With system integration and lightweight design to highest energy densities

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SmartBatt –
Smart and Safe Integration of Batteries in Electric Vehicles

Project within 7th Framework Programme of the EC

9 partners from 5 European countries

Project duration 01/2011 – 12/2012

Key aspects:

- Lightweight design
- Costs
- Functional integration
- Safety

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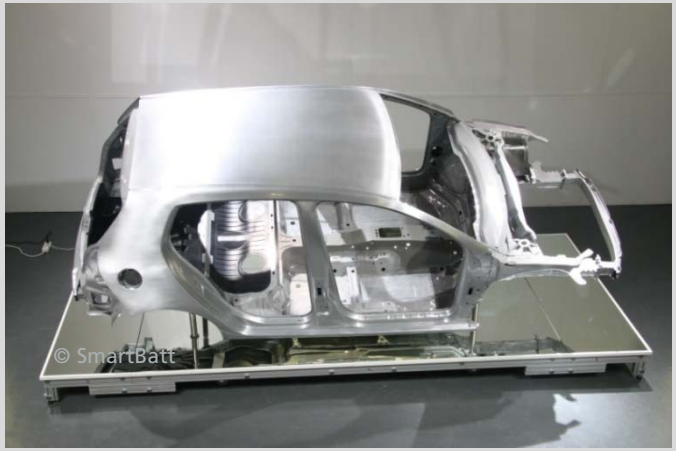
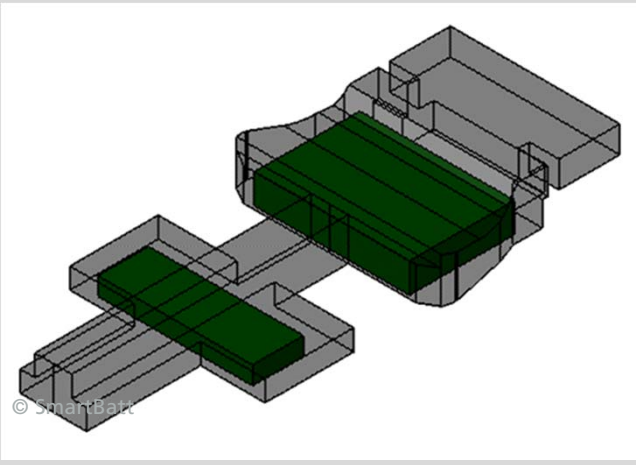
Project targets



- Segment C fully electrical vehicle
- Reference vehicle: SuperLightCar SLC
- Volume: no restrictions to passenger compartment
- Crash safety ≥ SLC
- Durability ≥ 150000 km

- Energy content > 20 kWh
  (> 100 km NEDC @ 1350 kg curb weight)
- P_{cont} = 42 kW (P_{peak} = 61 kW / 30 s)
- Operating temperature -20°C … 50°C
- m: SotA -15% (m_{cell}/m_{syst} = 0.75)



