Lightweight Design: The Vanguard of Automotive Engineering
Strategies for Materials and Construction Methods

Prof. Dr.-Ing. Horst E. Friedrich
Dipl.-Ing. Marco Münster
Dipl.-Ing. Gundolf Kopp

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Agenda

1. Growing importance of lightweight construction
2. Methodical approach in the development process
3. Lightweight construction strategies
4. Challenge: lightweight construction in the volume segment
5. Concepts for current and future cars
6. Trends in materials and structures yesterday, today and tomorrow

Megatrends

- We are reaching the limits of oil extraction
- Climate change is taking place
- Growing population, concentrated in big cities and conurbations
- Demographic trend

Source: http://www.fotocommunity.de/pc/pc/mypics/1438338/display/18369424

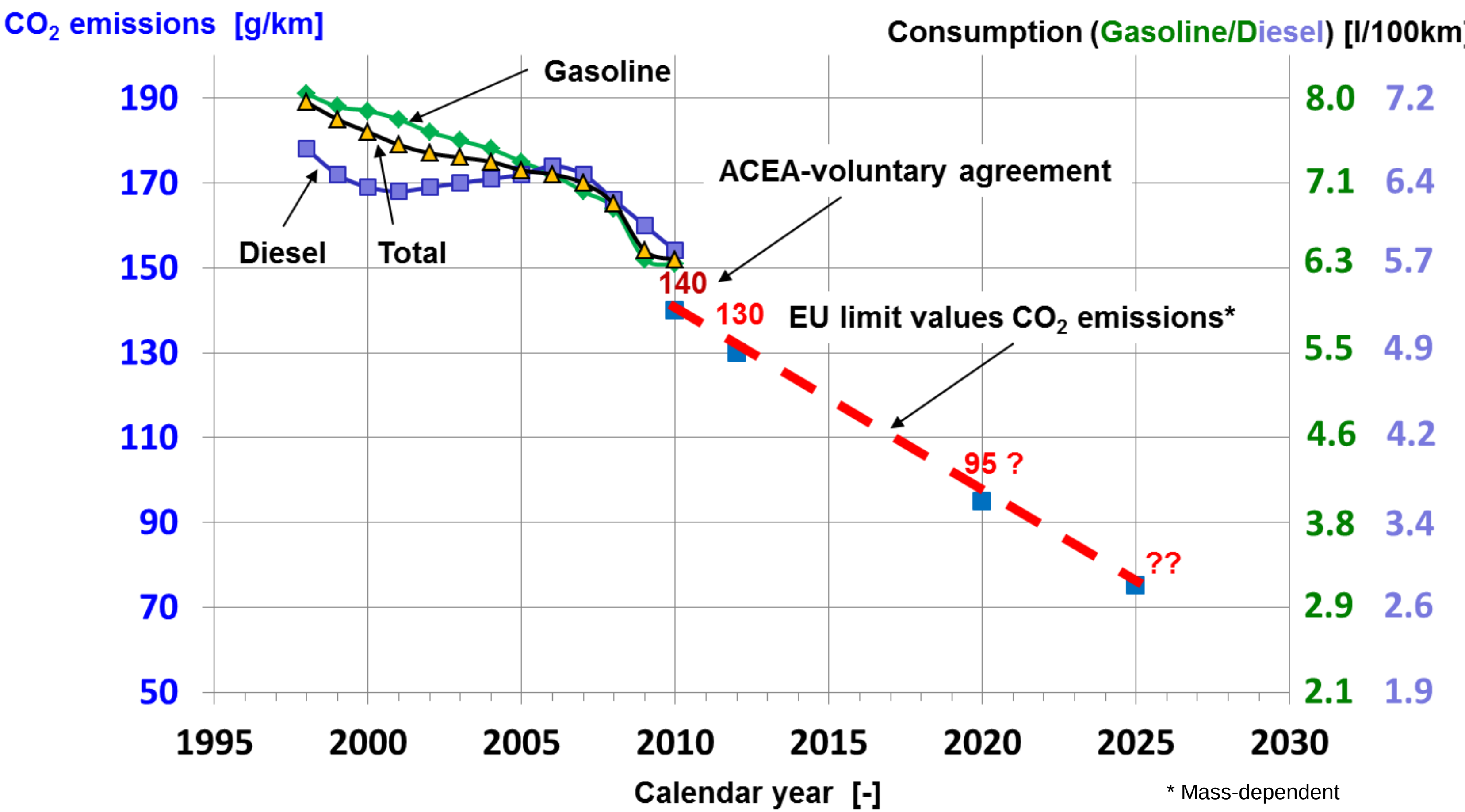
Source: DLR

Vehicle concepts

- Lower energy consumption
- Reduced CO_2 emissions
- Alternative and regenerative energy sources
- Automated driving / connectivity
- …

