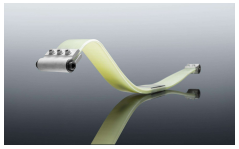
# Advances in Multimaterial EV Battery Enclosures

Dr.-Ing. Roman Hillermeier / Dr. Joseph Laux

*SPE ACCE Conference, Nov 2021*
*Novi, Mi*

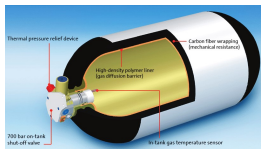
*Competence in Automotive-Composites Engineering & Development Services*

*Structural Components*



*Chassis / Suspension*

*Battery Enclosures*

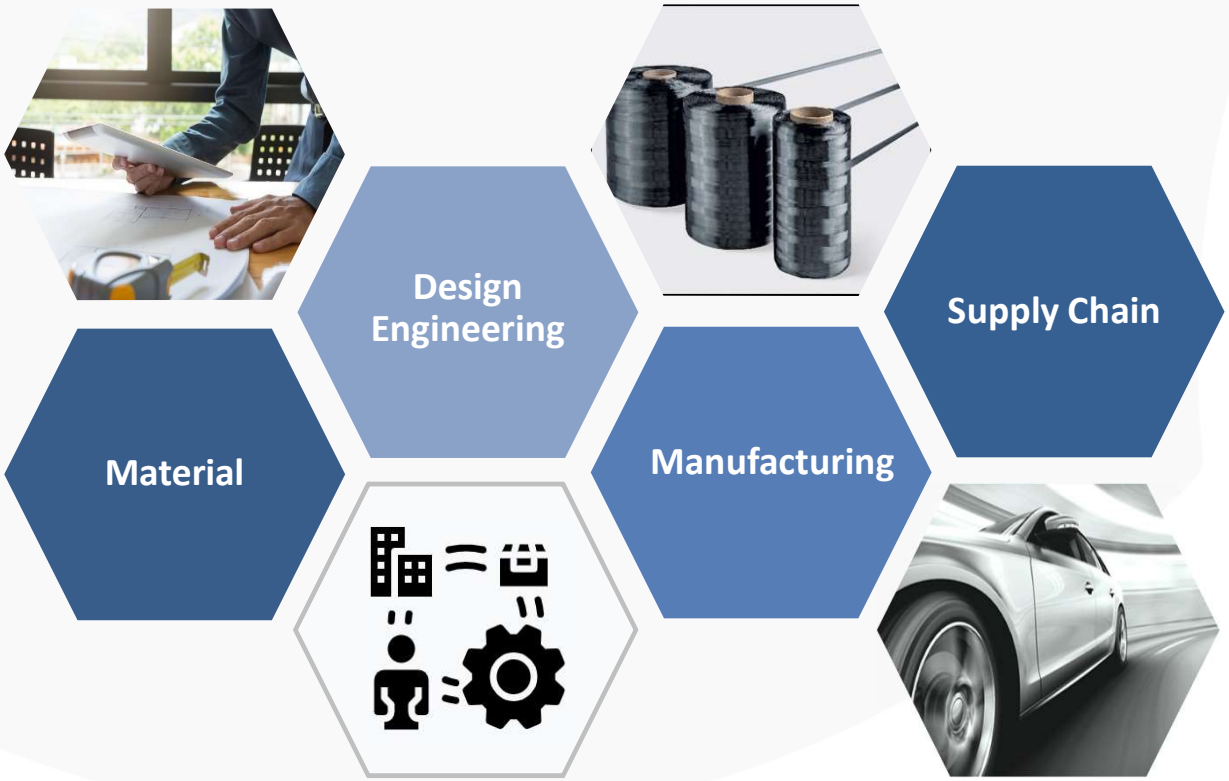


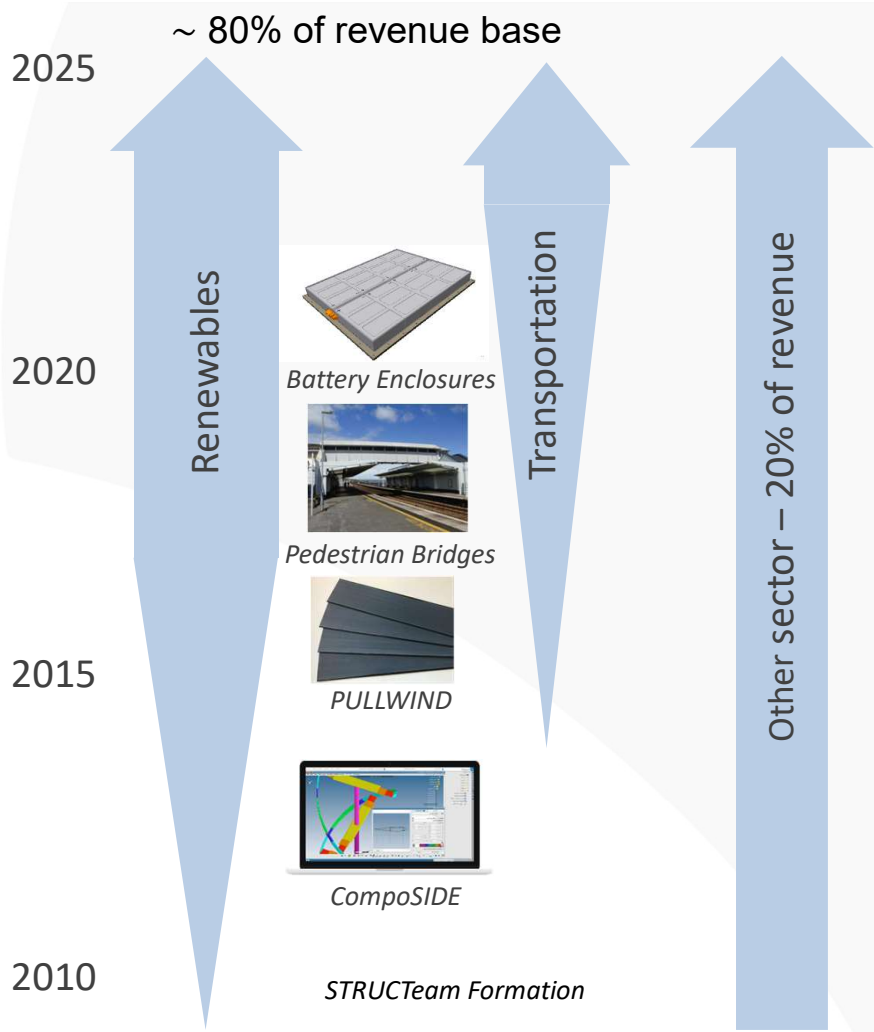
*Gas Cylinders*

# Agenda

- Introduction
- Electric Vehicle Battery Enclosures
  - Requirements
  - Concept Study
- Study Results
- Conclusions & Outlook

# STRUCTeam Ltd. Introduction



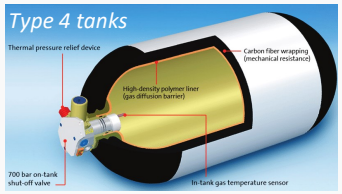

## Leading composites engineering services consultancy

- Renewable/Wind Energy
- Marine
- Automotive
- Civil
- Oil & Gas
- Materials Industry

# Sustainability Focus at STRUCTeam

## AUTOMOTIVE

- Electric Vehicle (EV) Batteries
- H2 Tanks for Fuel Cell Electric Vehicles (FCEV)
- Safety Parts Light Weighting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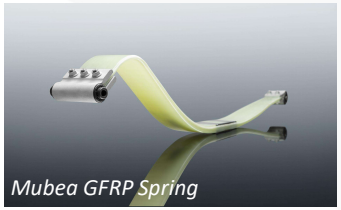
## CROSS SECTOR FOCUS AREAS

- Development/introduction of sustainable designs and materials
- Investigation of $CO_2$ balances & sustainability KPIs.



# Impact of Global Market Trends

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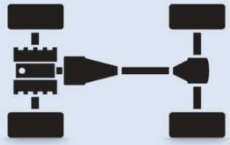
I) Powertrain Shift



