AMAP

Aluminium Application in Lightweight Electric Car Design

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Introduction of ika / fka
Full vehicle competence

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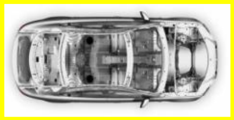
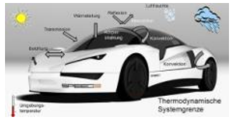



Full Vehicle

Chassis | Body | Drivetrain | Electrics/ Electronics | Driver Assistance


Strategy and Consulting


Vehicle Concepts


Thermal Management


Acoustics


Driver Experience and Performance

- Founded in 1902 (ika) and 1981 (fka)
- ika has approx. 350 employees:
  - 90 engineers, 56 workers, technicians and apprentices, about 200 student workers
  - Together with co-operation partner fka access to a total staff of approx. 450 employees
- References:
  - Automotive customers from Europe, USA and Asia
  - OEM and suppliers
  - Public funded research

Agenda

- Motivation of Lightweight Design
- Material Characteristics
- Multi-Material Concept Light-eBody
- Hydro's Full Aluminium Concept
- Outlook and Conclusion

Motivation of Lightweight Design
The Road Transport System is Facing a Multitude of Challenges

Individualisation of mobility needs

Urbanisation

Accidents

Limited resources

Demographic change

Crime

Congestion

Public debt

Rising costs of energy and fuel

Climate change

Emissions

Connectivity

Motivation of Lightweight Design
Saving Potentials and Weight Helix

Reduction of fuel consumption/CO_2 emission

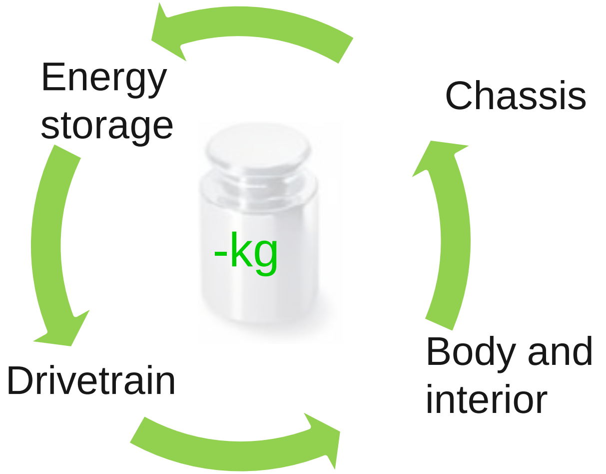
- Reduction per 100 kg weight saving (in NEDC):
  - 0.15 l/100 km/ 3.75 g CO_2/km (primary effects)
  - 0.30 l/100 km (secondary effects)

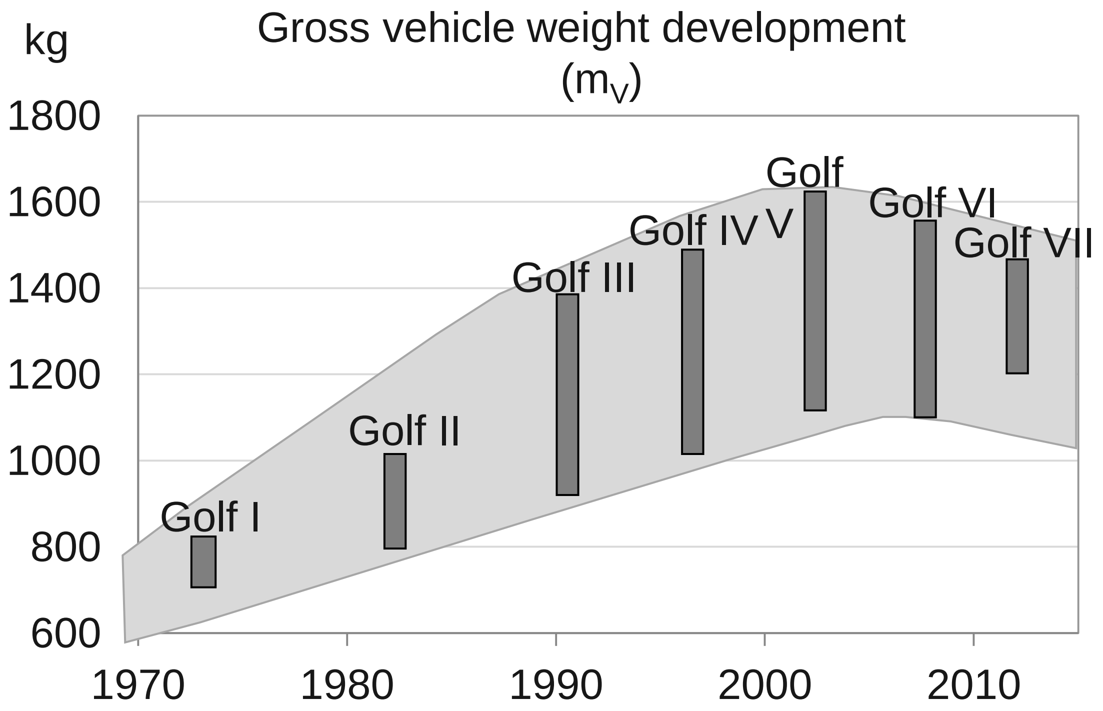
CO_2 emission targets correspond to

- 5.6 g / 100 km (Petrol)
- 4.9 g / 100 km (Diesel)

Source: Volkswagen

„Weight helix“

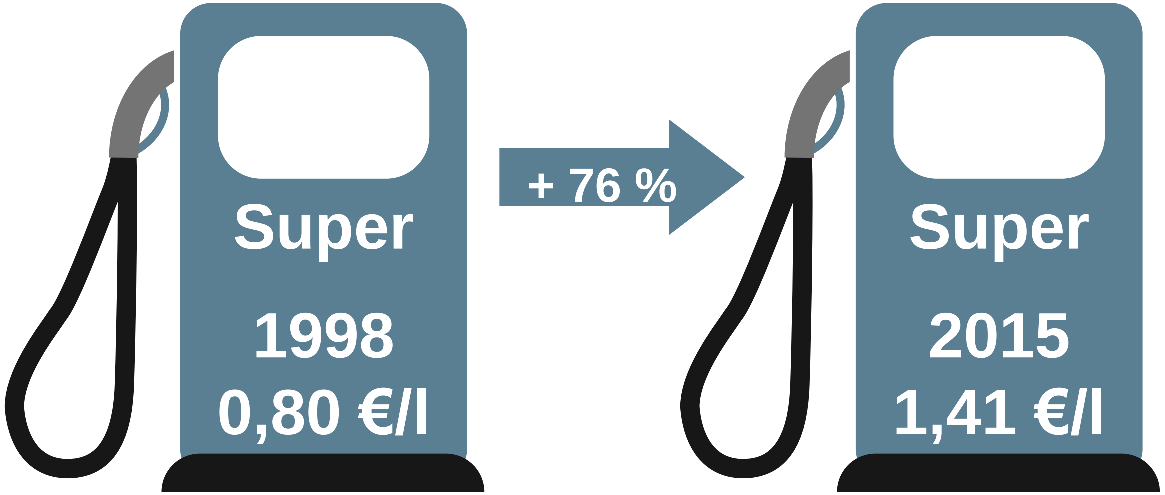




Motivation of Lightweight Design
CO_2-Regulation and Oil Price

- Limited resources
- Rising energy cost
- CO_2-emission Regulation

Europe	USA	China
		
2020 95 g CO_2/km	2020 101 g CO_2/km	2020 5 l/100 km



Fleet emissions 2009:

- VW: 153 g/km
- BMW: 158 g/km
- Audi: 163 g/km
- Daimler: 179 g/km

Fleet emissions 2013:

- VW: 134 g/km
- BMW: 139 g/km
- Audi: 140 g/km
- Daimler: 149 g/km

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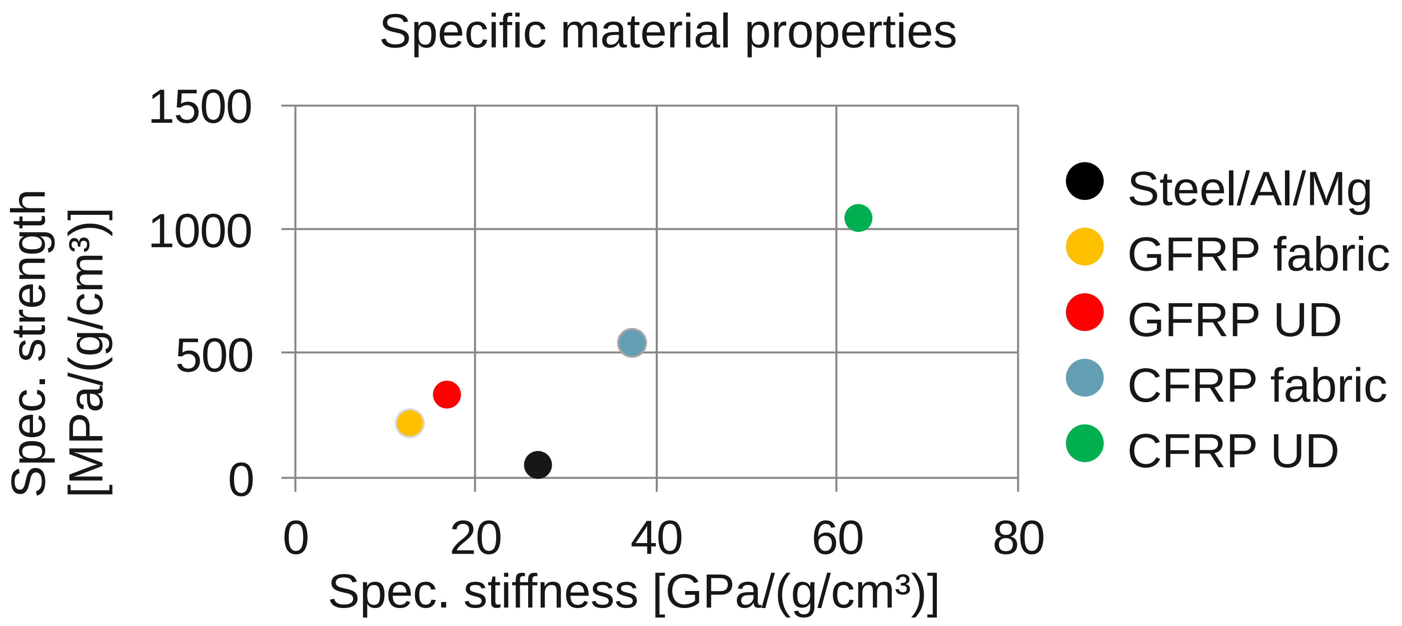
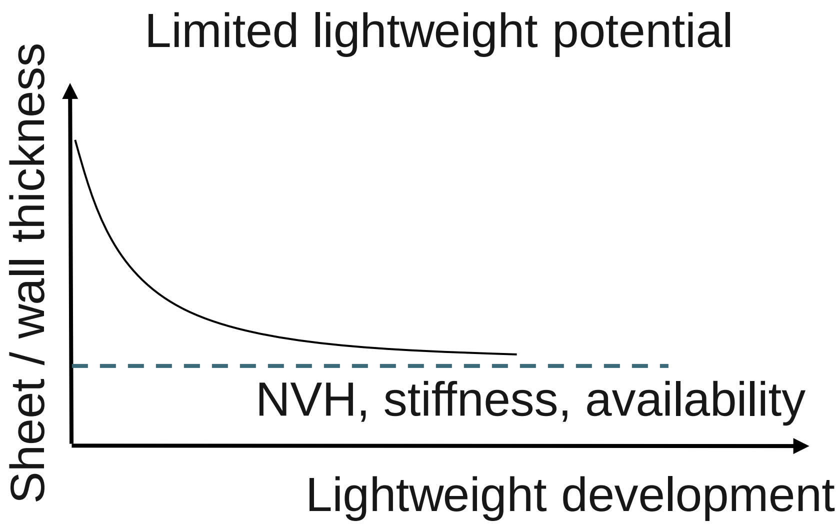
Material Characteristics
Limits of Steel Lightweight Design