Source: versust.blogsport

CO_2 emissions in new vehicles in Germany and EU CO_2 limits



* Mass-dependent

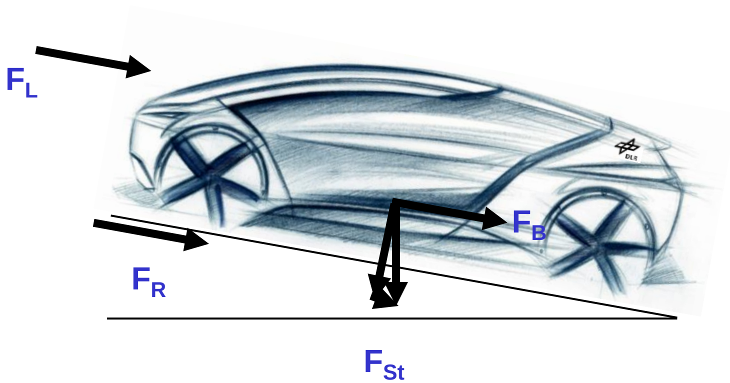
Source: KBA; DLR

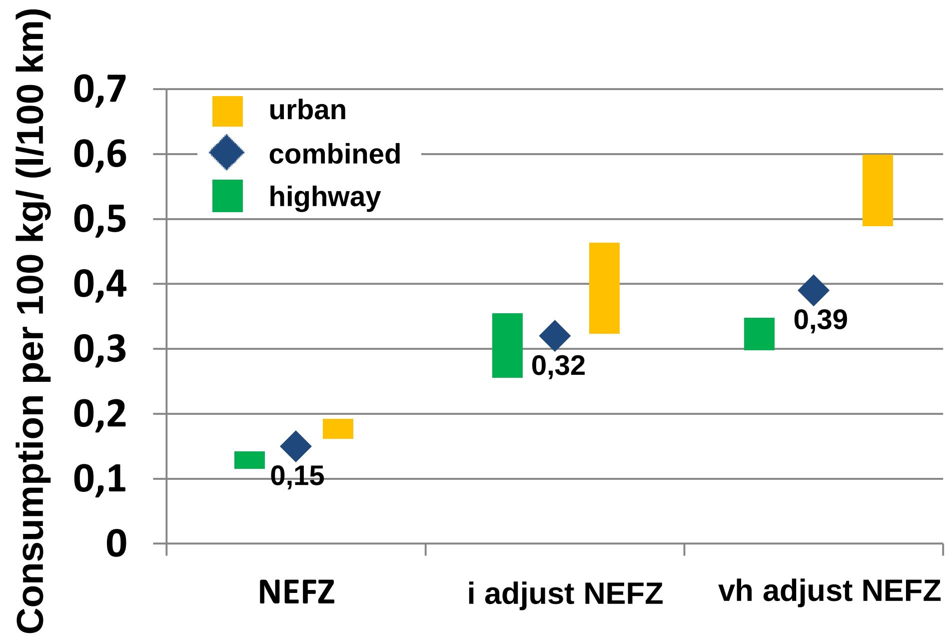
VDI Wissensforum

Total of normal resistances and consumption

$$\sum F_w = \underbrace{b \cdot \left(m_g + \sum m_{rot}\right)}_{F_B} + \underbrace{m_g \cdot g \cdot f_R \cdot \cos(\alpha)}_{F_R} + \underbrace{m_g \cdot g \cdot \sin(\alpha)}_{F_{St}} + \underbrace{\frac{\rho}{2} \cdot c_w \cdot A \cdot v^2}_{F_L}$$

$$B_e = \int b_e \cdot \frac{1}{\eta_{Antrieb}} \cdot \sum F_w \cdot \frac{v \cdot dt}{\int v \cdot dt}$$





Normal resistances

Differential consumption factors for 100 kg weight reduction in a vehicle with spark-ignition engine

Source: DLR; Rohde-Brandenburger, Volkswagen AG

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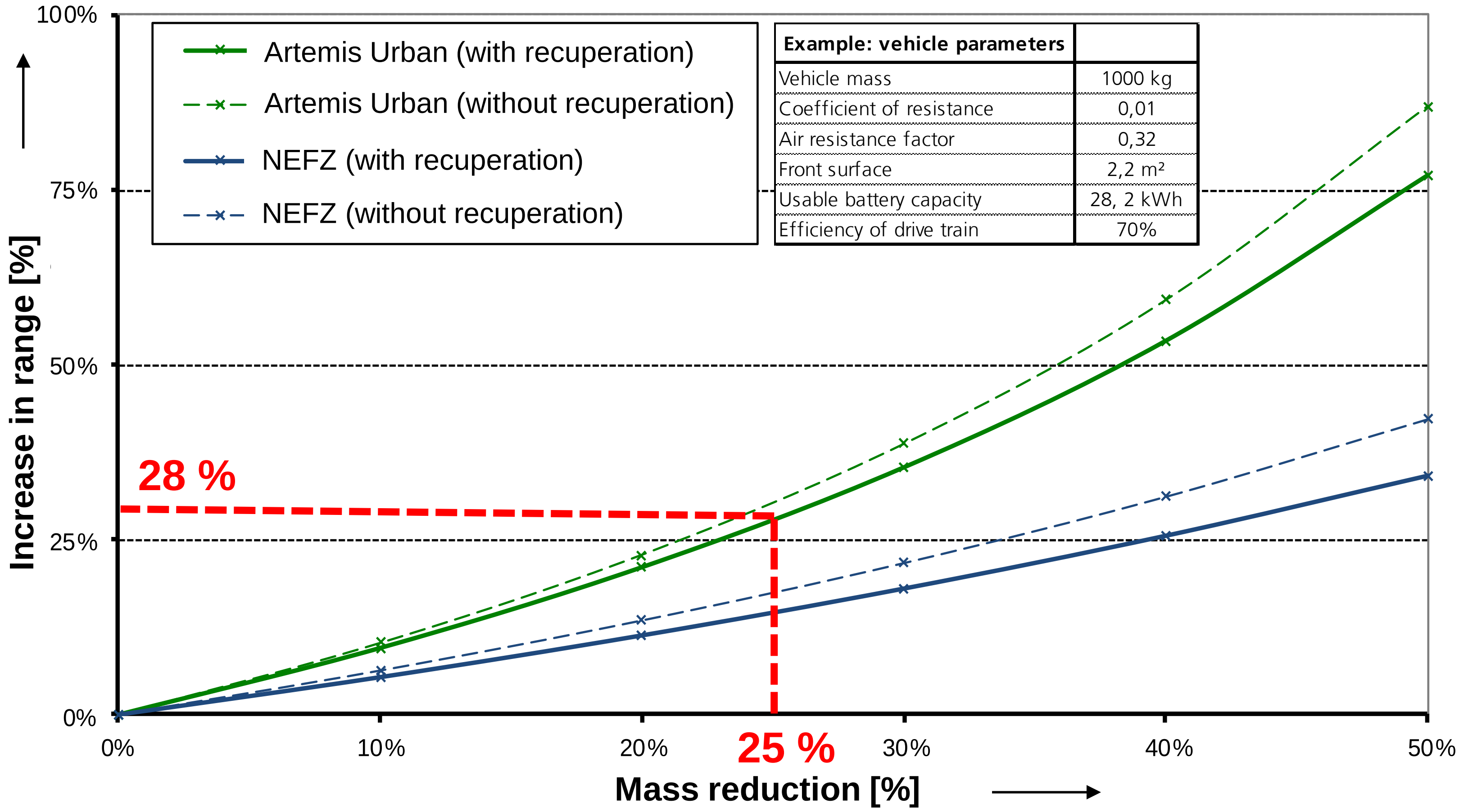
Extension of range with small electric vehicles



Example: vehicle parameters	
Vehicle mass	1000 kg
Coefficient of resistance	0,01
Air resistance factor	0,32
Front surface	2,2 m²
Usable battery capacity	28, 2 kWh
Efficiency of drive train	70%

Source: DLR

Lightweight construction, vehicle dynamics and electromobility

Influence of lightweight construction on vehicle dynamics

+

- Running resistances
- Lateral dynamics dependent on CG (SP)
- Unsprung mass
- Secondary effects