NEV: BEV, FCEV → Higher weight vs. ICEs

II) Autonomous Driving

Increased safety requirements

III) New Ownership Models

More users / mileage → Higher durability

IV) Trend I)-III) accelerate product commoditization

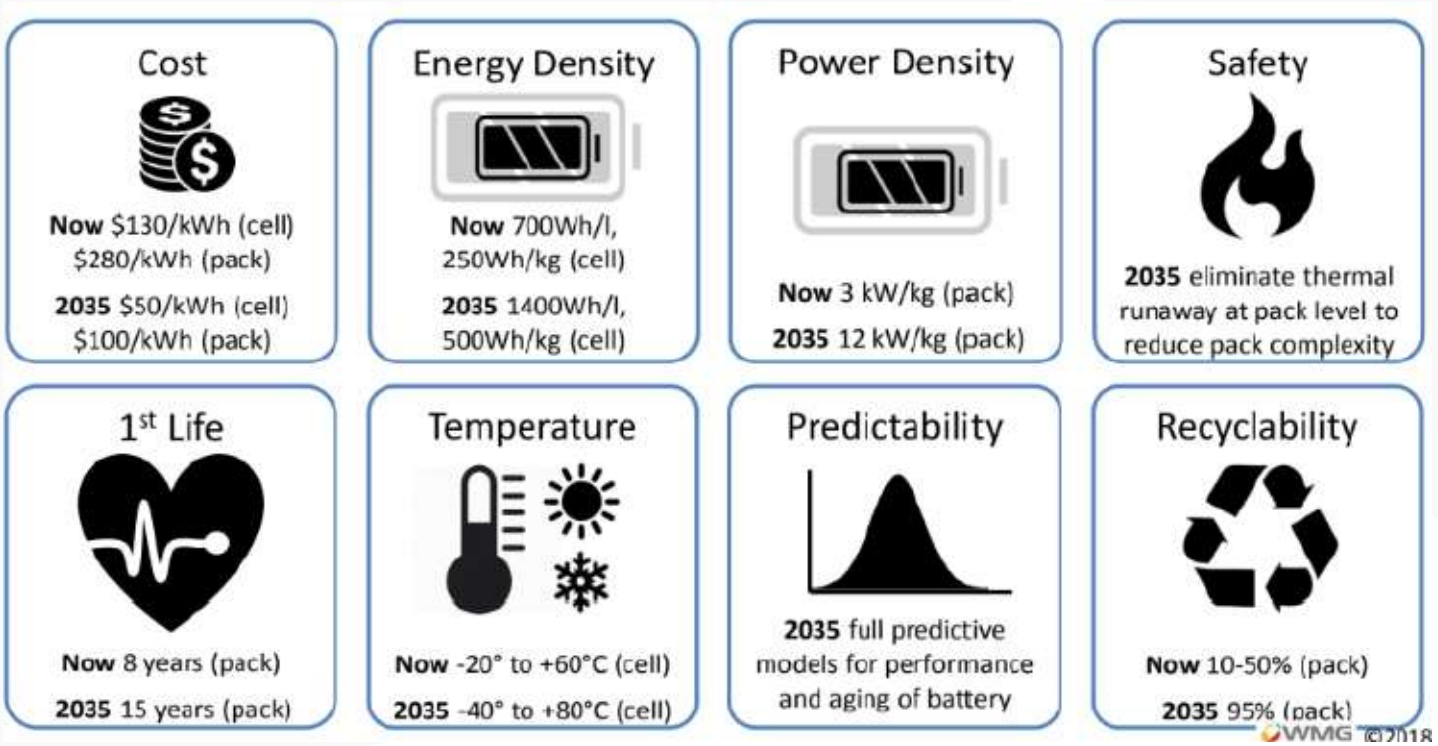
New technologies become important product differentiators

Opportunities for **NEW STRUCTURAL LIGHT-WEIGHT** Materials

# Vehicle Segment Opportunities

| Vehicle Segment | Applications | New Material Opportunity - Growth Outlook - |
|---|---|---|
| Commercial vehicles<br>Bus<br>Trucks<br>LCV – HCV<br>  <br>*Source: Zoox* | • Energy storage / powertrain<br>• Exterior<br>• Chassis | Strong incremental - select opportunistic |
| Premium<br>SUV<br>Full-size<br>Mid-size<br>  <br>*Source: NIO* | • Energy storage<br>• Structural – semi structural | Strong - Exponential |
| Compact<br>  <br>*Source: BMW* | • Energy storage | Incremental |
| Super premium<br>Super car<br>Luxury vehicles<br>…<br>  <br>*Source: Lamborghini* | • Structural<br>• Energy storage<br>• Exterior / Interior<br>• Chassis | Strong incremental |

# Industry Challenges – EV Energy Storage Systems
## (for BEV, FCEV, HEV)




Source: Automotive Council Electrical Energy Storage Roadmap 2017

**+ Coming decisions will be influenced by growing supply issues**

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# Electric Vehicle Battery Enclosures
## (for BEV, FCEV, HEV)

*Evolving vehicle architectures make composites an attractive material choice for the enclosures of future EVs.* ***The average enclosure weighs 80-150 kg.***