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Design space analysis

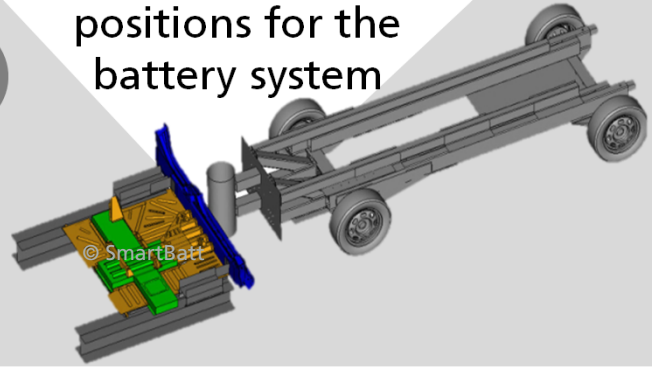
Macro Element approach

- Fast tool to simulate crashworthiness
  - Over 2000 variants were evaluated

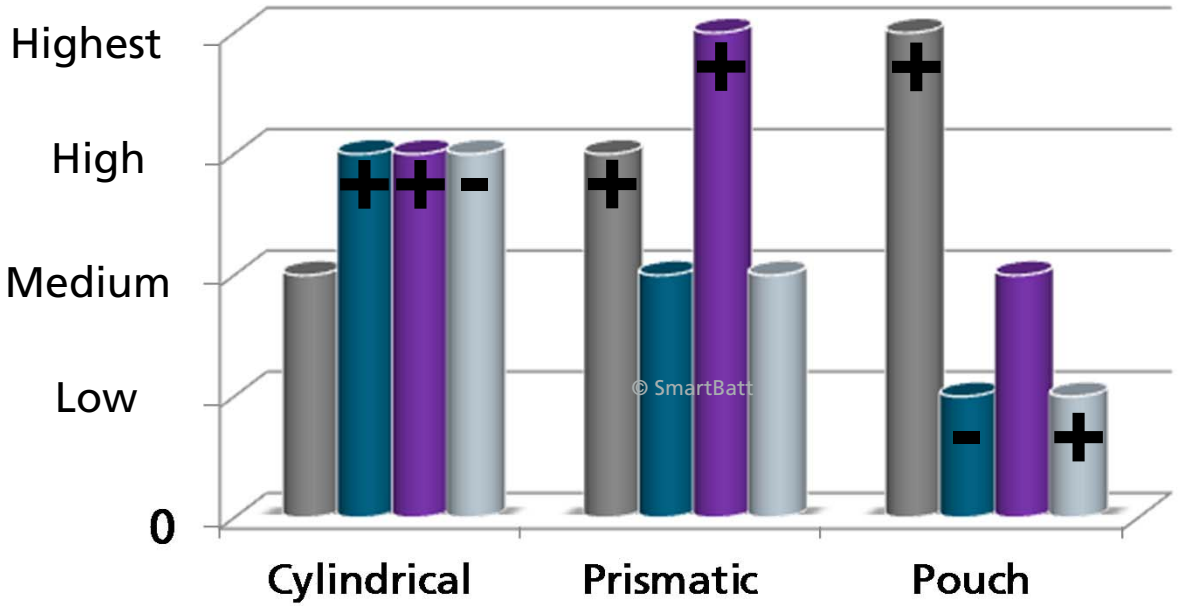
The most promising variants were analysed in FE

Results

Space below rear seats and in tunnel are safe positions for the battery system



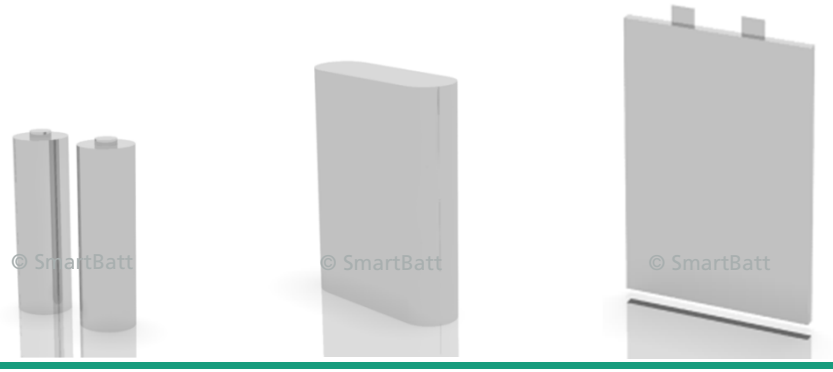
Types of battery cells



- Energy density
- Mechanical stability
- Thermal performance
- Manufacturing cost

\+ Desirable

\- Undesirable



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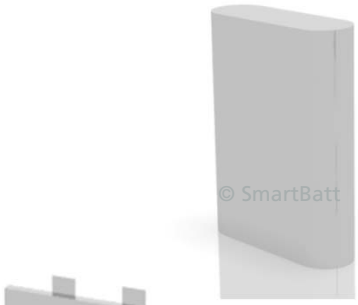
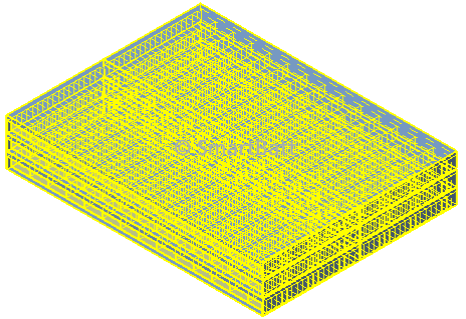
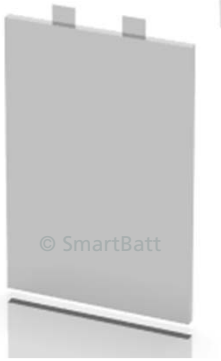
Tree possible battery concepts