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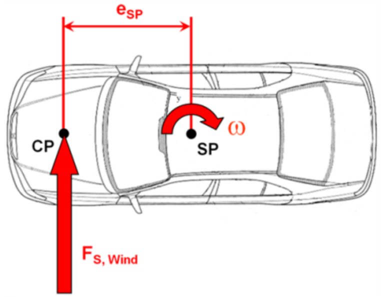
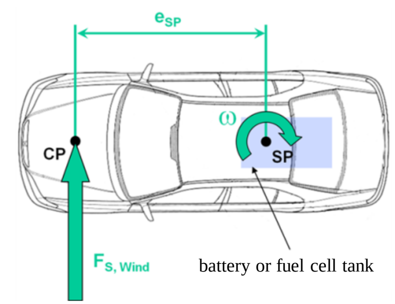
- Crosswinds
- Road transverse gradient
- Ruts, stochastic unevenness
- More sensitive to weight



conventional vehicle (ICE)



battery electric vehicle (BEV) or fuel cell vehicle (FCV)

Opportunity for electromobility

- Position of battery
- Wheel hub drive

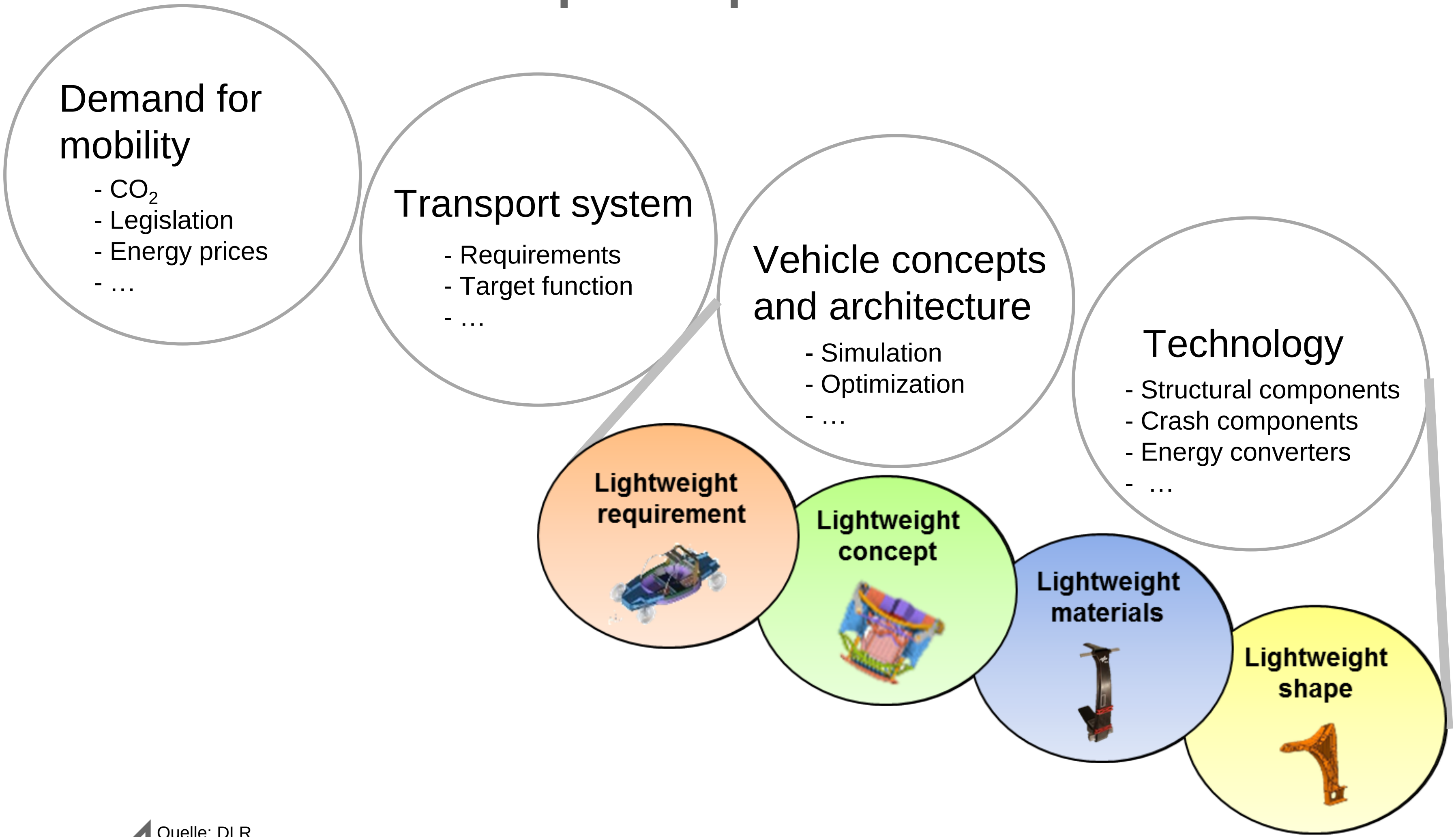
→ Roll behavior

→ Yaw behavior

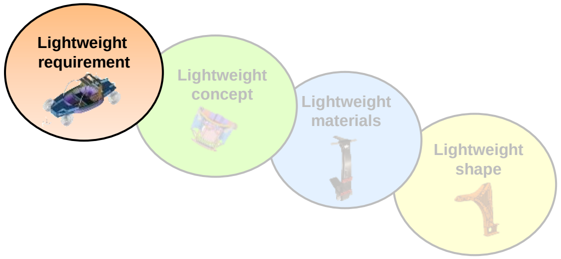
➔ Lightweight design measures required

Source: IVK Stuttgart, DLR

From the chain of effects of the traffic system to the methodical development process