**CHALLENGES**
- Many & evolving requirements
- Evolving battery cell chemistry
- Complexity in design & development
-…

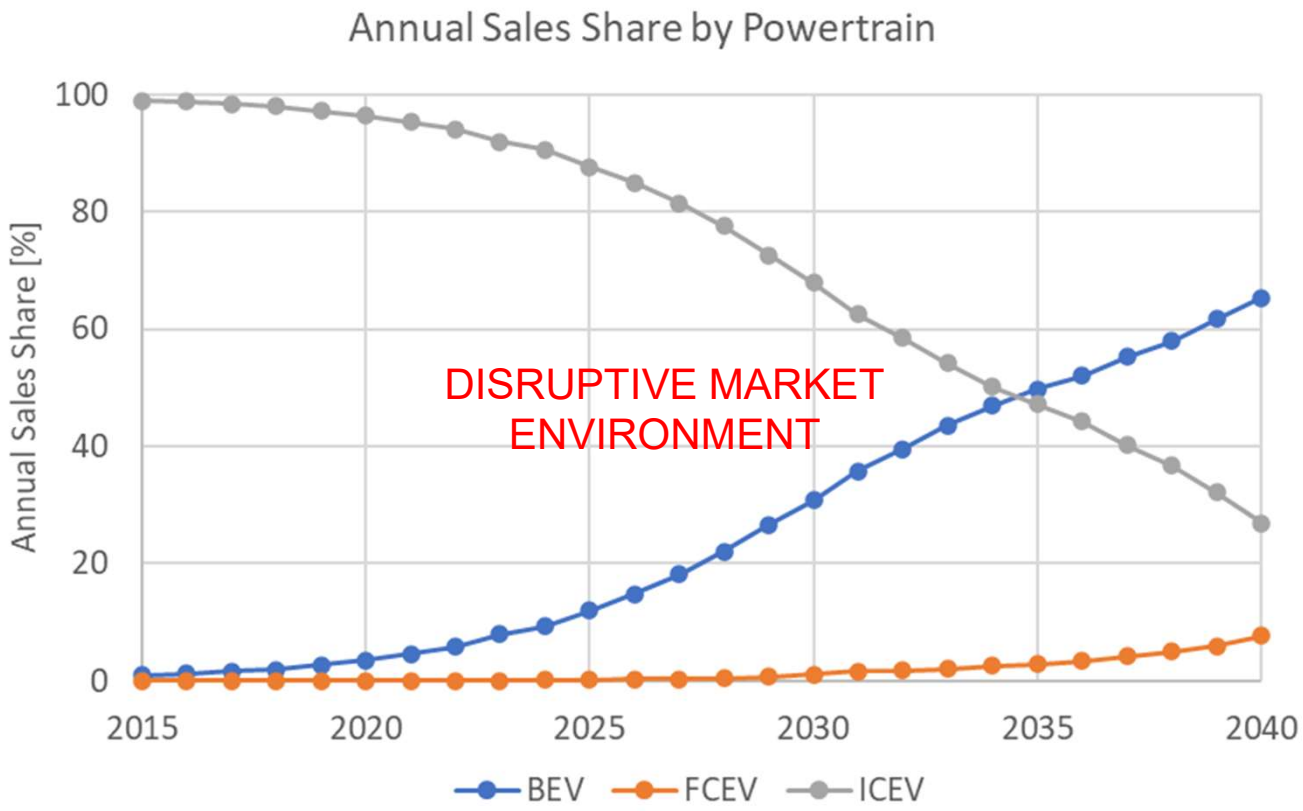
**DEVELOPMENT NEEDS**
- Cost, size, weight* reduction
- Improved structural & functional integration
- Simpler thermal management & EMI solutions
- …