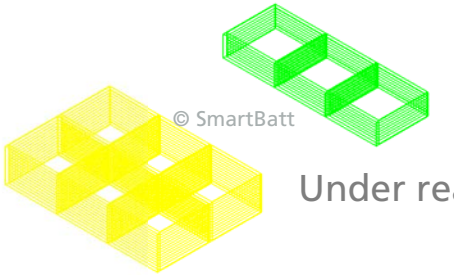
- Concept 1 (LCMO prismatic):
  E~23 kWh, 1408 cells
- Concept 2 (NCM pouch):
  E~27 kWh, 84 cells
- Concept 3 (LFP pouch):
  E~21 kWh, 324 cells



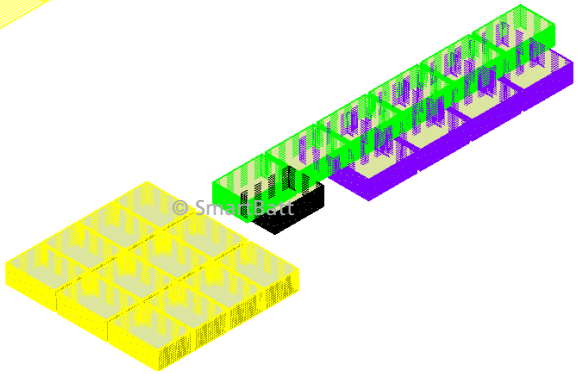
Under rear seats





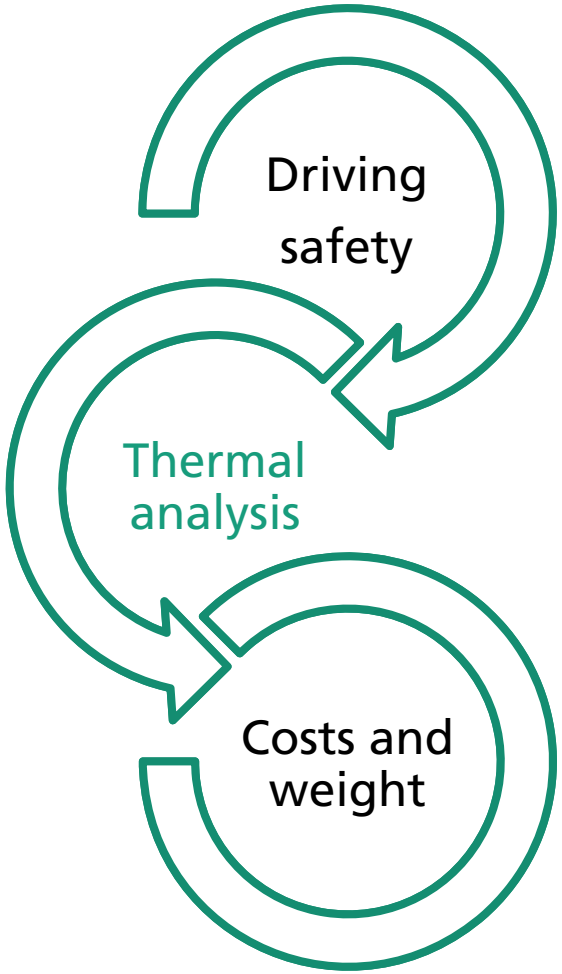


Under rear and front seats



Under rear seats and tunnel

Detailed assessment



- Numerical simulations on the vehicle to ensure driving safety
  - Brake test, steady-state skid pad test, slalom and lane change
- Thermal analysis
  - Artemis driving cycle
  - different ambient temperatures -30 up to 40 °C
- Preliminary weight and cost estimations for whole battery
  - Cells, Battery Management System (BMS)
  - Different materials:
    - Module housing
    - Battery housing