Quelle: DLR



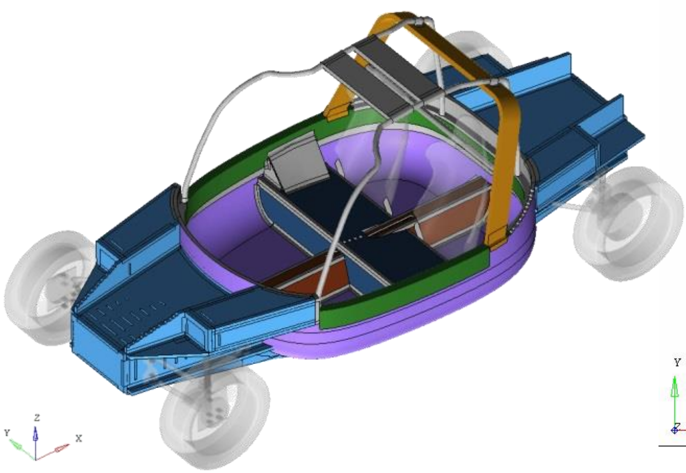
Lightweight requirement

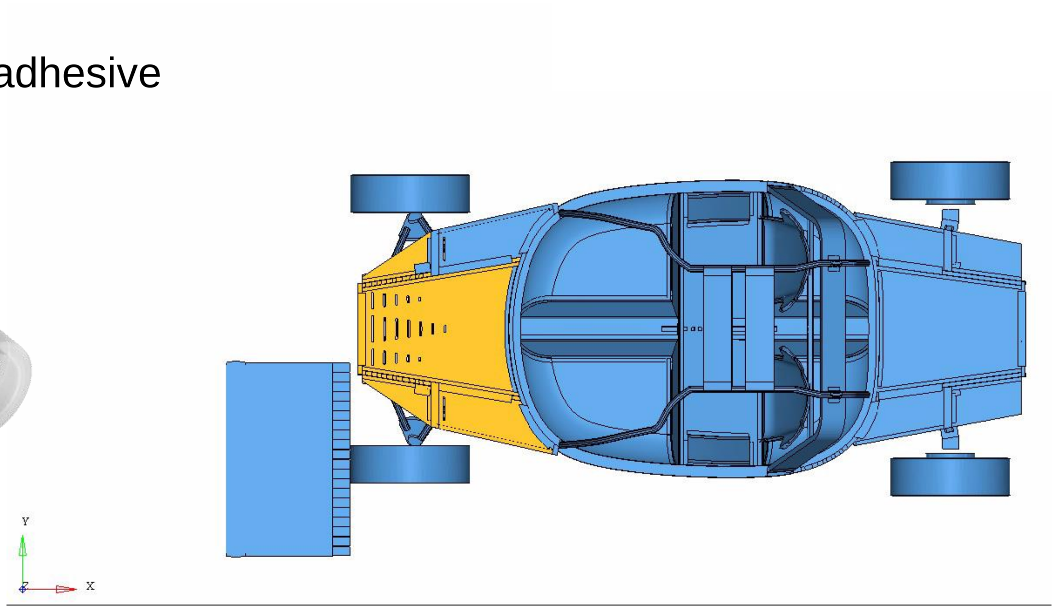
Objective:

- light vehicle with high crash performance (L7e)

Solution:

- Body structure in sandwich architecture
  - Skin layers aluminum alloy
  - Foam core polyurethane
- Joining process
  - Crash-stable structural adhesive
  - Welded parts





BIW < approx. 80 kg

Euro-NCAP frontal crash → intrusion approx. 102 mm

Source: DLR

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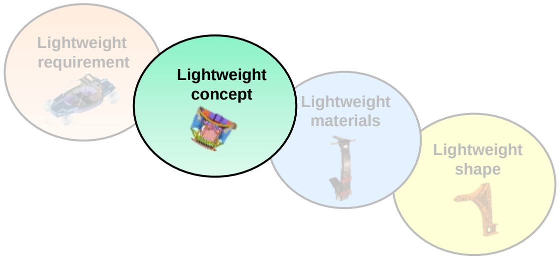


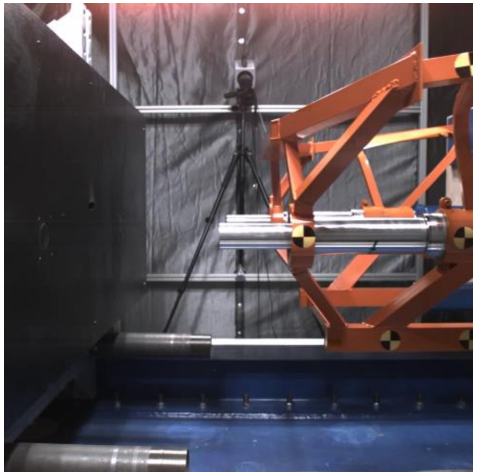
Lightweight design concept

Objective:

- Crash modular, adaptable vehicle front

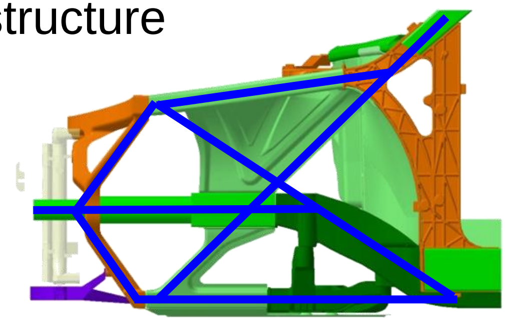
Solution:

- Energy absorbed through cutting

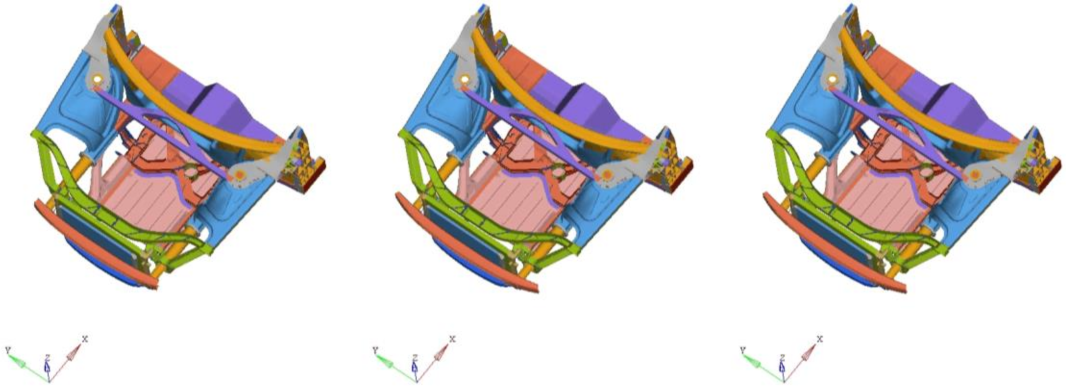


Approx. 20% lighter than steel reference structure

- Three-dimensional, reinforced light front vehicle structure

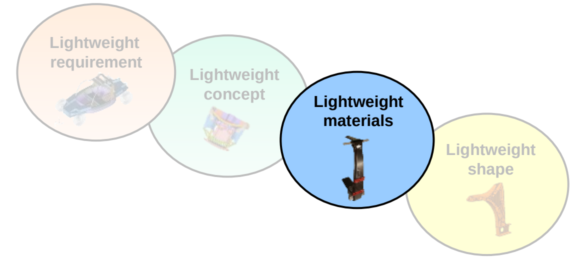


- Peeling pipes for adjustment of energy



„weak“ „medium“ „strong“

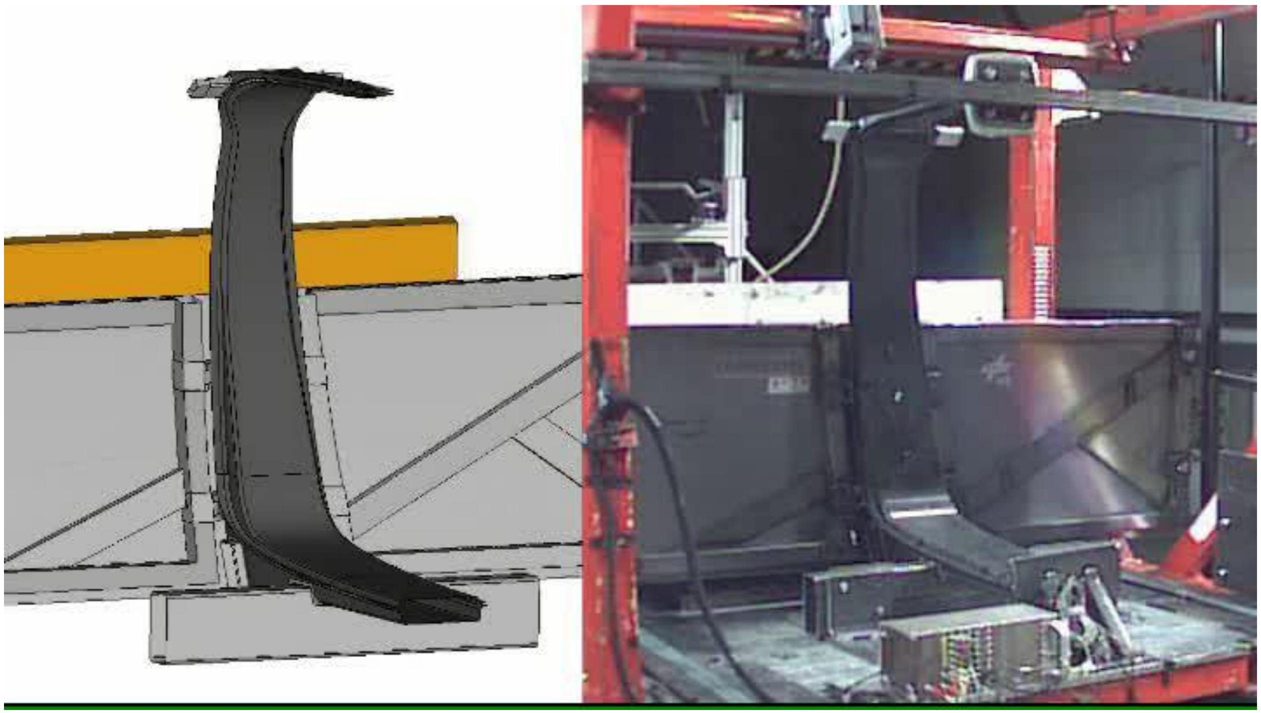
Source: DLR



Lightweight material design

Objective:

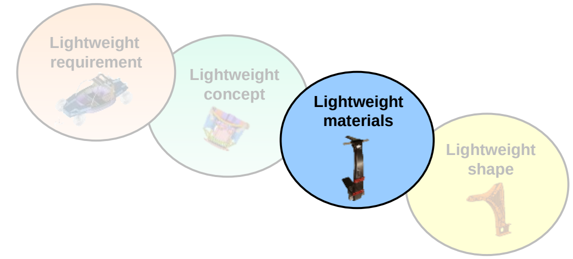
- Light CFRP B-pillar



Solution:

- Layer structure (0/90/±45)
- Manufacture using VARI procedure
- Internal reinforcement with additional Omega profile

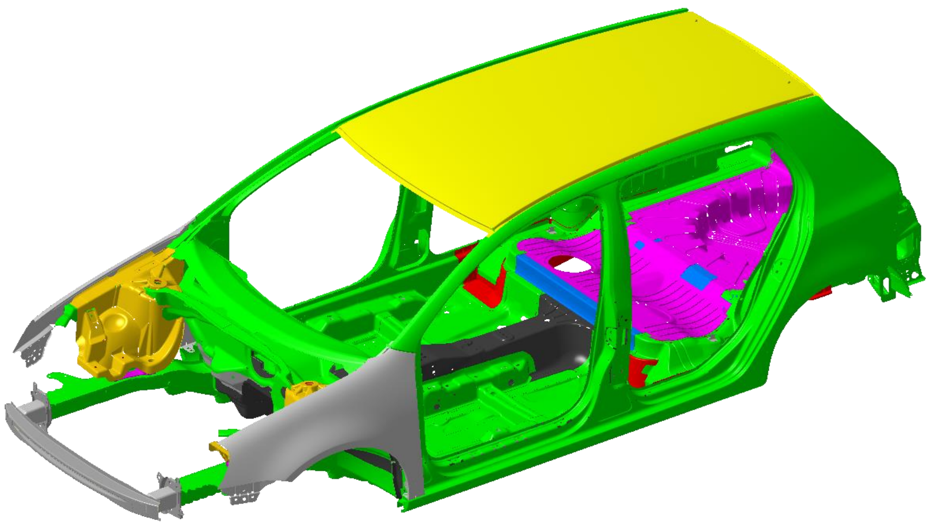
Source: DLR



Lightweight material design

Objective:

- BIW weight reduction ≥ 85 kg (≥ 30%)
- Lightweight construction costs (cost of parts) ≤ 5 €/kg



Materials

- Aluminium sheet
- Aluminium cast
- Aluminium extrusion
- Steel
- Hot-formed steel
- Magnesium sheet
- Magnesium diecasting
- Glasfibre thermoplastic

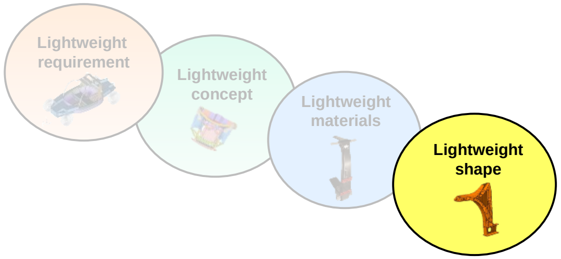
Percent by weight

Aluminium	**96kg (53%)**
Steel	**66 kg (36%)**
Magnesium	**11 kg (7%)**
Plastics	**7 kg (4%)**