*Source: Carmagazine*


*Source: Audi*

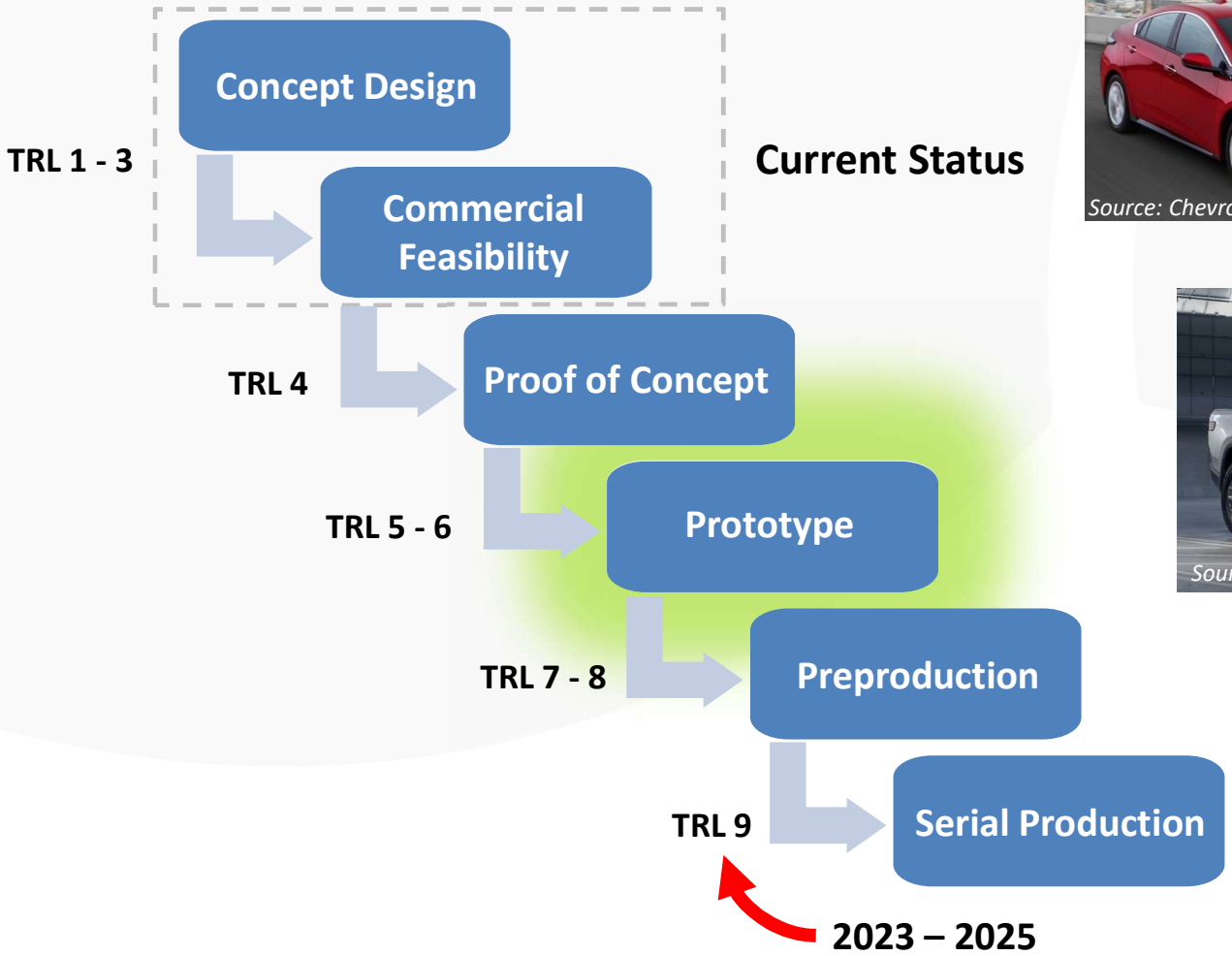
** Cost & weight of enclosure 10-25% of battery system*

# Market Share for Passenger & Commercial Vehicles by Powertrain Technology




- Battery Electric Vehicles (BEV): 2030 = 28 Mil. / 2040 = 64 Mil.
- Fuel Cell Electric Vehicles (FCEV): 2030 = 1.1 Mil. / 2040 = 7.7 Mil.