Final concept

- Concept 1 **(LCMO prismatic)**:
  E~23 kWh, 1408 cells
- Concept 2 (NCM pouch):
  E~27 kWh, 84 cells
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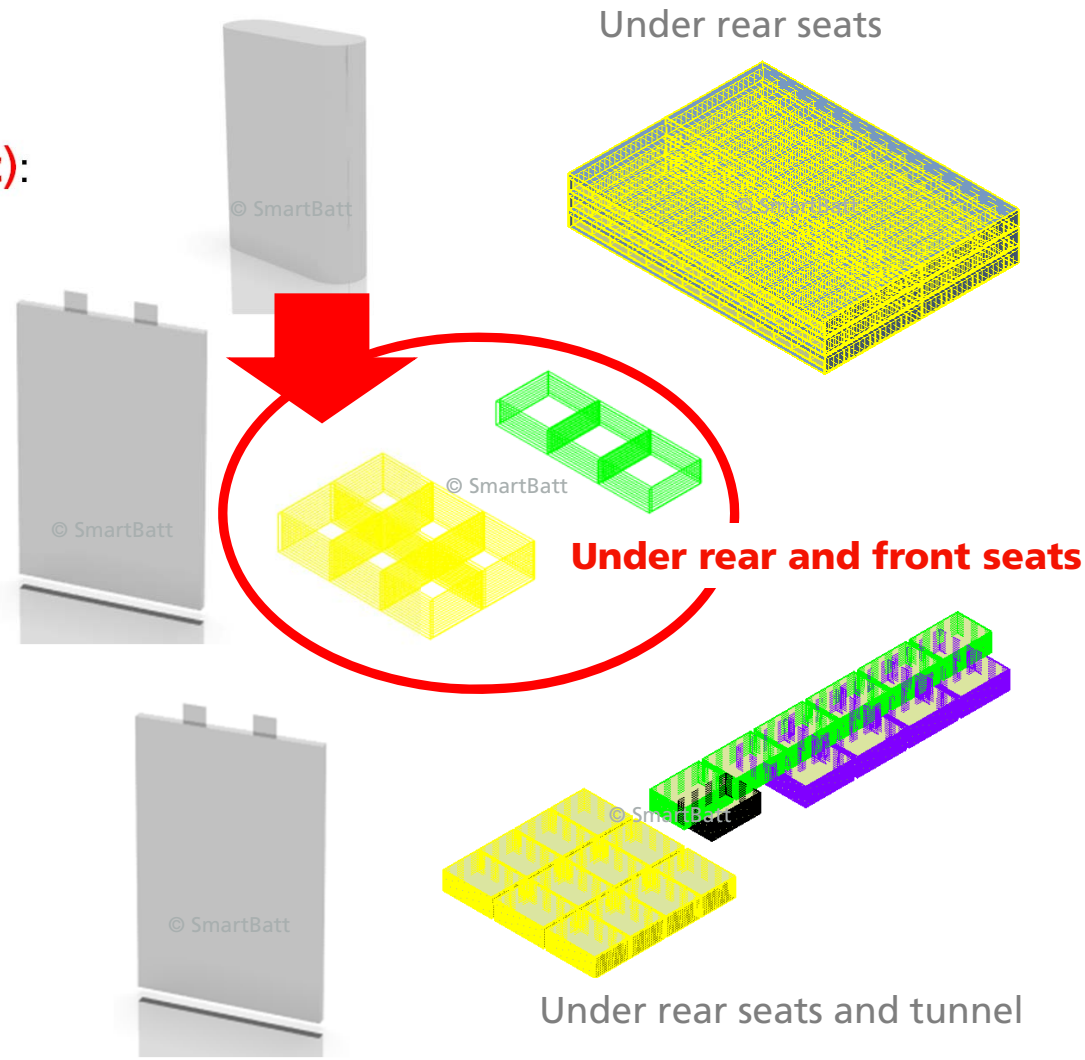
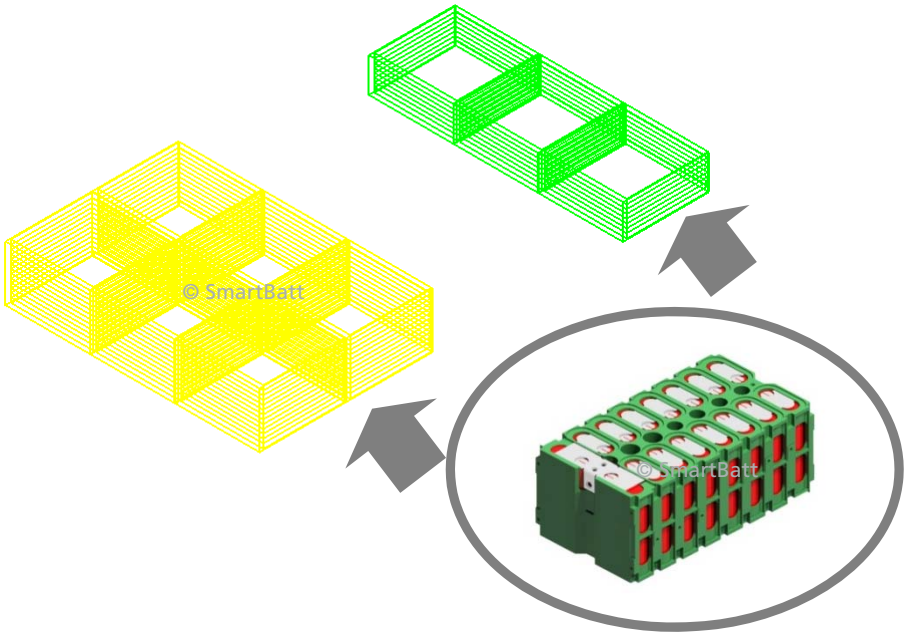
  E~21 kWh, 324 cells