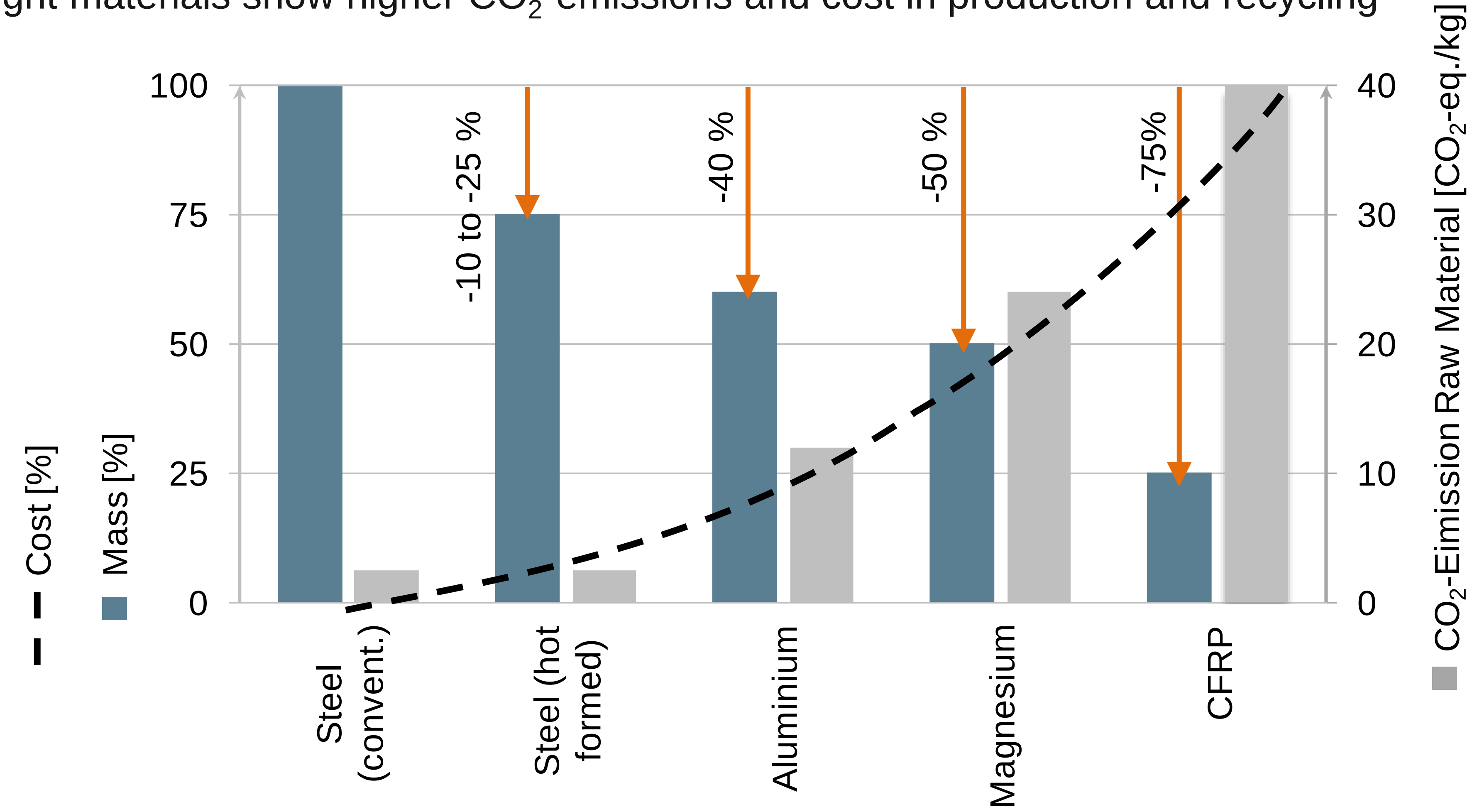
- The right material at the right place:
  - Choice of material depending on component requirements and material properties
- Sheet thickness reduction limited e.g. due to stiffness and NVH
- Global body stiffness declines because of equal Young’s modulus
- High strength steel not suitable for all components because of lower maximum elongation





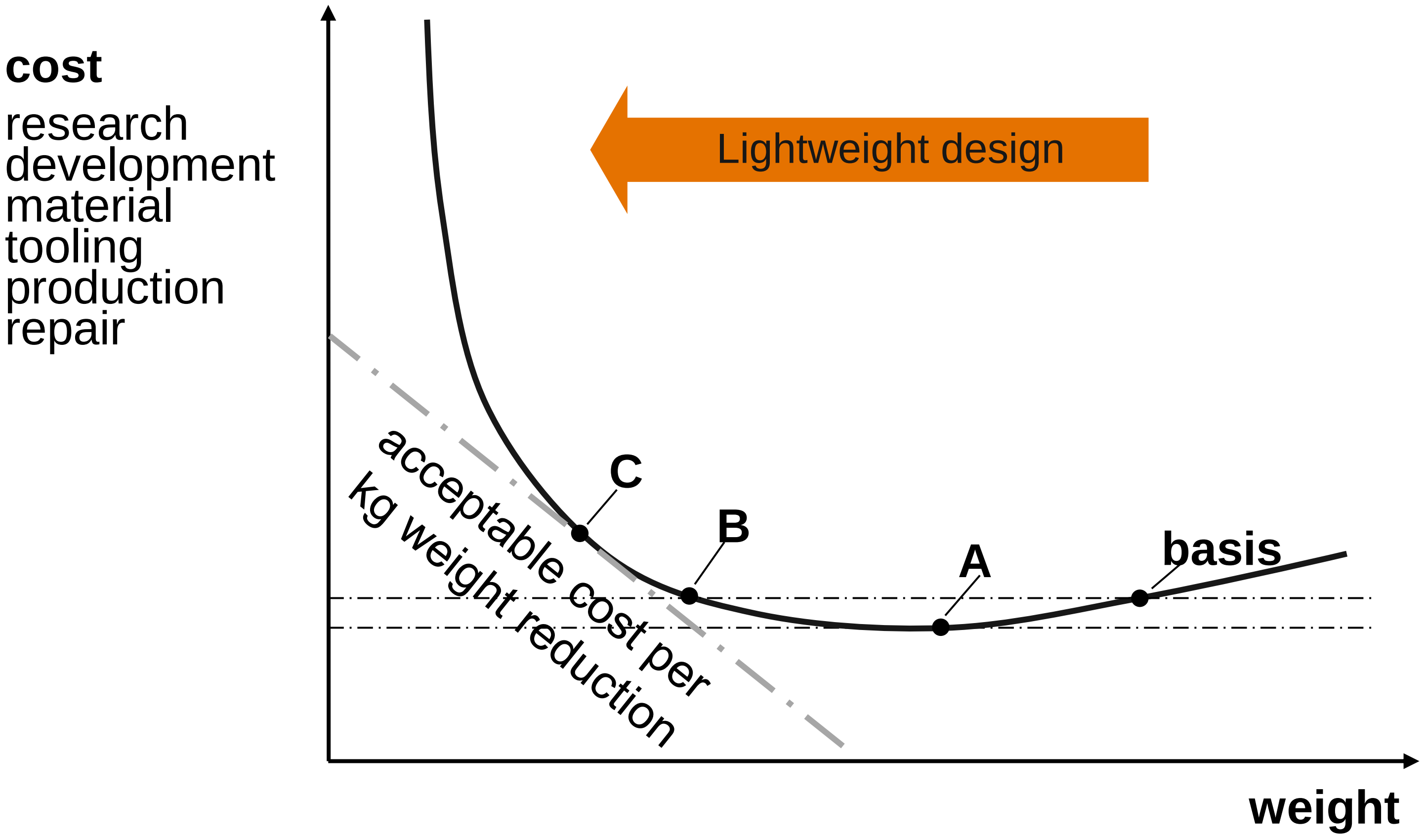
Material Characteristics
Lightweight Potential and CO_2-Emissions

- Lower vehicle weight leads to less energy consumption during usage
- Lightweight materials show higher CO_2-emissions and cost in production and recycling



Source: Volkswagen AG

Material Characteristics
Cost Versus Weight



Cost Breakdown for high-volume Car	
Material cost	53%
Production cost	30%
R&D costs	10%
Other costs	7%

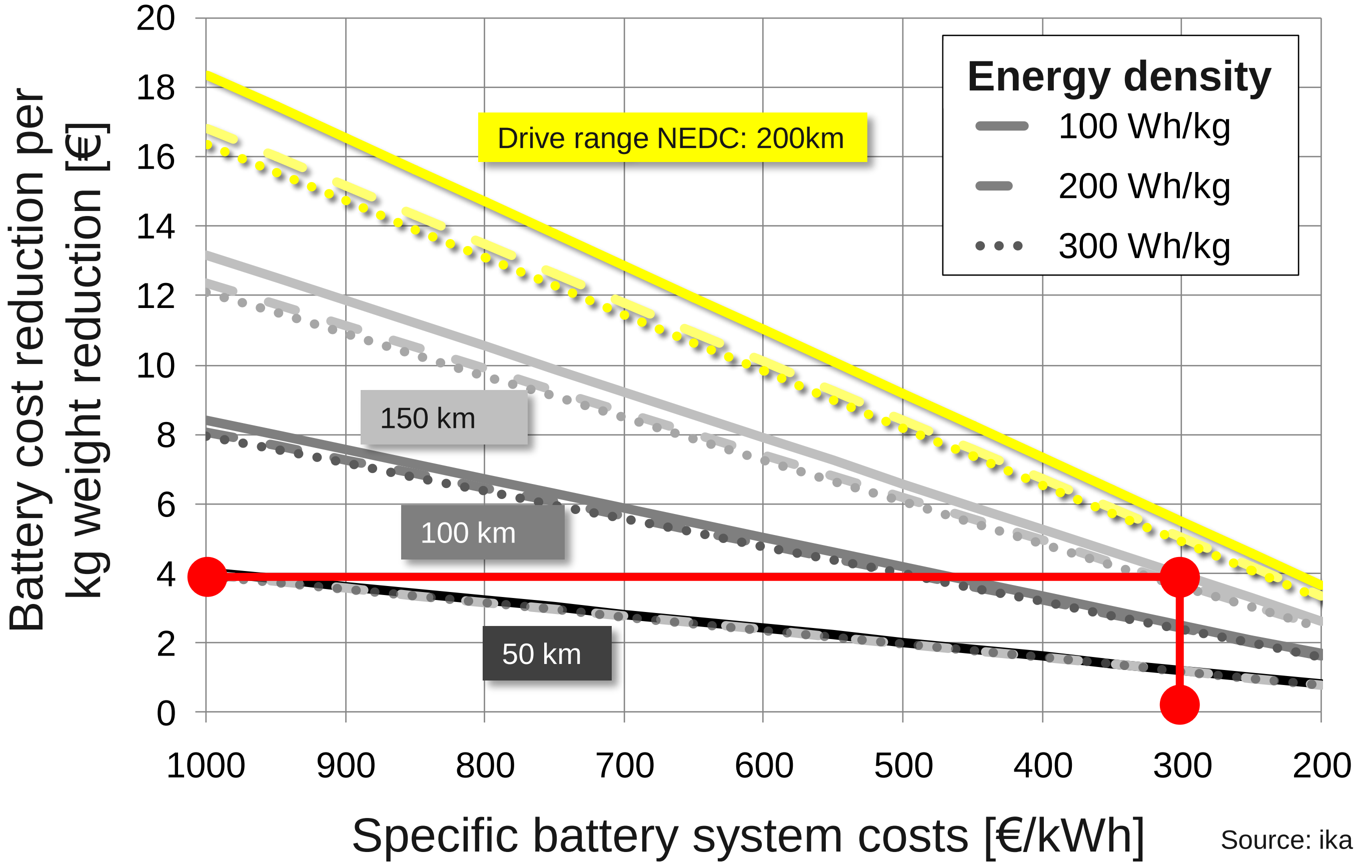
A: minimum cost

B: cost neutrality

C: economic optimum for the manufacturer

Material Characteristics
Compensation of Lightweight Cost

- Compensation of the higher weight of alternative drivetrains
- New economic aspects for lightweight design:
  - Lightweight costs for alternative drivetrains are (partly) compensable



Source: ika

Hybrid drive

Electric drive

Sources: BMW Group, Volkswagen AG

Material Characteristics
Aluminium Trend in Automotive Industry

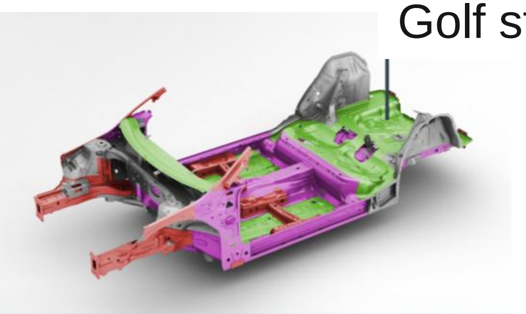
- Full aluminium versions also for high volume production
- Potential design approaches: space frame and self-supporting uniform

Steel
High strength steel
Ultra high strength steel
Aluminium

Time →

Passat

Golf study



Full Aluminium Body

From hybrid design to full aluminium design

From smaller to higher volume production

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- Multi-Material Concept Light-eBody
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Multi-Material Concept Light-eBody
Project Targets