Solution:

- Body in white 100 kg lighter than reference (approx. 35%)
- Complete CAD model of the BIW
- Validation of structure (crash, static etc.)
- Specification of joining and production processes
- Life cycle analysis for MMD concept

Source: VW, DLR



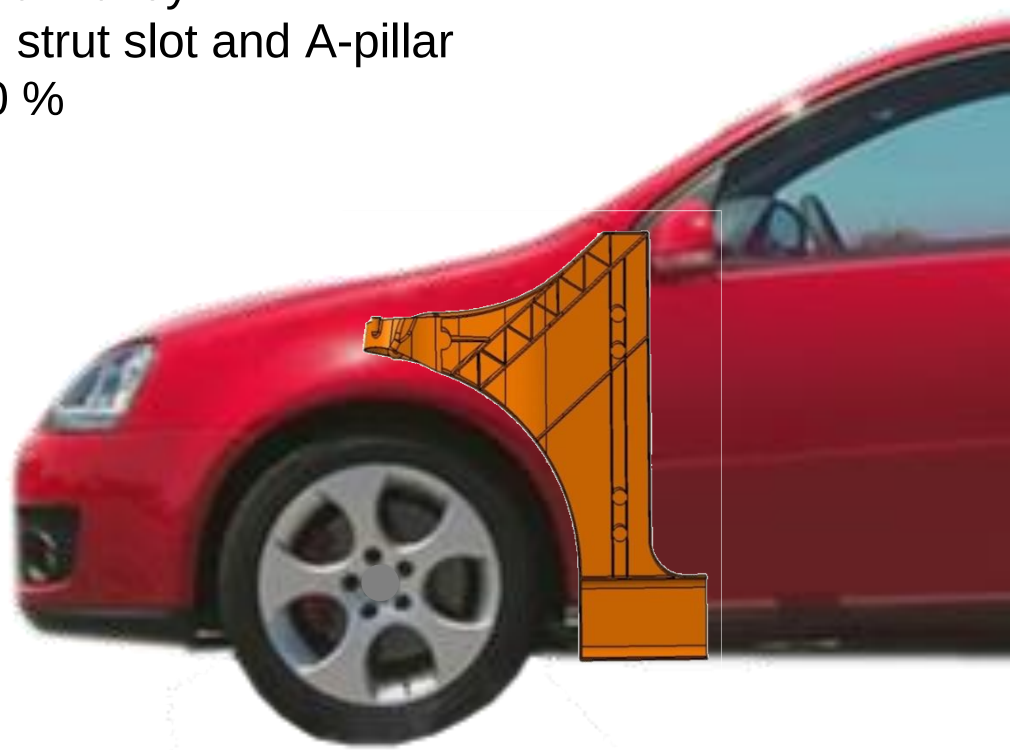
Lightweight shape

Objective:

- A-pillar cast node lighter and more cost-attractive

Solution:

- New design with magnesium alloy
- Integration of suspension strut slot and A-pillar
- Weight saving approx. 50 %



Source: DLR

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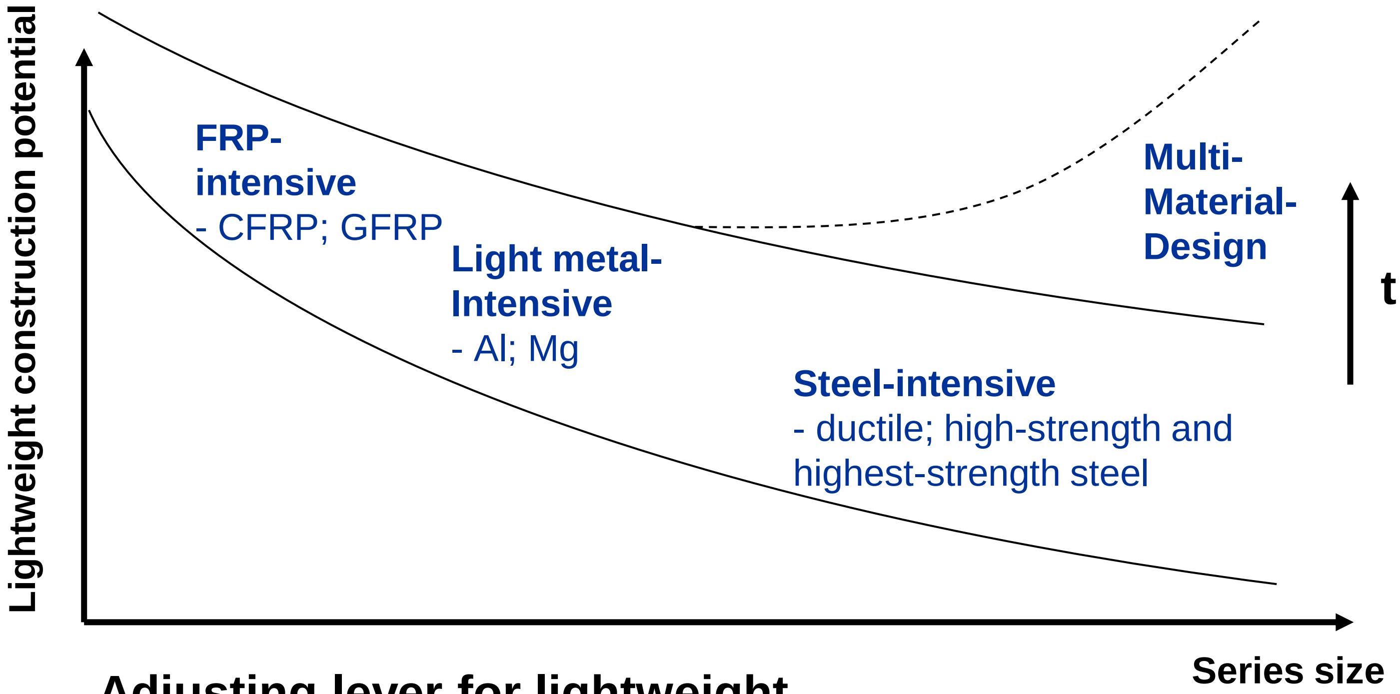
Challenge: lightweight construction in the volume segment