Final concept - modules

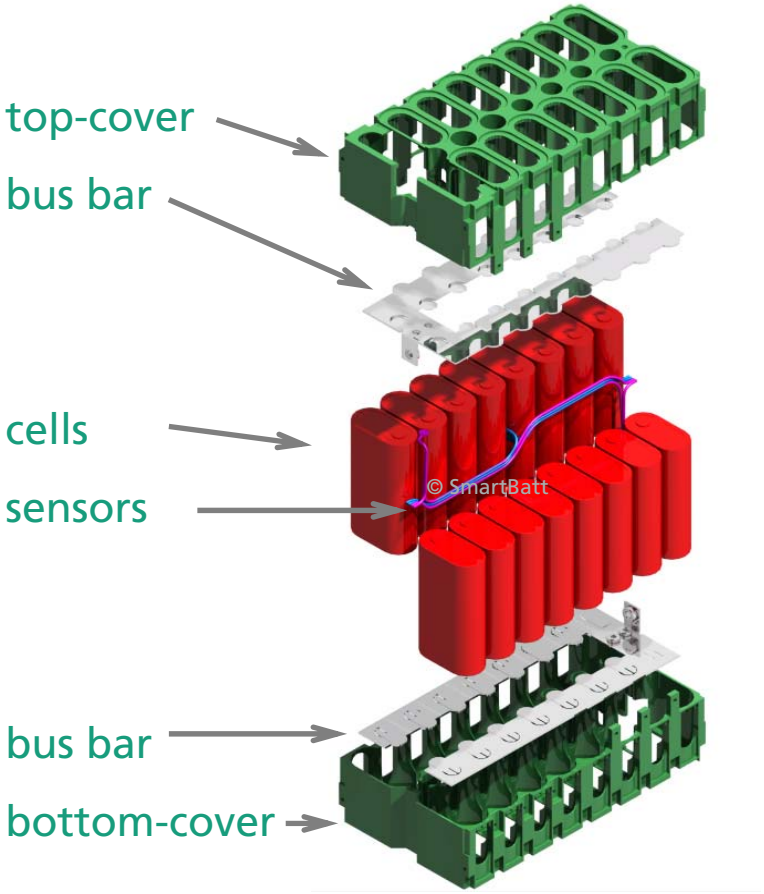


16-cell-module

- Weight including cells: 1.6 kg

structure weight / total weight **:**

- **12%**



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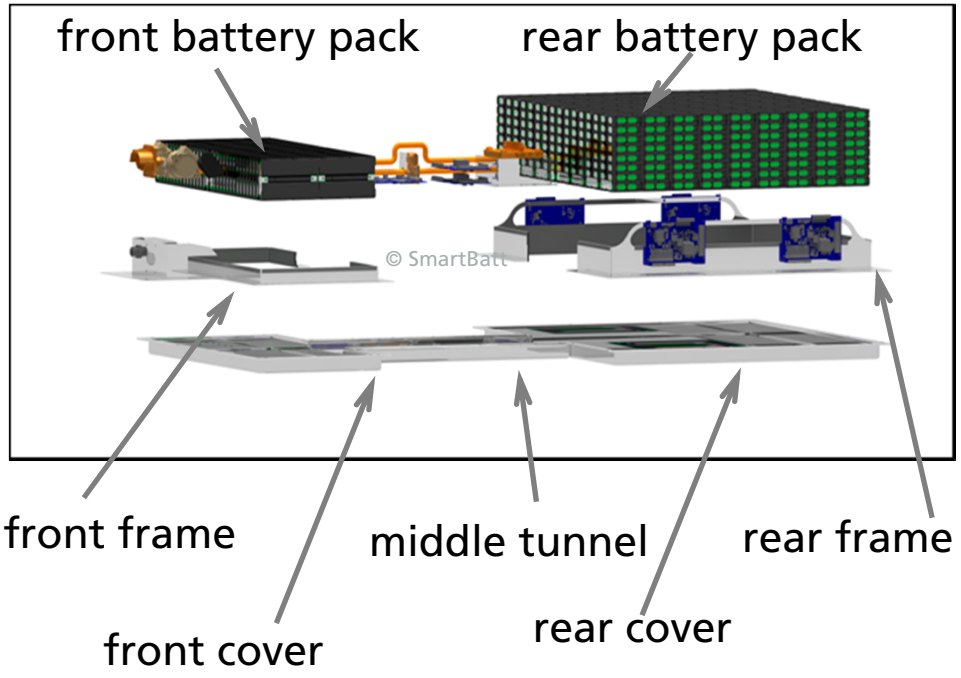
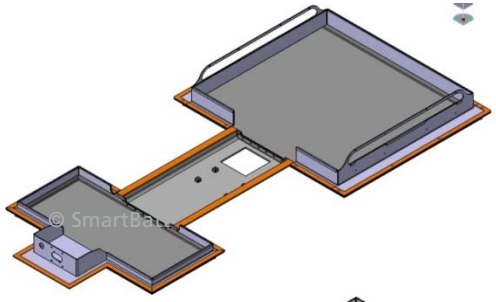
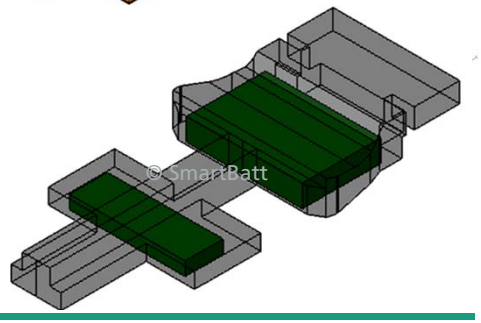
Concept selection criteria

	Final concept
Cell level	
Cell type	Prismatic
Chemistry	LCMO
Energy density	~181 Wh/kg
Mechanical shock	Passed
Thermal shock	Passed