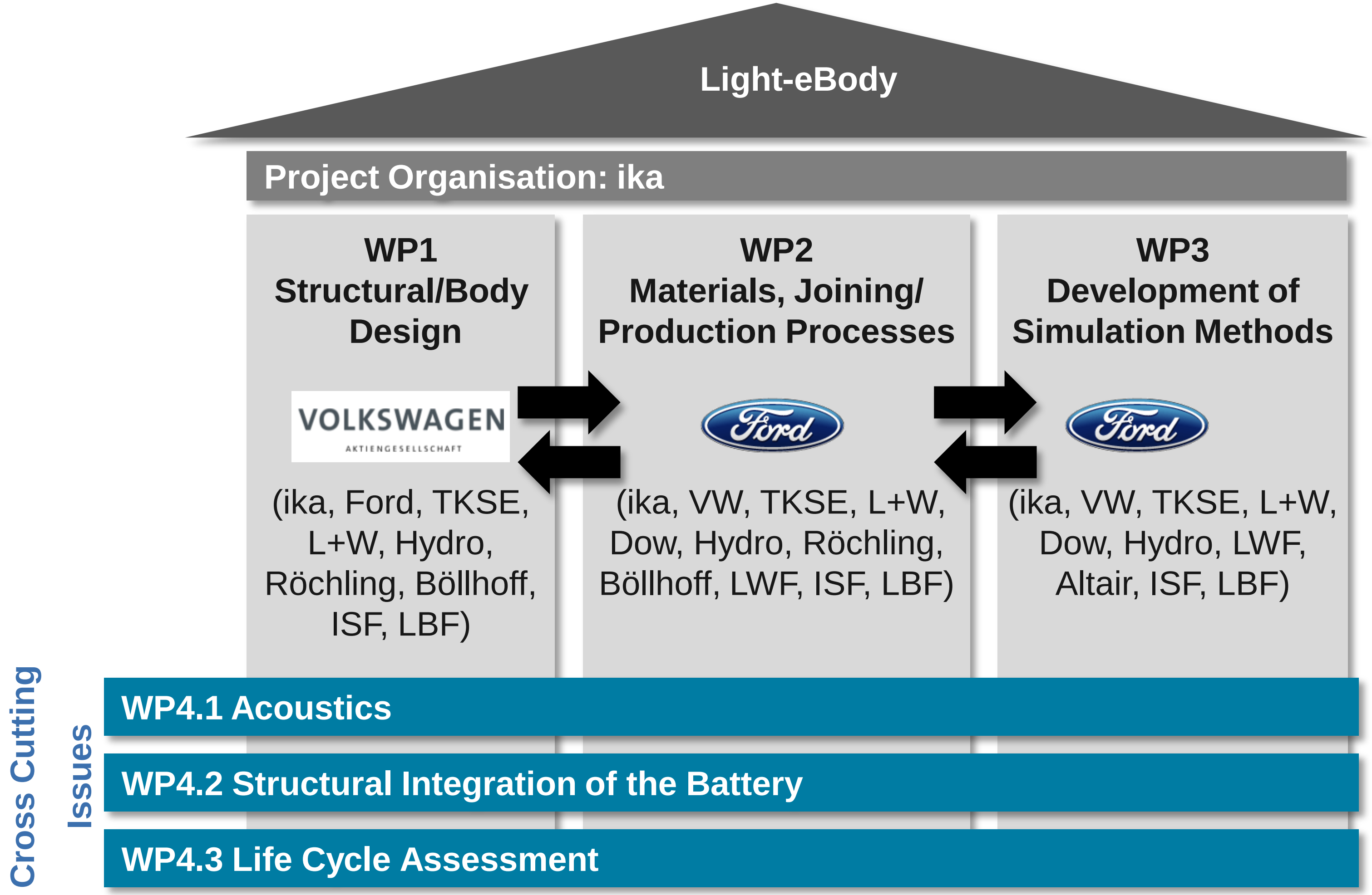
- Development of an innovative multi-material lightweight body-in-white (BIW)
- Suitable for an electric vehicle in mass production → Cost competitive lightweight design
- Intensive use of profiles for the vehicle load bearing structure
- Lightweight panels made from low density materials
- Integration of the battery in the vehicle structure as load bearing element
- Development of new material concepts and production processes for multi-material design
- Further development of simulation methods and joining technologies
- All technologies and lightweight cost have to be suitable for mass production (1.000 /d)
- Life Cycle Analysis to evaluate the environmental impact of the concept

LIGHT - eBODY

Multi-Material Concept Light-eBody
Project Structure

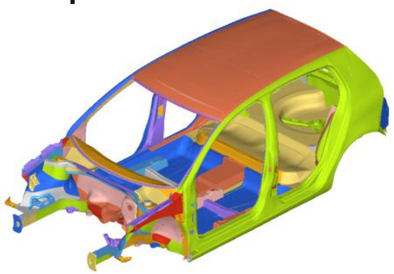
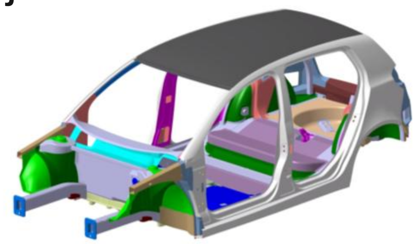
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

INSTITUT FÜR KRAFTFAHRZEUGE ika RWTH AACHEN UNIVERSITY



Multi-Material Concept Light-eBody
Use Case and Concepts

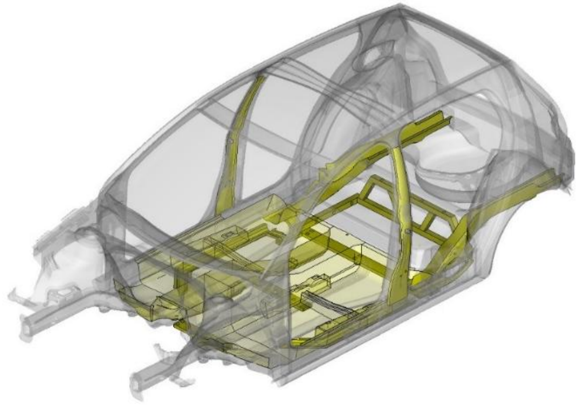
- Use case: urban/commute
- Seats: 2+3
- Range: > 150 km (NEDC)
- v_{max}: 150 km/h
- Production: large volume (1,000/d)
- Segment: C

Conservative Approach: Small changes Shell design	**Multi-Material Approach** Purpose design Profile intensive design
Conservative Concept 	Light-eBody Project 

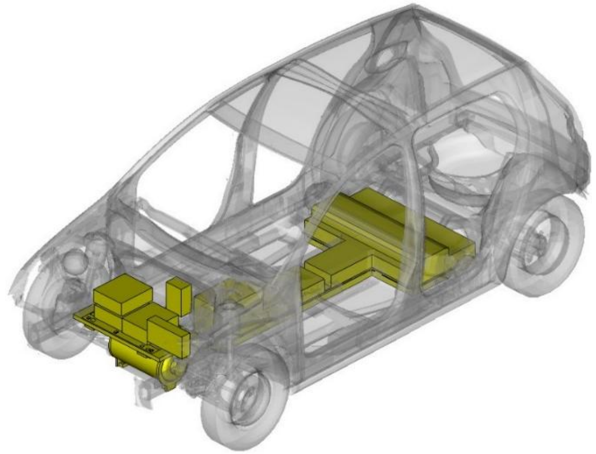
Multi-Material Concept Light-eBody
Conservative Concept

- Conversion of the conventionally powered Golf V into an electric vehicle
- Changes and reinforcements are necessary for
  - Protection of the battery cells
  - Adaption for new crash load cases
  - Define project target values e.g. reference weight and intrusion limits
- Additional weight of reinforcements, changes and the battery structure: 35 kg