# Multi Material Composite Enclosures
# - Industry Progress -



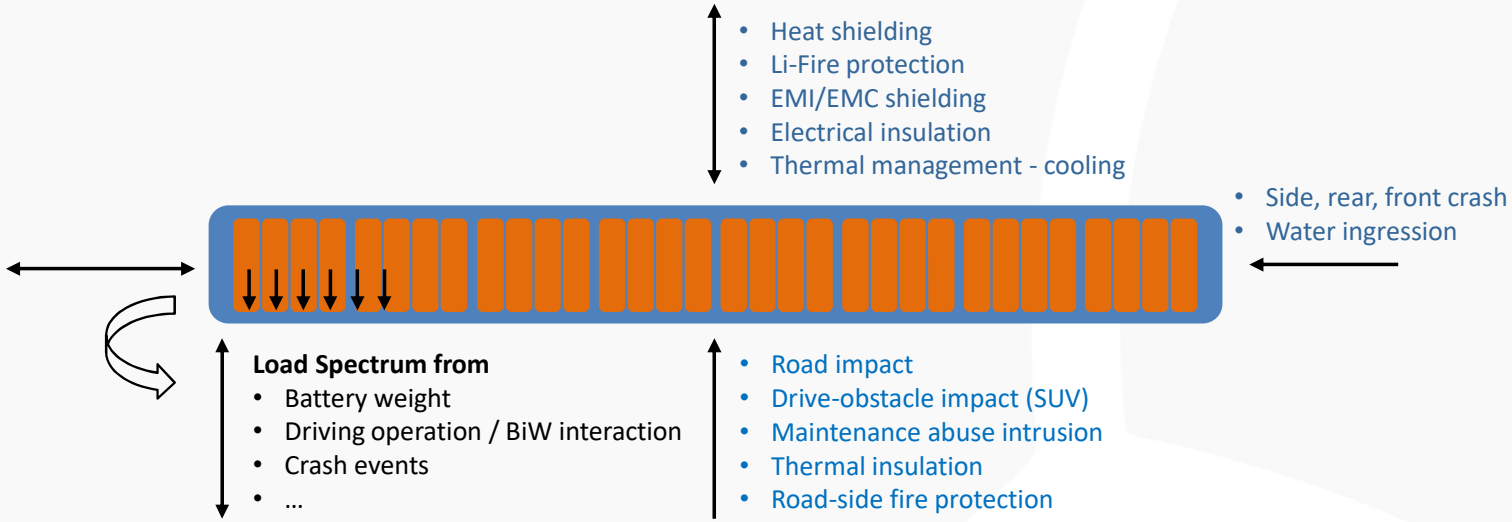


Source: Chevrolet


Source: Rivian


Source: Porsche

# Enclosure Structural Requirements
## (for BEV, FCEV, HEV)




**Main Load Origin**

- Weight of battery cells & modules, typical 300-700kg
- Interactions with BiW architecture
- Driving operation
- Impact during operation
- Crash events
- External & internal pressure build up

**Allowable Enclosure Structural Response**

- Intrusion protection
- Minimum deformation
- Vibration control
- Potential BiW architecture reinforcement requirement

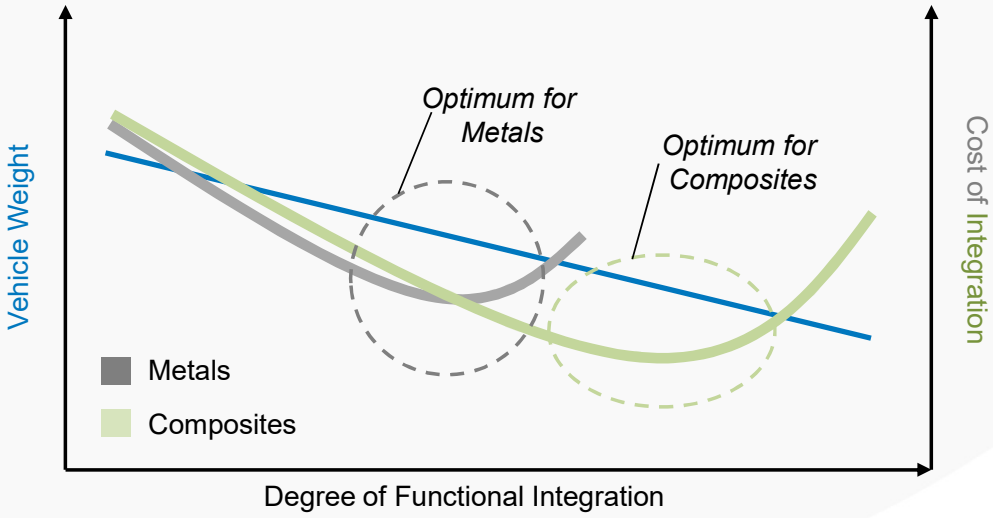
# Enclosure Requirements - Fire
## (for BEV, FCEV, HEV)

- When battery temperatures exceed 150°C, there is a high risk of thermal runaway (typical ignition temp. ~200°C)
- Many national and international standards & requirements
- Requirements will get more stringent in future

Tesla Model S crashed on concrete construction barrier in Austria

- Protecting passenger and batteries from thermal runaway events remains to be a key challenge in automotive battery pack/enclosure design

