Stakeholders actively incorporate ecodesign actions into technical aspects.
- Results pave the way for scalable, circular design frameworks that maximize resource recovery, extend EV battery lifespan, and minimize environmental footprints.

MARBEL

Manufacturing and assembly of modular and reusable EV battery for environment-friendly and lightweight mobility

THANK YOU!

PRESENTER NAME: Violeta Vargas (EURECAT)
EMAIL: violeta.vargas@eurecat.org

DATE: June 13th 2024

A project coordinated by:

eurecat