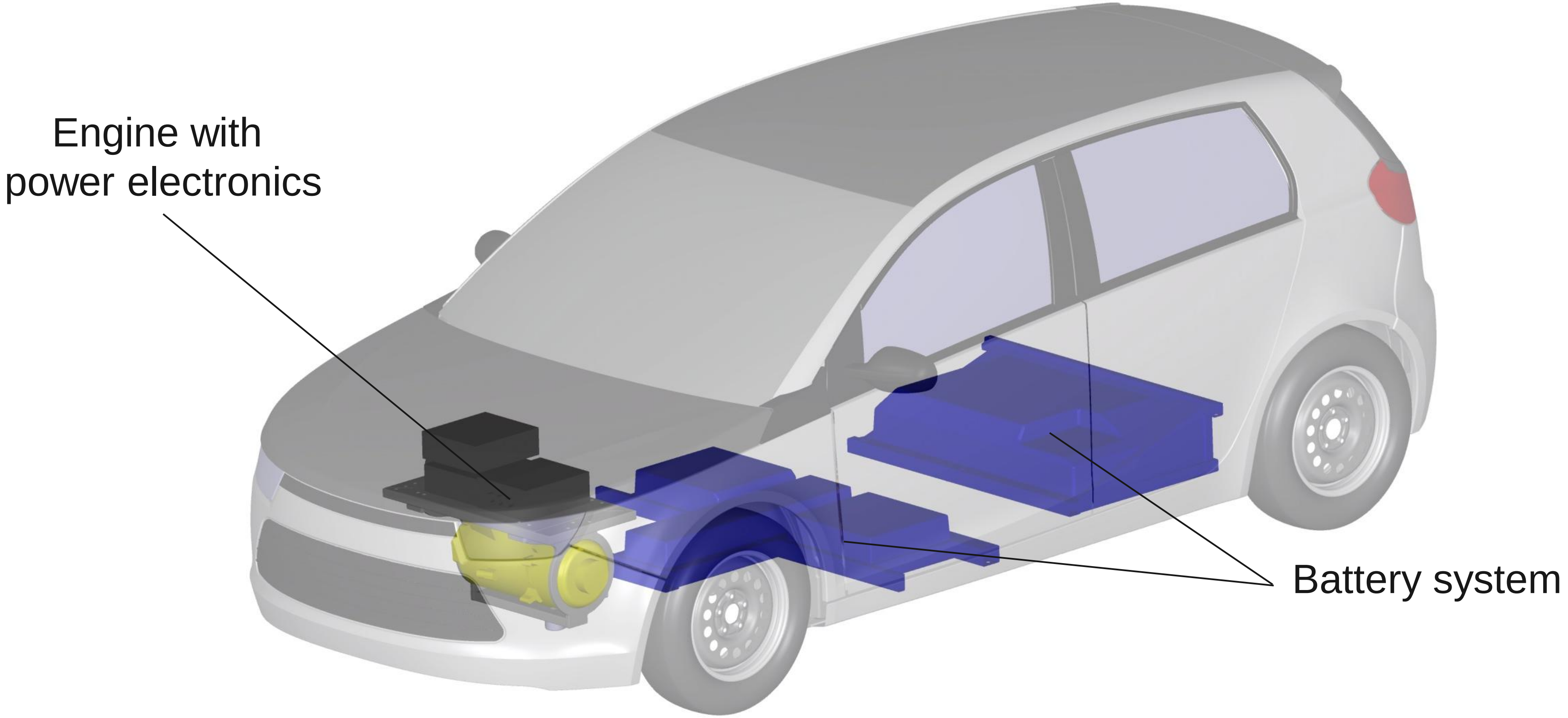
Additional structure / Reinforcements



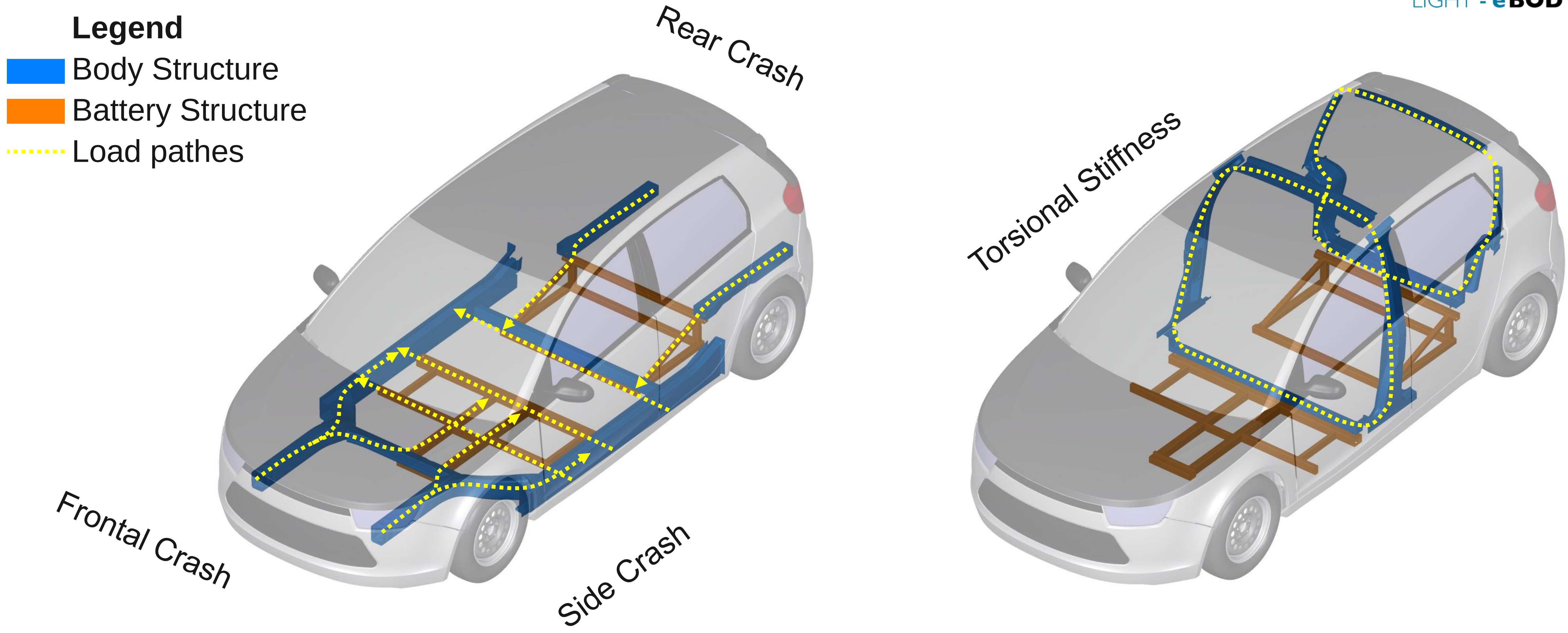
Drivetrain



Multi-Material Concept Light-eBody
Drivetrain of the Light-eBody and the Full Aluminium Concept



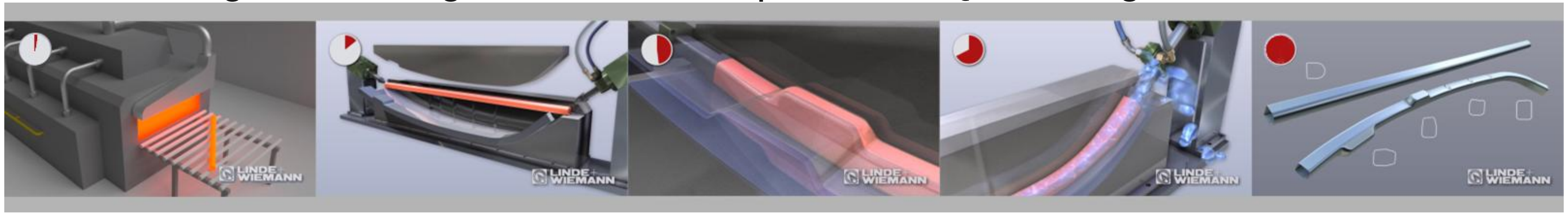
Multi-Material Concept Light-eBody
Load Pathes of the Light-eBody and the Full Aluminium Concept



Multi-Material Concept Light-eBody
Accra Technology

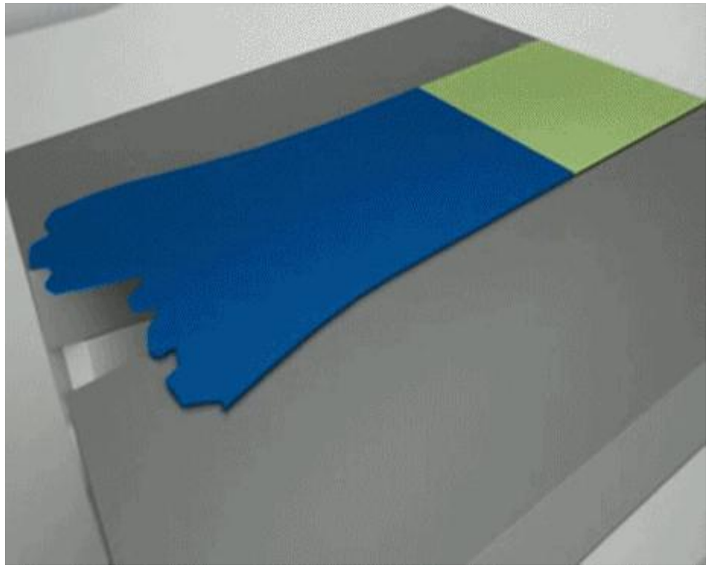
- Profile based structural components in the area of the passenger cell
- Based on simple modes of action
- Combination of Hotforming, Hydroforming and Hardening
- Material grades comparable to press hardening components
- Complex three dimensional formed part geometries with load optimised sections
- High repeat accuracy by high cooling rates

Austenitising Molding Inside pressure Quenching

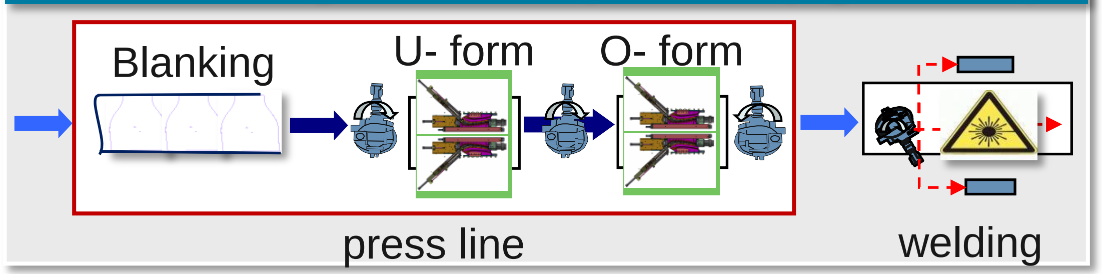


Multi-Material Concept Light-eBody
T³ Profile Technology

- Flangeless profiles for optimal usage of the section space
  → Thickness and weight reduction
- Design benefits from part integration
- Crash performance benefits from reduced pre-strain
- Wide range of different cross sections is possible
- All steel grades, Tailored Blanks possible
- Indirect press hardening



Manufacturing on standard press line (high volume)



ThyssenKrupp Steel Europe

Multi-Material Concept Light-eBody Design

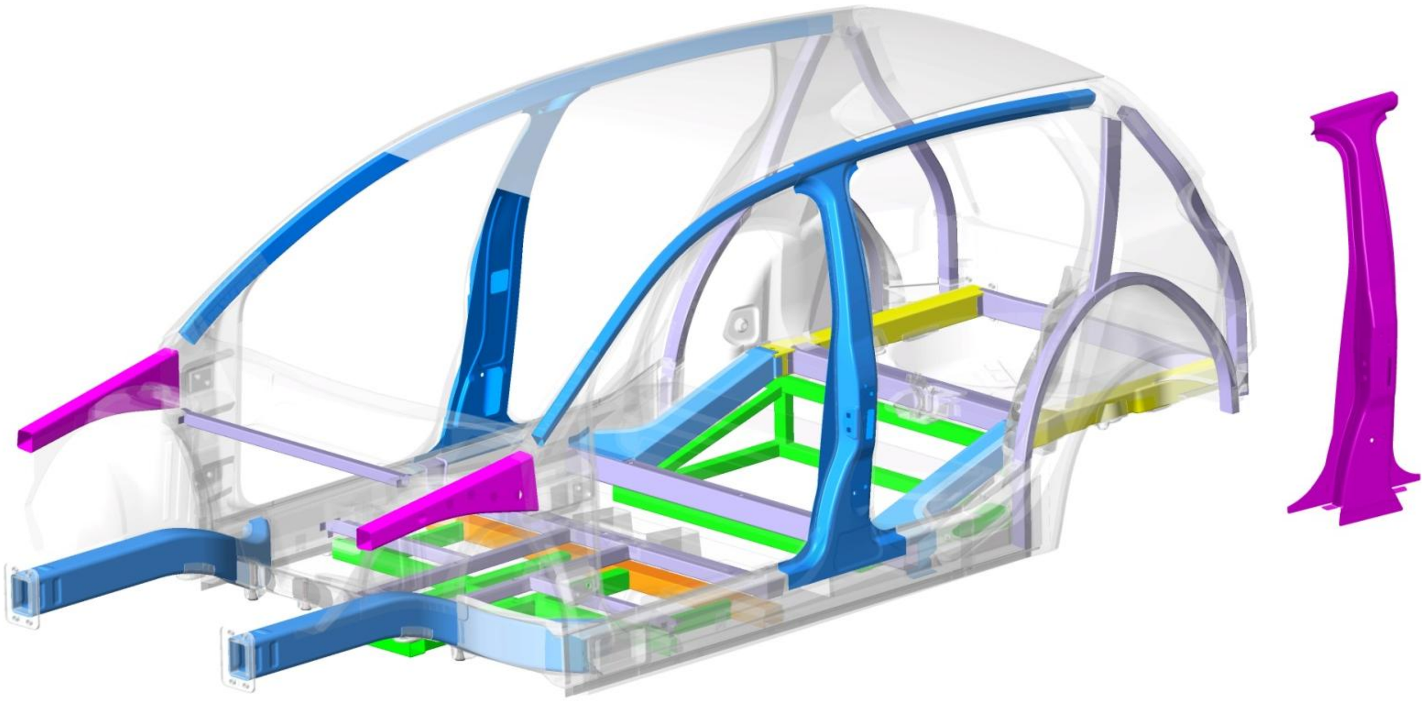
Multi-Material Concept Light-eBody
Body-in-White

Multi-Material Concept Light-eBody
Profile Technologies

Steel Profiles
- Accra
- T³
- Hydroforming
- Rollforming

Aluminium Profiles
- Tailor Rolled Tube
- Extrusion

Lightweight Panels
- Aluminium Sheet
- Stratura

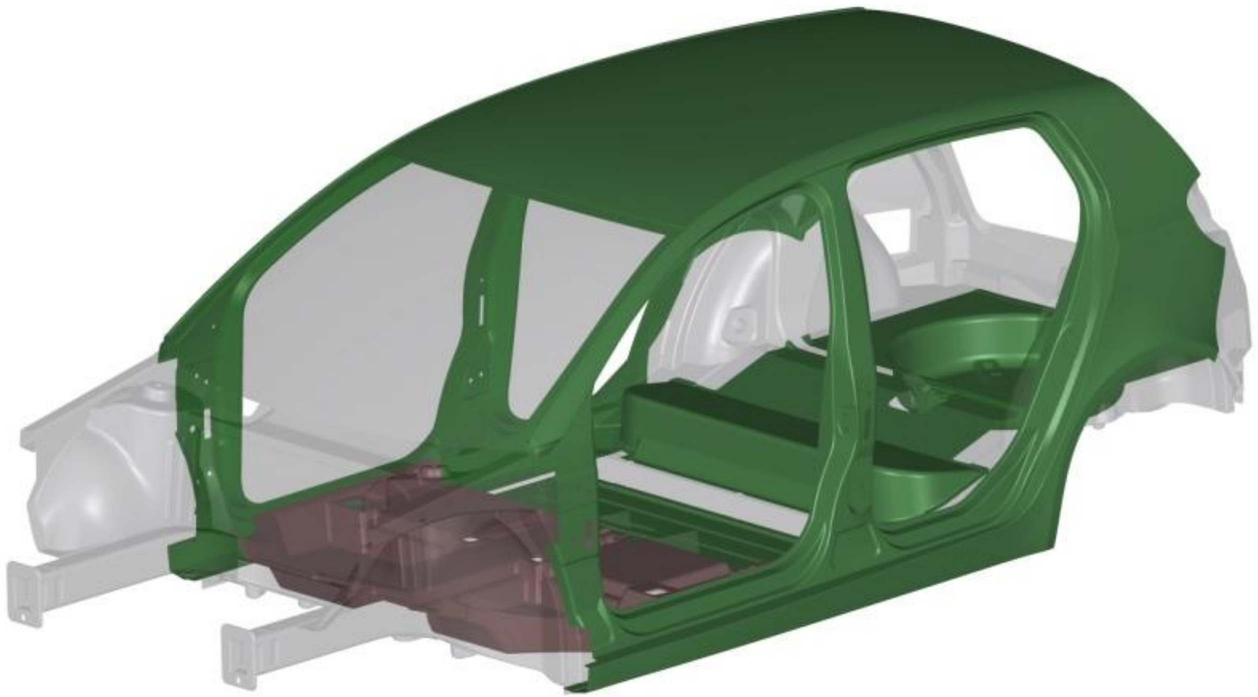


Multi-Material Concept Light-eBody
Aluminium Sheet Applications

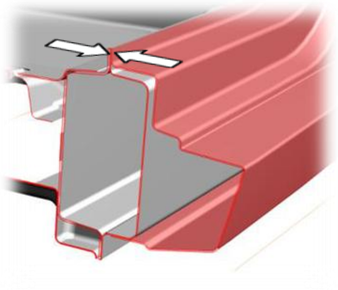
Steel Profiles
- Accra
- T³
- Hydroforming
- Rollforming