# Why Multimaterial Composite Designs?




- Capability to integrate many functions
  - Structural functionality
    - Primary loads
    - Secondary loads
  - Thermal management
    - Cooling / heating / insulation
    - Fire protection
  - Reduce # of screws, bolts, joints,…
  - Simplify sealing provisions
  - Noise vibration and harshness (NVH)
  - Underbody aerodynamics
- Best material & process for each application / task
- Lower system weight & life cycle cost

- Reduction in Assembly Efforts
- Weight Reduction
- CAPEX & Direct Production Cost Reduction

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# Study Sponsors & Partners

STRUCTeam

3A COMPOSITES CORE MATERIALS — Core Materials

Olin™ — Epoxy Resins

Schill+Seilacher struktol® — Reactive Polymers & Flame Retardants

Sika® — Adhesive, Sealants & Coatings

We thank our partners for their project support!

# Enclosure References & Concept Study Benchmark

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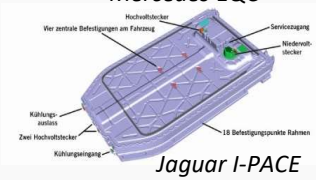
*Enclosure reference examples*

*Mercedes EQC*

*Ford Mach E*



*Jaguar I-PACE*

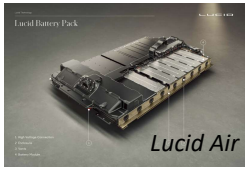
*21' Tesla Model 3*

*Audi e-tron*

*VW ID4*

*BMW iX3*

*Polestar 2*



*Lucid Air*

## Benchmark Specification

- AL enclosure (extrusion, die castings, deep draw)
- High specific energy density (> 130Wh/kg)
- ~ 80 kWh capacity
- Height: 140mm
- Uses cells that are not-structurally loaded
- Weight: among lightest in industry, ~ 25% of total weight is for underbody protection
- Enclosure includes liquid cooling circuit

Selected benchmark captures many of current trends in enclosure designs and is challenging target in terms of cost & weight

# Composite Battery Enclosure Concept Study

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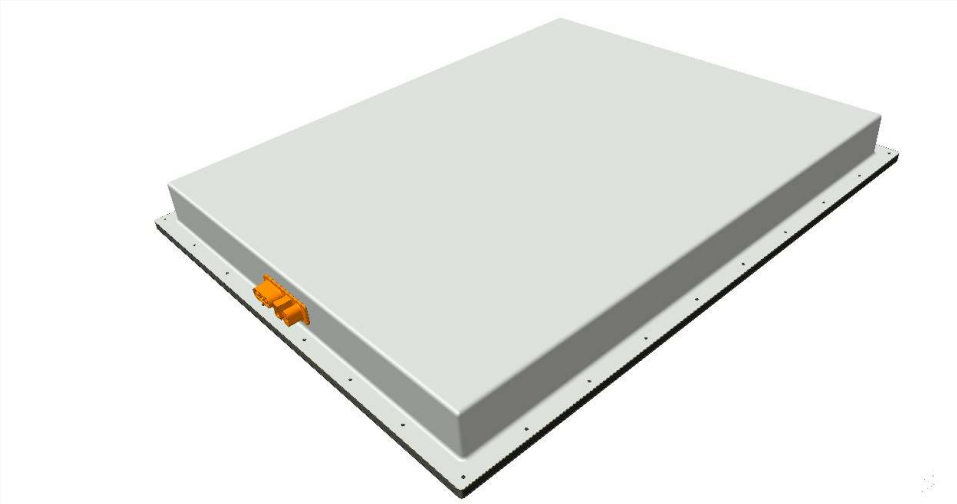
## Concept A - Non-Structural Enclosure

- Minimized contribution to primary loads
- No support of BiW structure in crash load cases
- Minimized number of connection points to chassis structure



*Design Specifics*

- Designed for ease of manufacturing & low cost
- Maximized available cell/module space
- High degree of functional integration

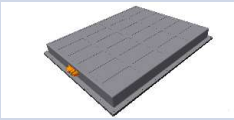
## Concept B - Structural Enclosure

- Strong contribution to BiW rigidity in bending & torsion
- Supports BiW structure in crash events, mainly in side impact
- Takes additional function to support BiW

*Design Specifics*

- Design for ease of manufacturing & lost cost
- Designed for weight effectiveness
- High degree of functional integration