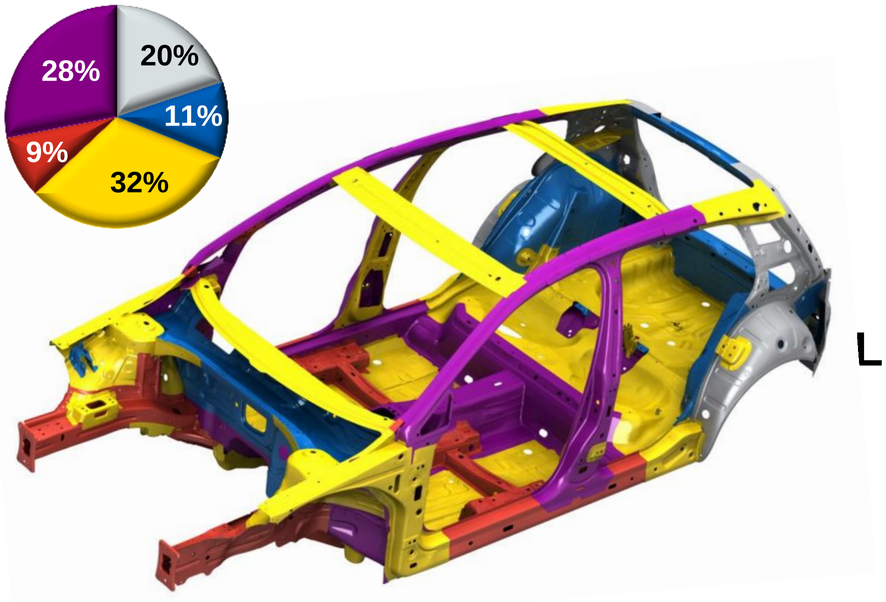
Adjusting lever for lightweight construction:

- Materials
- Concepts
- Production technology
- etc.
- …

- Weight
- Safety
- NVH
- etc.

Source: VW; Daimler; DLR

Concept: steel-intensive
Example: Golf VII



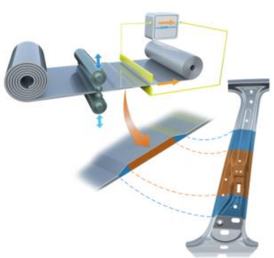
- Mild Steel
- High-Strength Steel
- Highest-Strength Steel
- Advanced-High-Strength Steel
- Ultra-High-Strength Steel, hot formed

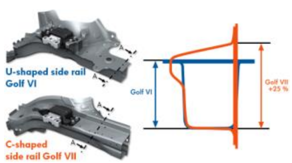
Weight saving:

- structural weight reduced by about 100 kg
  - Electrics - 6 kg
  - Drive train - 40 kg
  - Chassis - 26 kg
  - Body - 37 kg

Lightweight design measures:

- High-strength and higher-strength types of steel, reduced sheet thickness (TRB)
- Only using material where it is needed
- Optimal geometry of profiles and surfaces





Source: VW

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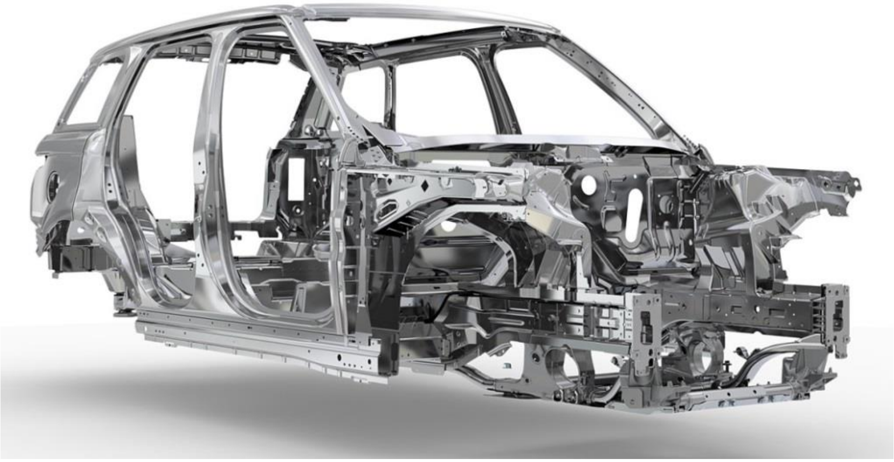
Concept: Aluminum-intensive
Example: Range Rover V

Weight saving:

- Vehicle about 420 kg lighter than its predecessor
- Weight saved in basic shell approx. 39% (almost 180 kg)

Lightweight design measures:

- External skin panels between 0.9 and 1.5 mm
- All body joints riveted or bonded
- Side parts compressed in a single aluminum component
  → Fewer body joints
- High-strength Al AC300 for the crash structure



Source: ATZ; www.carsuk.net

Concept: Aluminum-/steel-intensive hybrid design
Example: Audi TT 2nd generation

Weight saving:

- Weight of body: 206 kg
- Reference body in steel would be 48% heavier
- Pure Al body would be 12% lighter

Lightweight design measures :

- Multi-material-desgin
- Shell and space frame structure combined

Aluminum 69%

- Sheet metal 63 kg
- Cast components 45 kg
- Extruded profiles 32 kg

Sheet 31%

- Sheet metal 66 kg

Source: Audi

Concept: Bi-module (CFRP-Al-intensive)
Example: BMW i3

Weight saving:

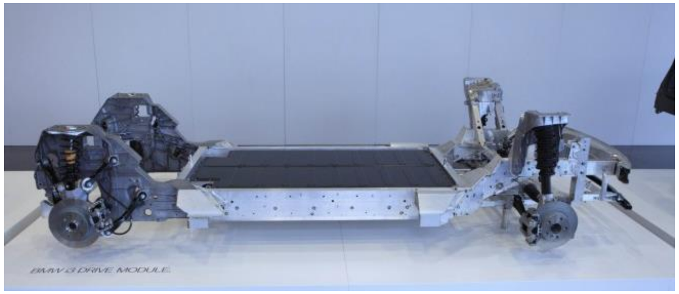
- Vehicle total weight approx. 1195 kg with battery
- Approx. 300 kg saved through new material and purpose-built design

Lightweight design measures:

- Material combination CFC + aluminum
- Bi-modular design
  - "Life" module - CFC monocoque body
  - "Drive" module - crash and structural components, Al chassis