Aluminium Profiles
- Tailor Rolled Tube
- Extrusion

Lightweight Panels
- Aluminium Sheet
- Stratura

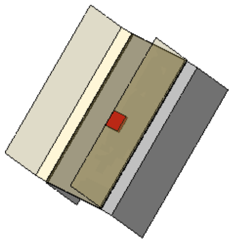


Multi-Material Concept Light-eBody
Joining



Definition of requirements and identification of potential technologies

Source: LWF



Source: FORD

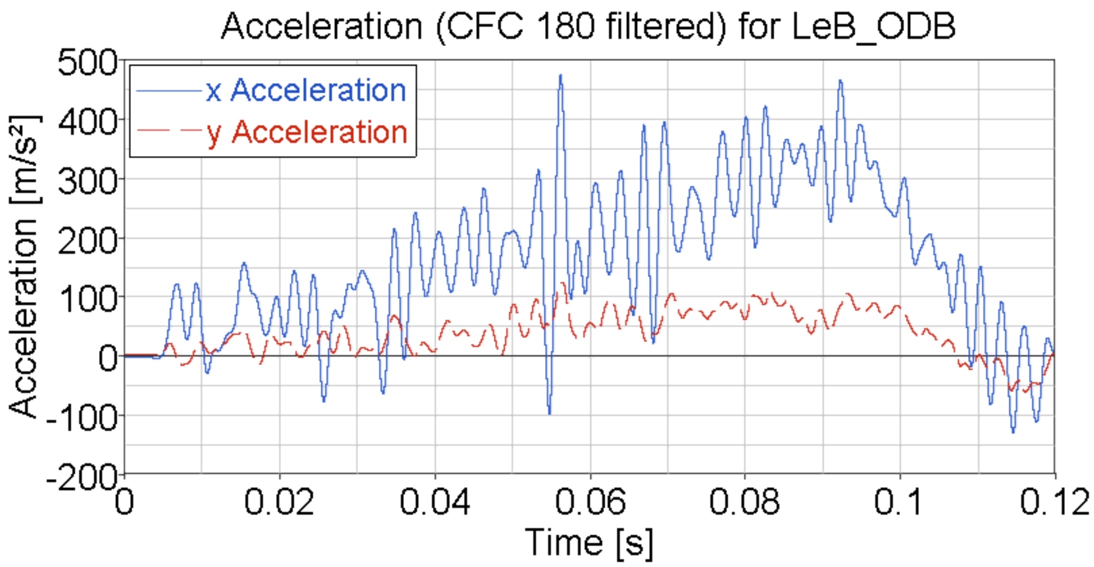
Development of models for representation of joint properties in car body FE-model

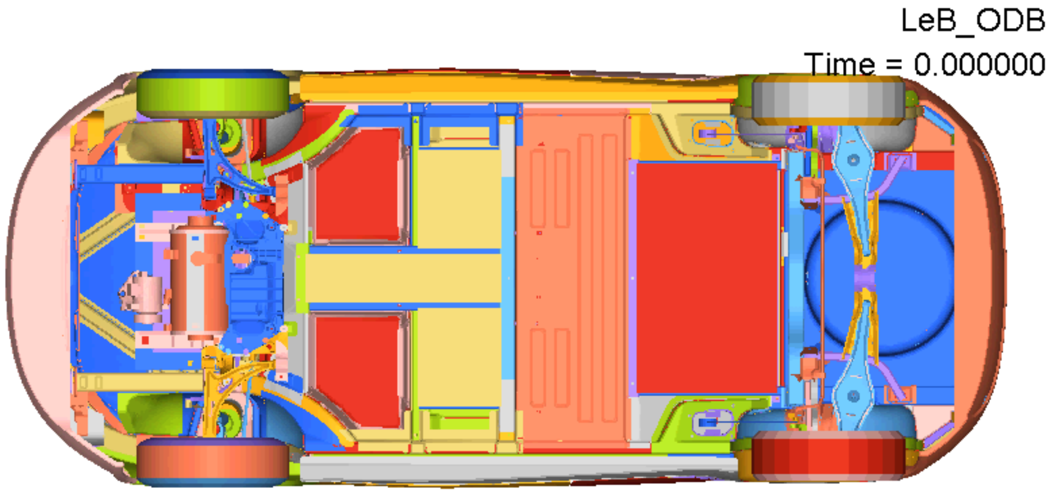
Experimental analysis and optimization of suitable joining technologies

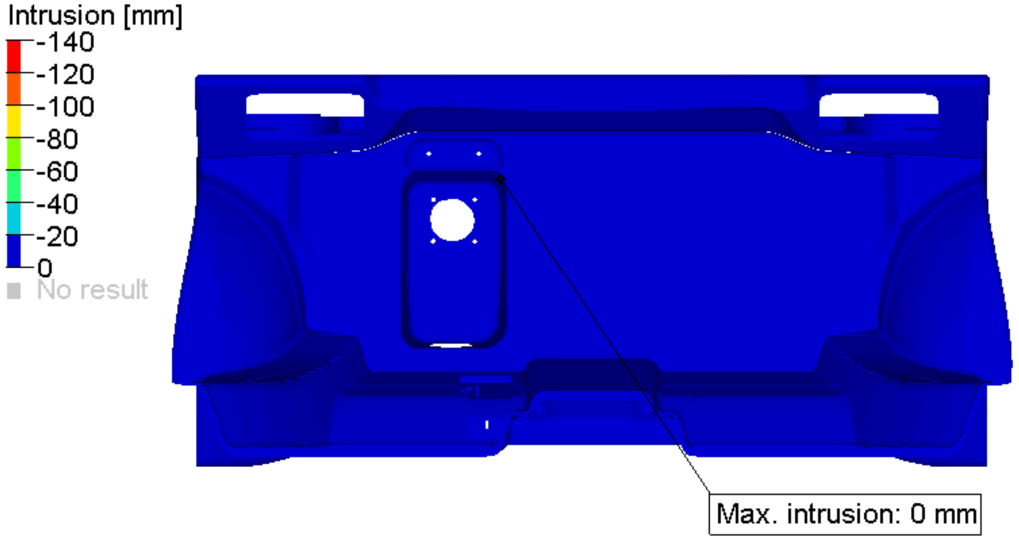
Joining technologies used for the Light-eBody concept:

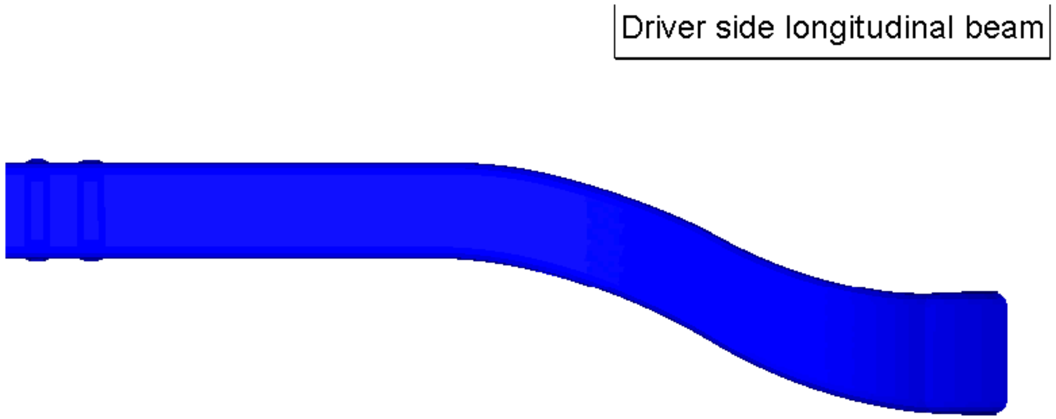
(Indirect) resistance spot welding, GMA welding, laser beam welding, resistance element welding, self-pierce riveting, RIVTAC® and more

Multi-Material Concept Light-eBody
FEM Analysis Euro NCAP ODB









Multi-Material Concept Light-eBody
FEM Analysis

LIGHT - eBODY

Euro NCAP

Frontal Offset Impact	Target	Evaluation
Firewall intrusion	< 125 mm	✓
A-Pillar displacement	< 20 mm	✓
Intrusion into battery compartment	< 15 mm	✓
Deceleration pulse	max. 50 g	✓
Side Impact - Pole	**Target**	**Evaluation**
Sidewall intrusion	< 340 mm	✓
Intrusion into battery compartment	< 15 mm	✓
Deceleration pulse	max. 30 g	✓

FMVSS

Rear Impact	Target	Evaluation
Max. intrusion	< 465 mm	✓
Intrusion into battery compartment	< 15 mm	✓

Multi-Material Concept Light-eBody
FEM Analysis

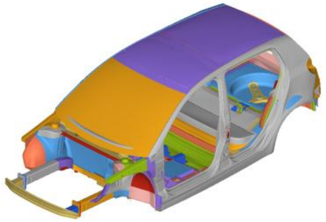
IIHS

Side Impact	Target	Evaluation
Sidewall intrusion	< 320 mm	✓
Intrusion into battery compartment	< 15 mm	✓
Deceleration pulse	max. 35 g	✓

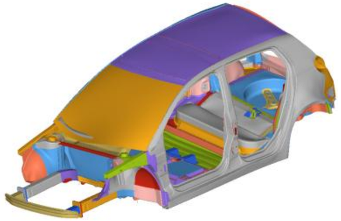
Static Analysis

Static Torsion	Target	Evaluation
Torsional stiffness	≥ 25500 Nm/°	✓
Eigenfrequencies	**Target**	**Evaluation**
Torsion global	≥ 45 Hz	✓
Lateral bending	≥ 48 Hz	✓

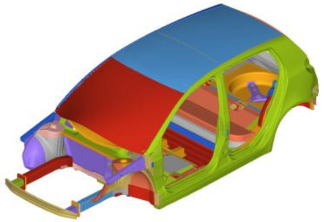
Bending

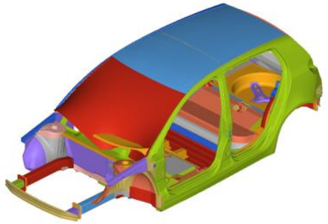


Torsion



Eigenfrequencies



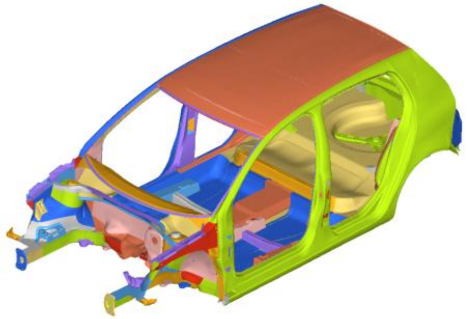


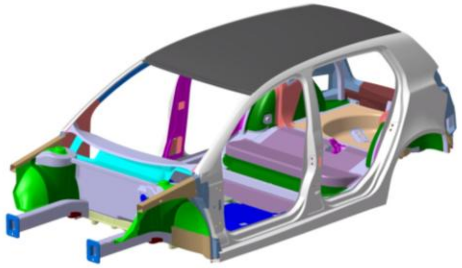
Multi-Material Concept Light-eBody
Weight Reduction

- Conservative concept
  - Body-In-White + Battery structure — 314 kg
- Light-eBody
  - Body-In-White + Battery structure — 256 kg
  - Secondary weight reduction by Stratura — ca. 10 kg

- **Weight reduction** — **58 kg + 10 kg = 68 kg**

- Lightweight cost (€/kg) are suitable for mass production





Multi-Material Concept Light-eBody Demonstrators

LIGHT - eBODY

- Stratura panel, Accra and T³ profiles were build up as prototypes and included into a demonstrator