Overcharge	Passed
Nail penetration	Passed
Module level	
Energy density	~160 Wh/kg
Different parts	4
Assembly	Simple
Number of modules	88
Thermal management	No
Vehicle dynamics	No change

Final concept - SmartBatt battery system





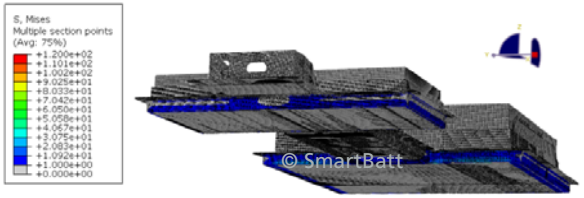


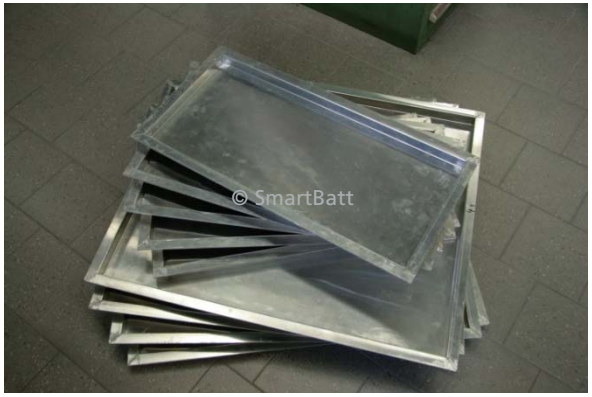
- Integration of the battery housing into the floor structure, i.e. using the floor structure as top of the battery housing
- Redesign of side pockets to redirect the load path in a side pole crash