Source: www.bimmertoday.de

CFRP "Life" module



Source: www.bimmertoday.de

Aluminum “Drive" module

Source: BMW

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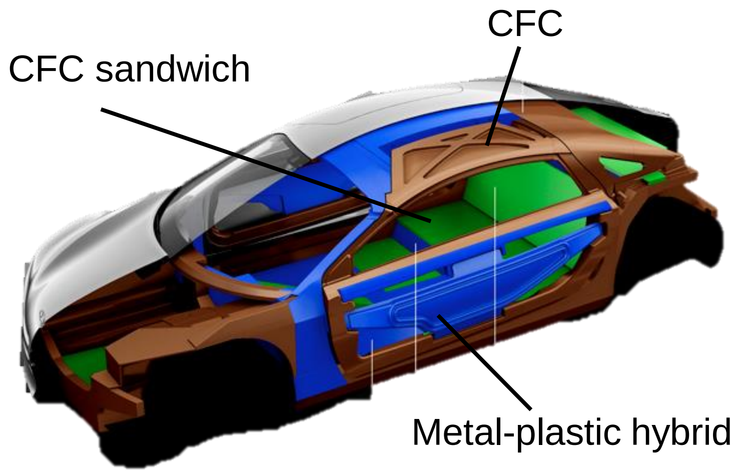
Concept: CFRP-intensive Example: F125!



Weight saving:

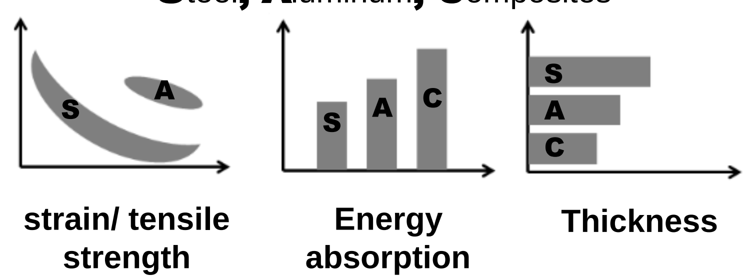
- CFRP-intensive design approx. 250 kg lighter than current reference
- Front curved and support structures designed as load-bearing assembly unit in CFRP sandwich hybrid design

Lightweight design measures:

- Ultra-light fiber composite body
- Structure-integrated hydrogen storage
- Function integration through CFRP e.g. safety belt integrated into seat structure

Correctly use the good material characteristics of

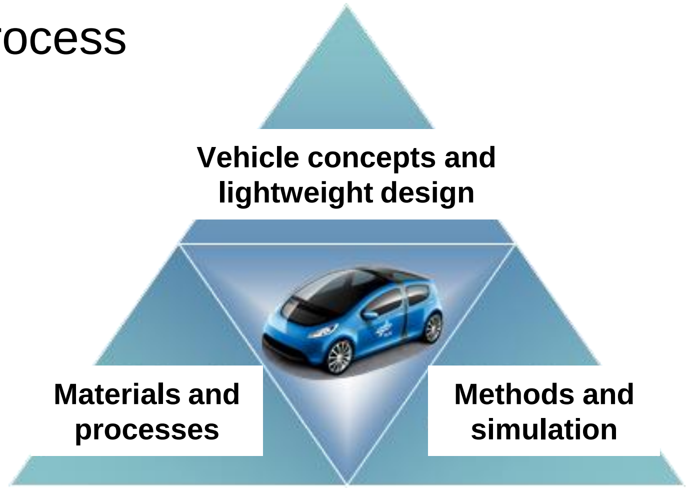
Steel, **A**luminum, **C**omposites



Source: Daimler

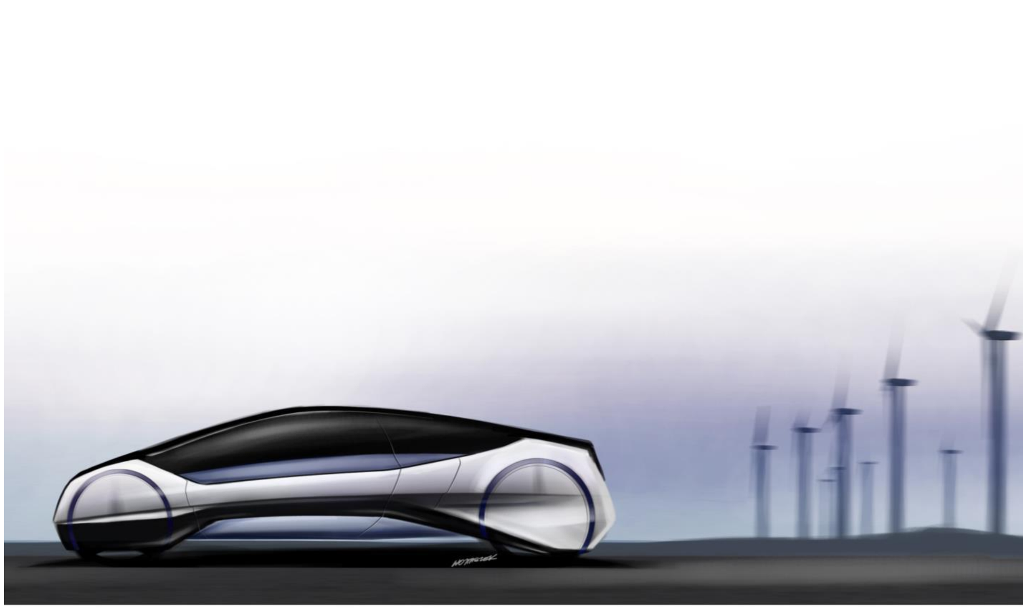
Summary

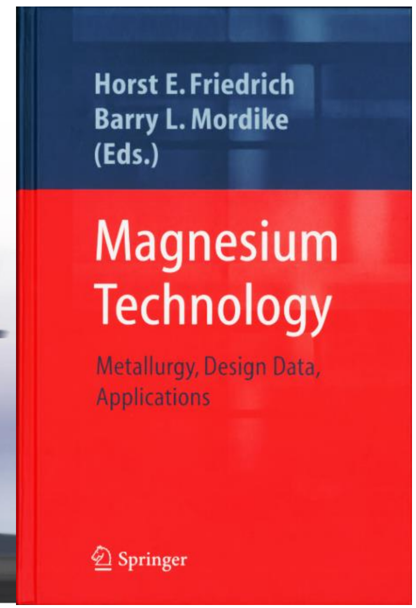
- CO_2 limits are driving forward lightweight construction in vehicle design
- Gradual electrification is reinforcing the trend towards lightweight construction
  - Compensation for extra weight of new components
- Further development of construction methods:
  - Increase in MMD in volume-intensive production sector
- Focus for research and development:
  - Consideration overall, methodical approach in the product development process



Source: DLR

Thank you for your attention!





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