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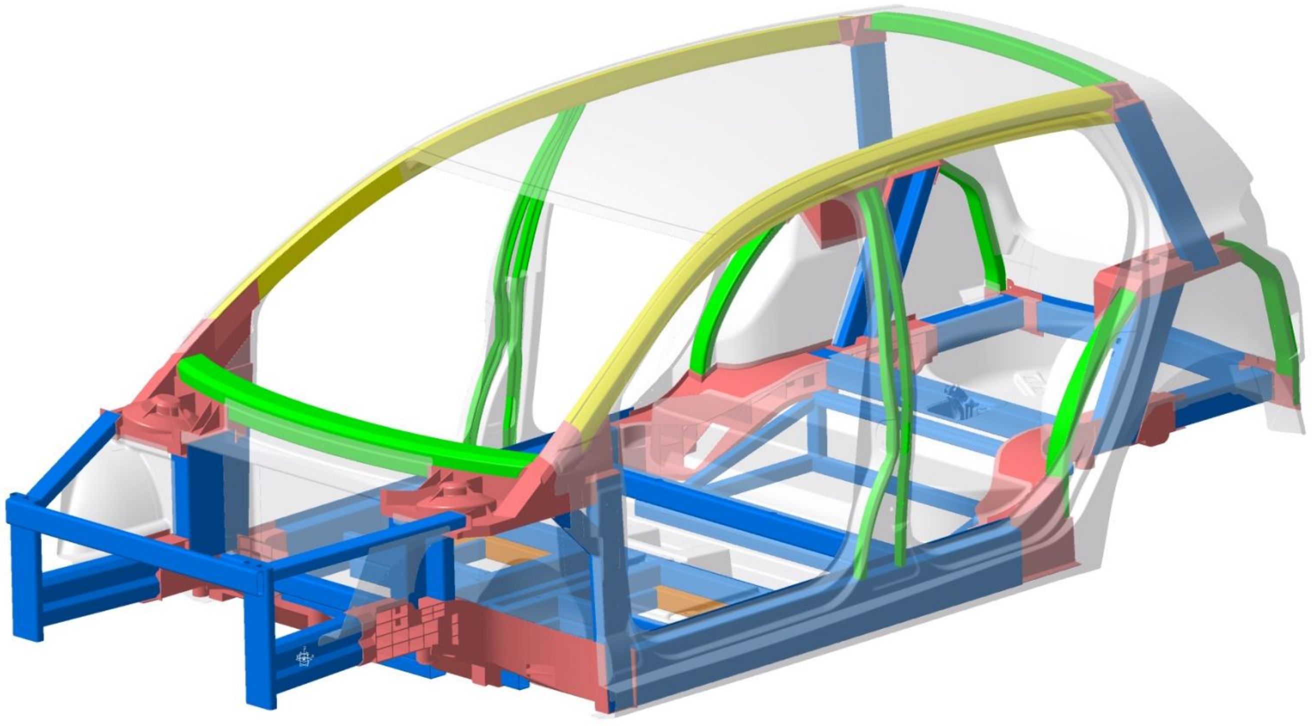
Hydro's Full Aluminium Concept
Weight Reduction

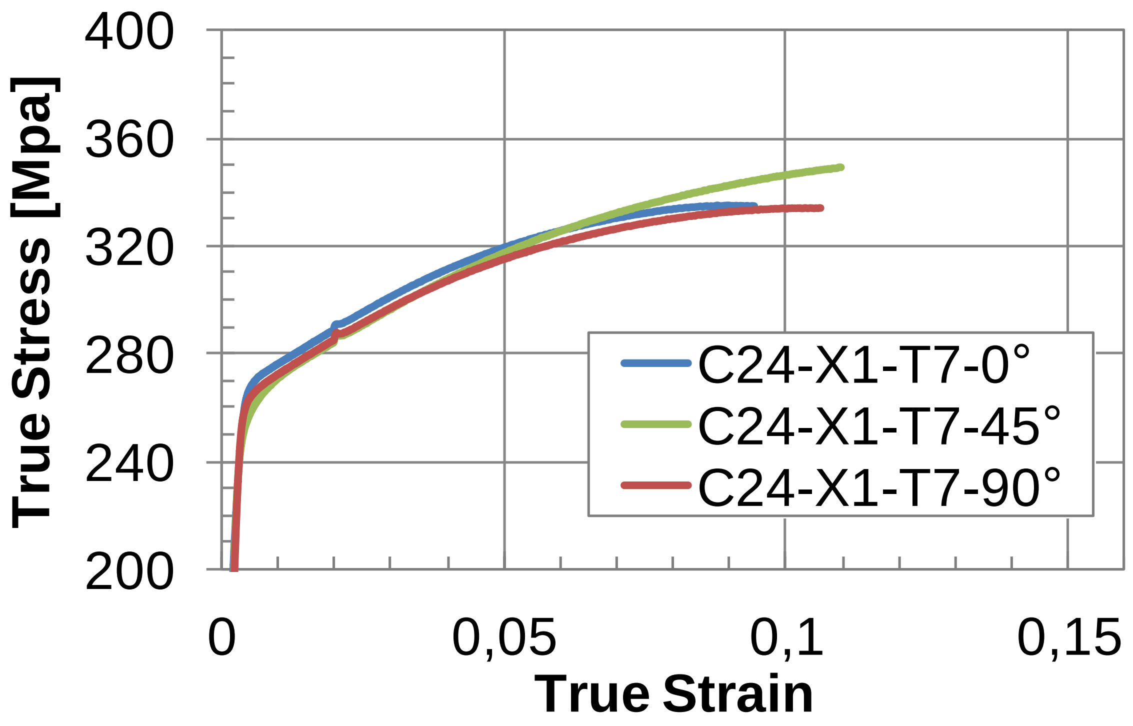
Hydro's Full Aluminium Concept
Profile Technologies

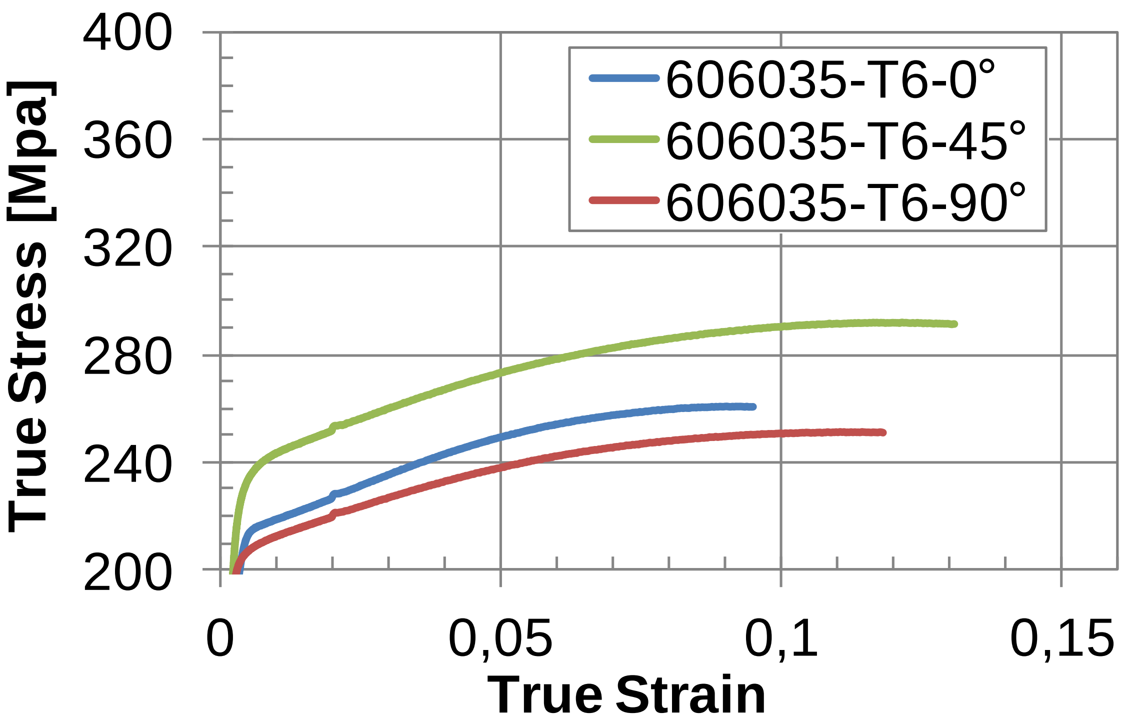
- Extrusions
- Bended extrusions
- Tailor Rolled Tube
- Hydroforming
- Cast nodes



Hydro's Full Aluminium Concept
Material Validation and Choice of material models

- Test data example 606035-T6 and C24-X1-T7



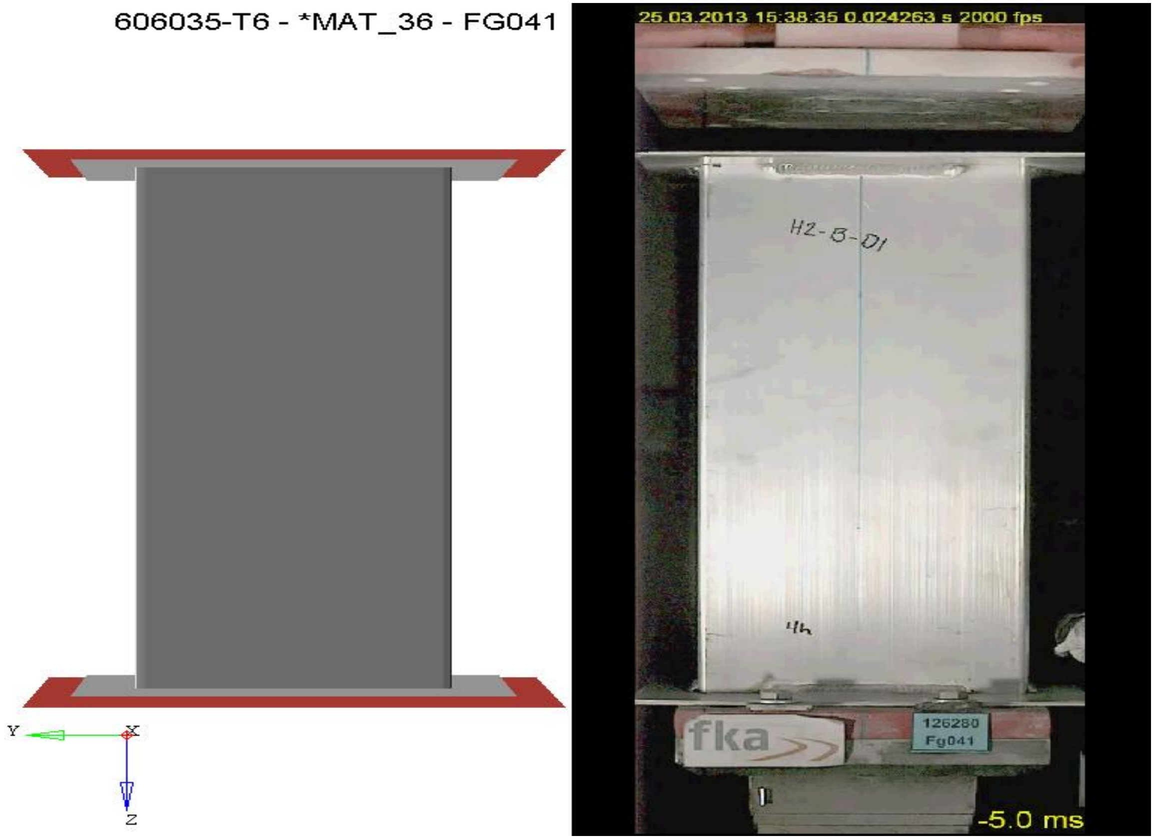


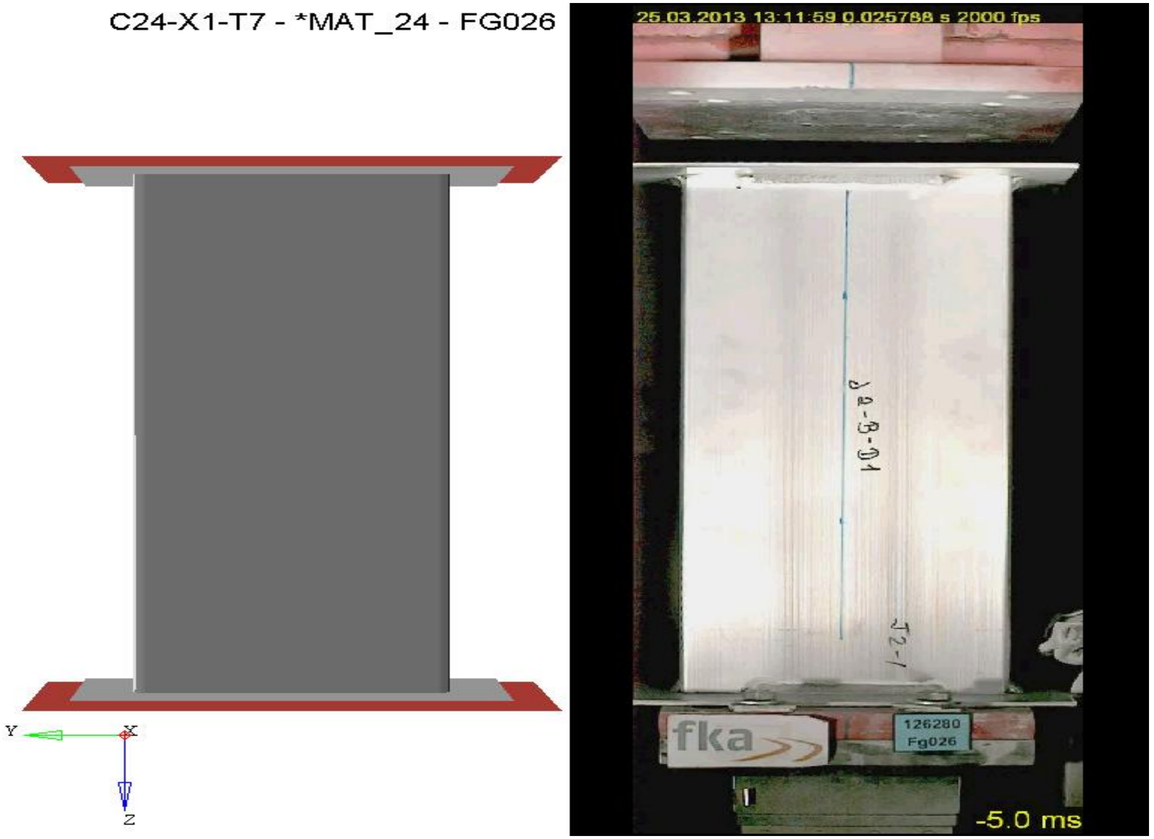
➔ anisotropic material model (*MAT_36) for 606035-T6 and C20-Y1-T6