Innovative materials

Aluminium hybrid foam sandwich material

- Core: spheres of Al-foam (4 mm) in a foamed epoxy adhesive
- Top and bottom layer: 0.5 mm Al sheet metal
- Integral density 0.94 g/cm³
  Al: 2.7 g/cm³ (- 70%)
- Bending stiffness 3.54·10⁸ Nmm²
  Al: 2.1·10⁸ Nmm² (+ 69%)
- Thermal conductivity 0.4 W/(m·K)
  Al: 220 W/(m·K) (- 99.8%)

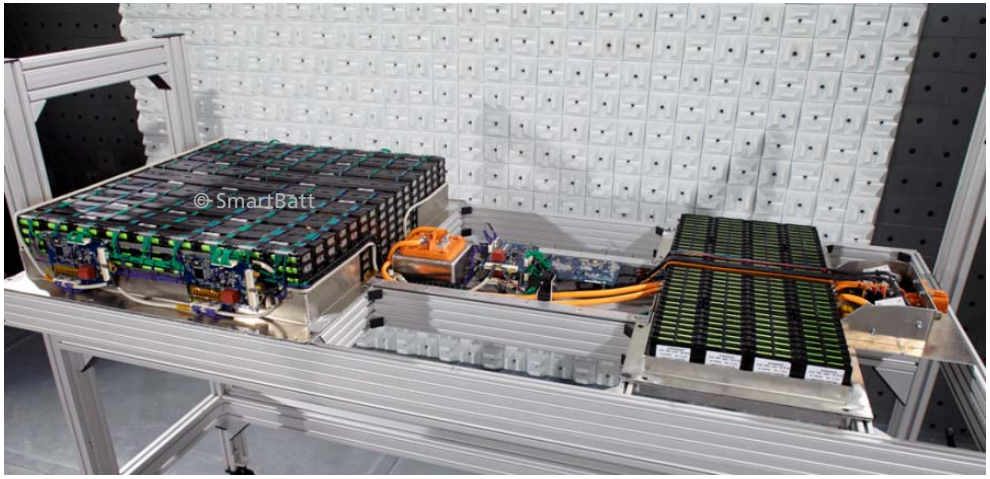


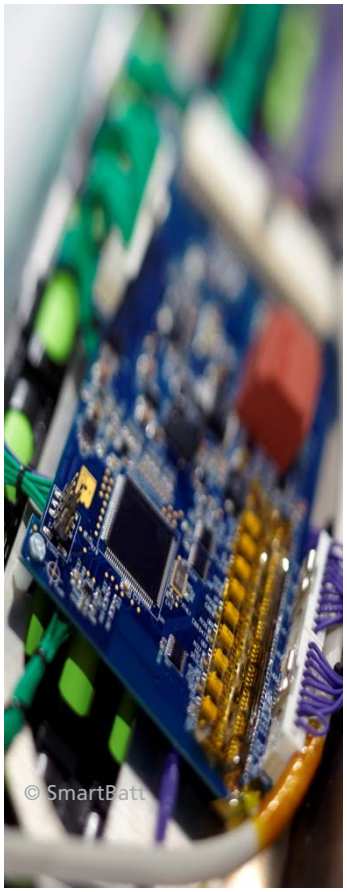


Further functional integration

1408 cells have to be connected - significant influence on system weight!