# Key Design Features

| | Industry Benchmark | Non-Structural | Structural |
|---|---|---|---|
| Basic Description | • AL sheet upper cover<br>• AL extrusions/sheets/cast lower tray, beam reinforced |  • Composite upper cover<br>• Composite lower tray |  • Composite upper cover<br>• Composite lower tray |
| Material Combinations | > 75% AL<br>< 10% ST<br>> 10% Sealants, Adhesives, FR Layers | > 60% FRP<br>< 15% ST & AL<br>< 40% other non-metallic materials | > 60% FRP<br>< 15% ST & AL<br>< 40% other non-metallic materials |
| Cells/modules are structural | No | No | No |
| Enhances BiW torsional stiffness | Slightly | No | Substantially |
| Side crash / res. load support | Yes | No | Yes |
| Takes additional BiW load | No | No | Yes |
| Includes cooling circuit | Yes | Yes | Yes |
| Improved thermal insulation | No | Yes | Yes |
| Thermal runaway protection | No / Yes* | Yes | Yes |
| Best Part Cost Index<br>(1=lowest, 5=high) | 2 – 2.5 | 1 | 2 |

** Depends on country of delivery*

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# Bill of Materials

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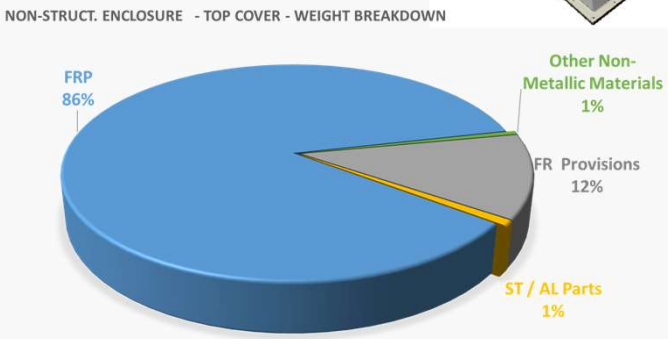
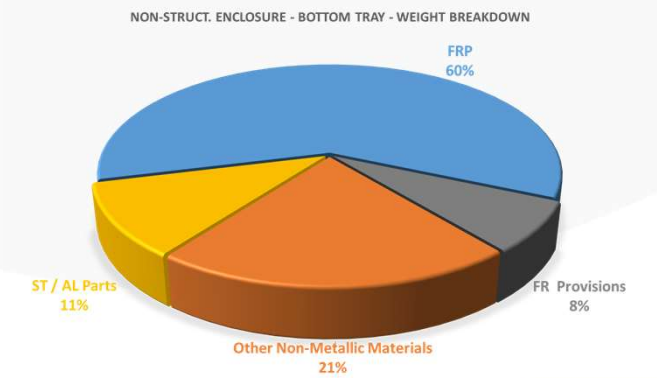
## Concept A - Non-Structural Enclosure

Top cover




Bottom tray




## Concept B - Structural Enclosure

Top cover


Bottom tray


**Weight & cost effective multi-material design**

# Results

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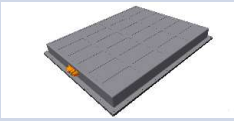
| Basic Description | • AL sheet upper cover<br>• AL extrusions/sheets/cast lower tray, beam reinforced |  • Composite upper cover<br>• Composite lower tray |  • Composite upper cover<br>• Composite lower tray |
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| Takes additional BiW loads | No | No | Yes |
| Includes cooling circuit | Yes | Yes | Yes |
| Improved thermal insulation | No | Yes | Yes |
| Thermal runaway protection | No / Yes* | Yes | Yes |
| Enclosure Weight | 100 % | 91 % | 70-90 % |
| BiW Wt Savings | 0 % | 0 % | 10-50 kg |
| Available space for batteries | 100 % | 105 % | 100 % |
| Best Part Cost Index<br>(1=lowest, 5=high) | 2 – 2.5 | 1 | 2 |

** Depends on country of delivery*

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# Conclusions

- Automotive industry requirements for EV batteries will continue to evolve
- Fire safety requirements will further increase
- Reducing cost and weight of battery enclosures are a major focus area for OEMs
- Multimaterial designs using non-metallic solutions are at an infant stage

- Multimaterial composite battery enclosures can help to reduce system weight & cost
- Structural battery enclosures can achieve secondary savings, such as BiW weight reduction

# Next Steps & Outlook

- Joint proof of concept validation activity, including OEM & tier specific requirements
- Implement viable multi-material solutions in OEM's own developments
- Embodied $CO_2$ analysis and end of life solutions
- Formation of Phase 2 program including needed project partner forum

# Contact

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