➔ isotropic model (*MAT_24) for C24-X1-T6/7 and C28-C2-T6

Hydro's Full Aluminium Concept
Simulation in Comparison to the Test data

- Comparison with test videos of 606035 (anisotropic) and C24 (isotropic)



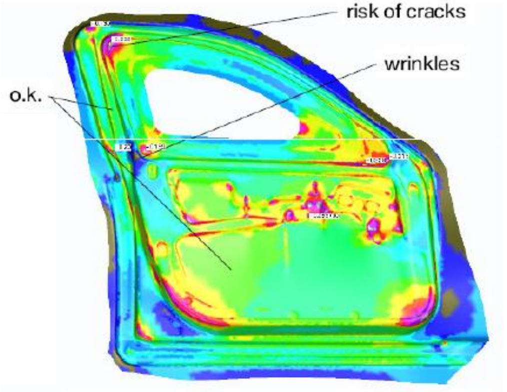


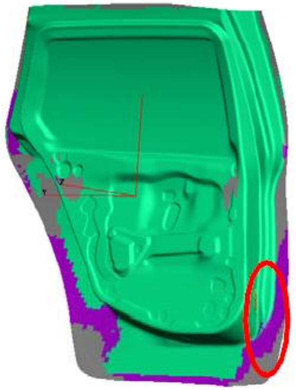
Hydro's Full Aluminium Concept
Forming Optimised AA5182 for Inner Applications

- High formability, good corrosion resistance

- Established alloy type: AA5182

- Door inner panels with requirements on:
- **Strength**
- **Stiffness**
- **Good corrosion resistance (IGC)**
- **High formabilty** to allow for:
- => integrated window frame
- => large depth of draw

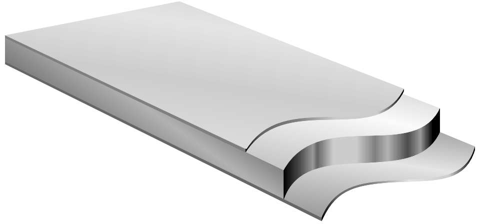


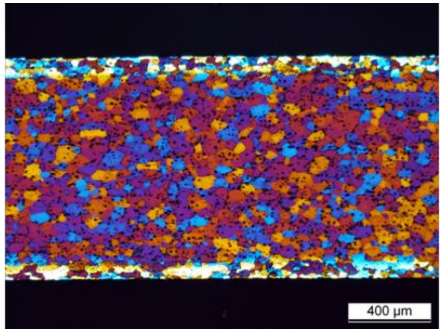


(examples presented by BMW at ACI Insight Ed. 2010 ; Castle Bromwich)

Hydro's Full Aluminium Concept
New Alloys for Outer Skin Parts, e.g. the Sidewall

- Hydro‘s HA6016-U is a conventional, AA6016-based alloy, for applications:
  - Requiring **high formability**
  - Combined with **typical mechanical properties**
  - High demands on **surface appearance** (outer skin quality)
- Hydro‘s HA6016-X is a AA6016 multilayer alloy
  - *Step change* with regard to **formability** of 6xxx alloys
  - High demands on **surface appearance** (outer skin quality)





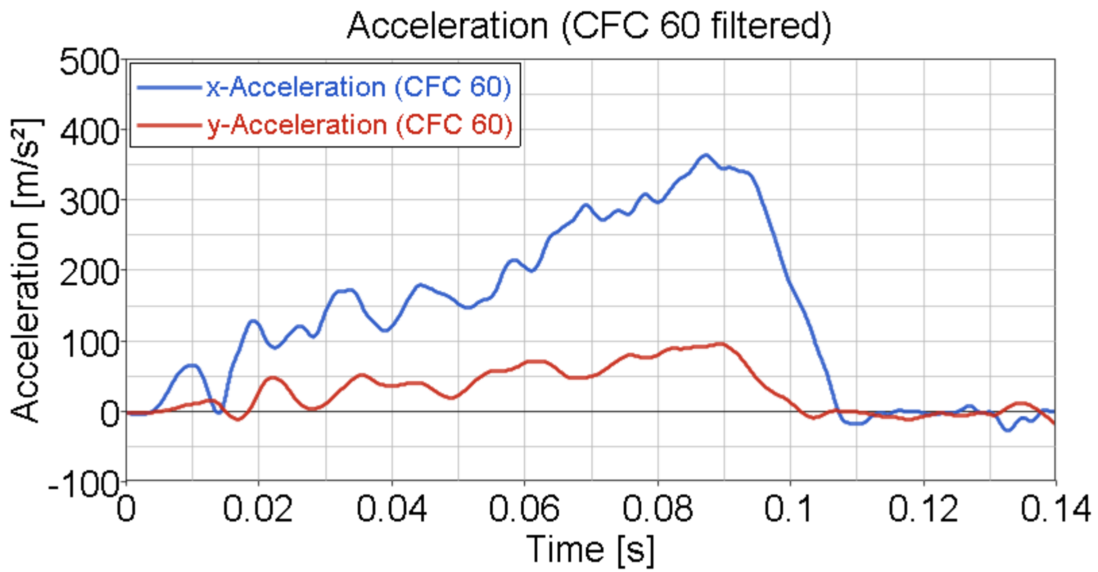
functional Al-layer

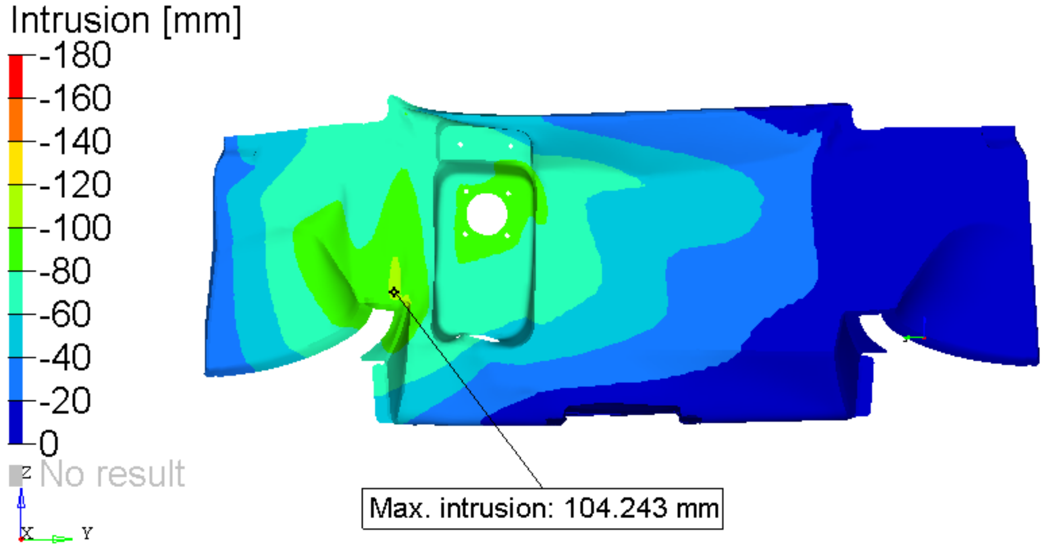
HA 6016-U

functional Al-layer

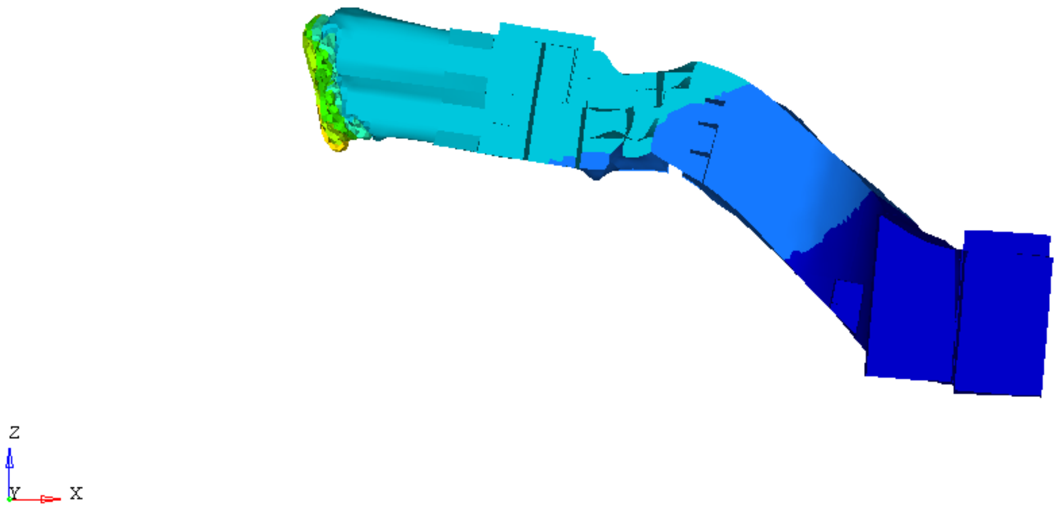
1-piece side panel Bolloré Bluecar.

Hydro's Full Aluminium Concept
Euro NCAP – Frontal Impact (ODB)