- Aluminium bus bars for connecting and fixing
- Different topologies analysed with respect to the total length
- 1 central Battery Control Unit (BCU) and
  6 Voltage Temperature Balance Modules (VTBM)
- VTBMs placed near by the modules

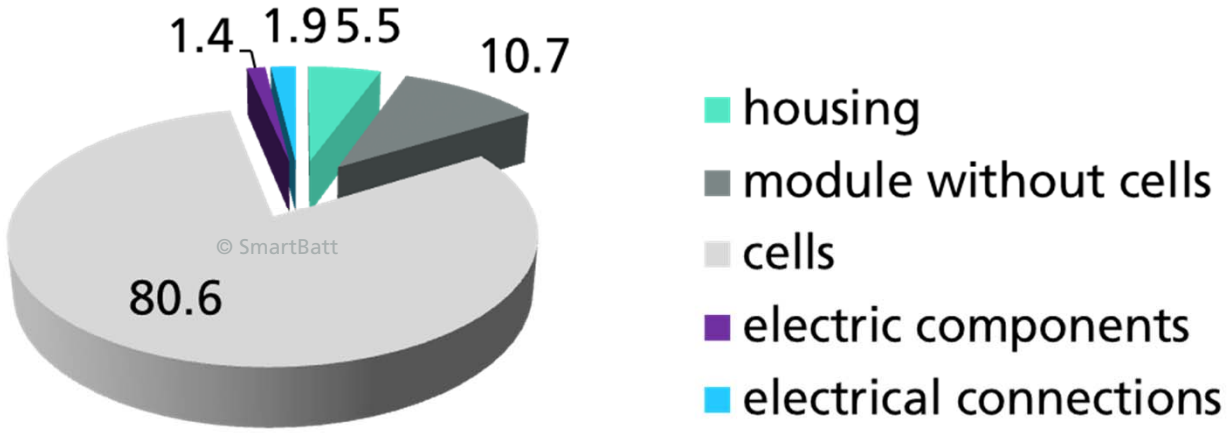




Overview results

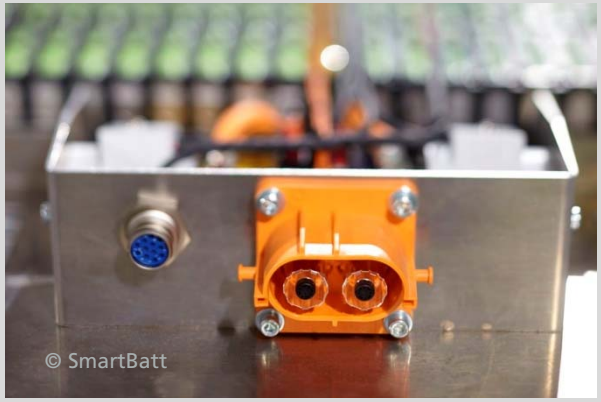
	mass	fraction
housing	8.5 kg	5.5 %
module without cells	16.6 kg	10.7%
cells	125.3 kg	80.6 %
electrical components	2.1 kg	1.4 %
electrical connections	2.9 kg	1.9 %
Total	**155.4 kg**	

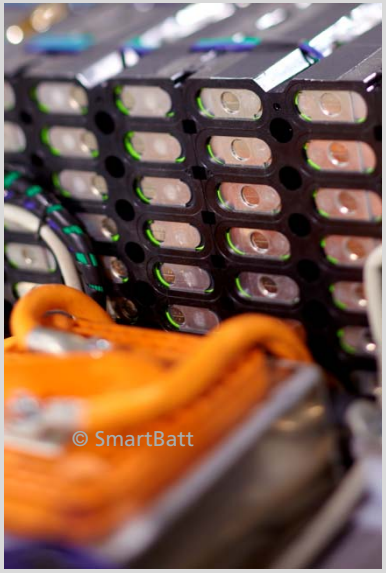
- Energy content: **23 kWh**
  => Range for segment C EV
  > 120 km
- Energy density: **148 Wh/kg**
  >> SotA ~ 80 Wh/kg (Nissan Leaf)
- Crash safety ≥ SLC with ICE



Conclusions

- Longer range of EV implies weight reduction and/or higher energy content of batteries
- This can be achieved by increasing the energy density
- Only evolutionary progress on cell level in next decade
- Intelligent engineering, i.e. lightweight design and system integration leads to significant higher energy densities on system level
- Energy density of the SmartBatt battery system:
  148 Wh/kg >> SotA ~ 80 Wh/kg





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Thank you for your attention!

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