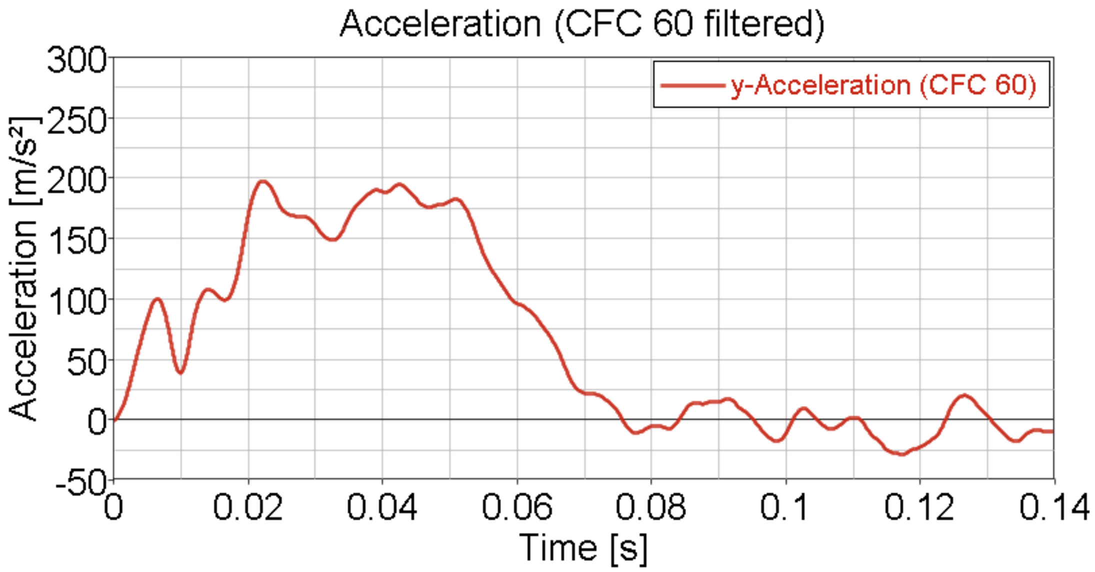


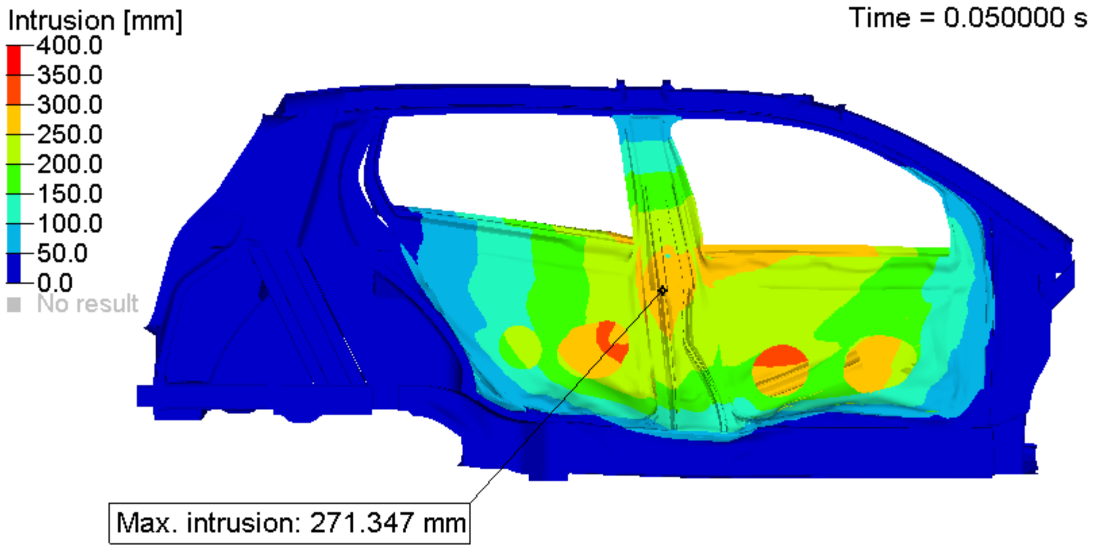


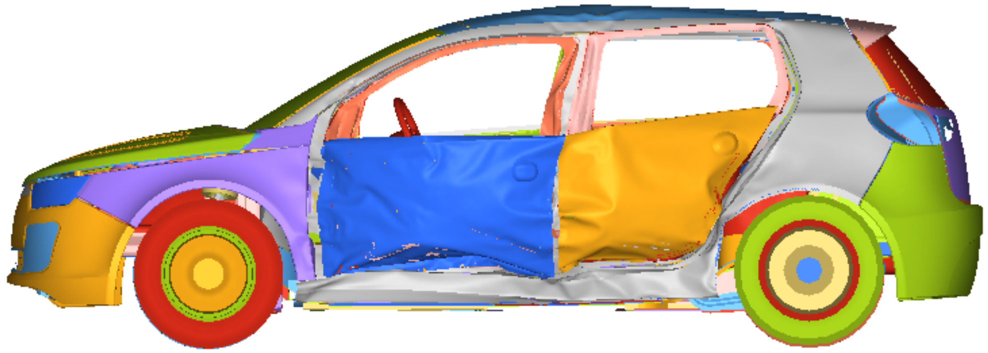
Driver side longitudinal beam



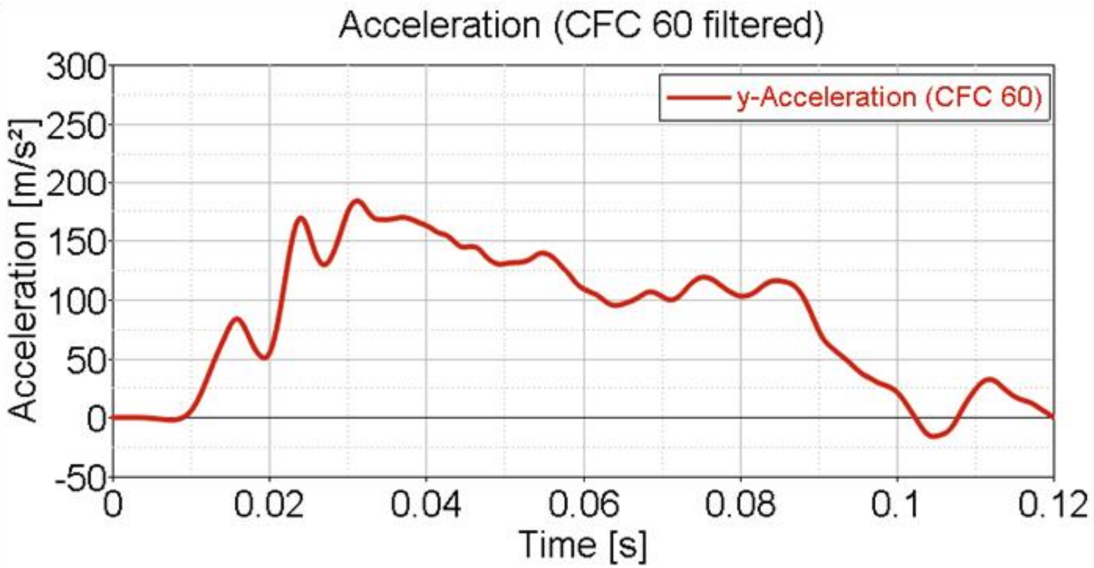
Hydro's Full Aluminium Concept
IIHS – Side Impact

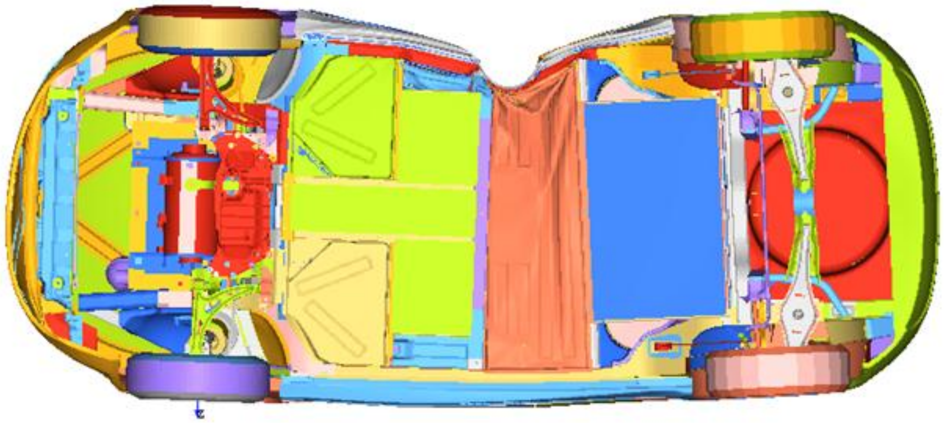


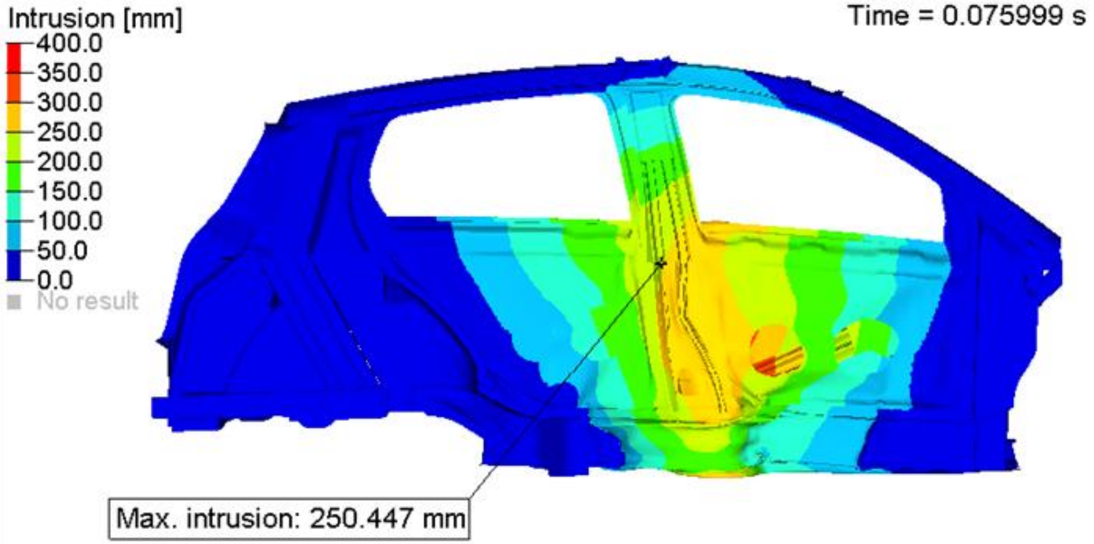


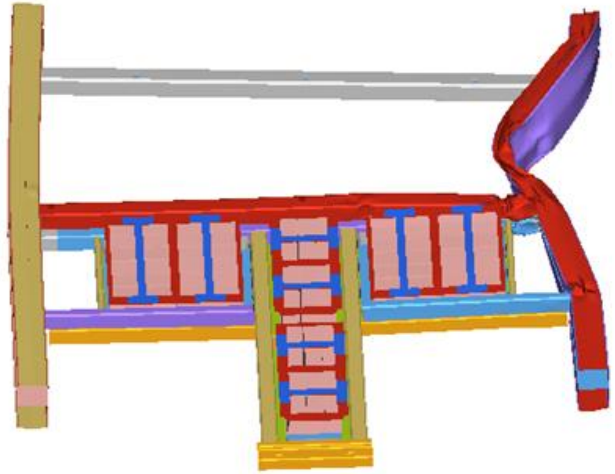


Hydro's Full Aluminium Concept
Euro NCAP – Pole Impact









Hydro's Full Aluminium Concept
Overview Results

EuroNCAP

Pole Side Impact	**Target**	**Evaluation**
Sidewall intrusion	< 340 mm	✓
Intrusion into battery compartment	< 15 mm	✓
Deceleration pulse	max. 25 g	✓

ODB Front Crash	**Target**	**Evaluation**
Firewall intrusion	< 125 mm	✓
Intrusion into battery compartment	< 15 mm	✓
Deceleration pulse	max. 50 g	✓

FMVSS

Rear Impact	**Target**	**Evaluation**
Max. Intrusion	< 465 mm	✓
Intrusion into battery compartment	< 15 mm	✓

Hydro's Full Aluminium Concept
Overview Results

IIHS

Side Impact	Target	Evaluation
Sidewall intrusion	< 320 mm	✓
Intrusion into battery compartment	< 15 mm	✓
Deceleration pulse	max. 25 g	✓

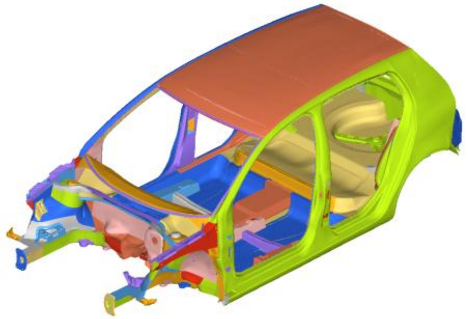
Stiffness

Stiffness	Target	Evaluation
Torsional stiffness	> 25.500 Nm/°	✓

Eigenfrequencies	Target	Evaluation
1st Torsion	> 45 Hz	✓
1st Bending	> 48 Hz	✓

Multi-Material Concept Light-eBody
Weight Reduction

- Conservative concept
  - Body-In-White + Battery structure 314 kg
- Light-eBody
  - Body-In-White + Battery structure 199 kg



- **Weight reduction 115 kg**

- **Assumed lightweight cost (€/kg) are higher as for the Light-eBody concept**

  (Weight reduction of the Light-eBody Concept 68 kg)

Agenda

- Motivation of Lightweight Design
- Material Characteristics
- Multi-Material Concept Light-eBody
- Hydro's Full Aluminium Concept
- Outlook and Conclusion

Outlook and Conclusion

- Lightweight design lowers the energy demand of electric vehicles
- Integration of the battery structure as load bearing exploits lightweight potential
- Light-eBody (Multi-Material Design)
  - New production processes and joining technologies were analysed and developed for mass production suitability
  - CAE methods for the simulation of the joining of the material combination were developed
- Full Aluminium Concept (Hydro)
  - Improving design for suitable light-weight-car design concepts Hydro Aluminium R&D together with fka helps to develop new economic and efficient electric car concepts
  - High lightweight potential is achieved with Aluminium at reasonable cost level, suitability for large scale production
  - Improving specific properties of Aluminium alloys (5xxx, 6xxx, …)
- Aluminium shows higher lightweight cost but also a higher lightweight potential
- Suitability of the lightweight concepts depends on the affordable lightweight cost

Contact

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