89. AMAP Colloquium
October 30, 2024
Aachen, Germany

Lightweighting in times of electrification

Dr. Jürgen Wesemann
Ford-Werke GmbH

Changes in the Automotive Industry

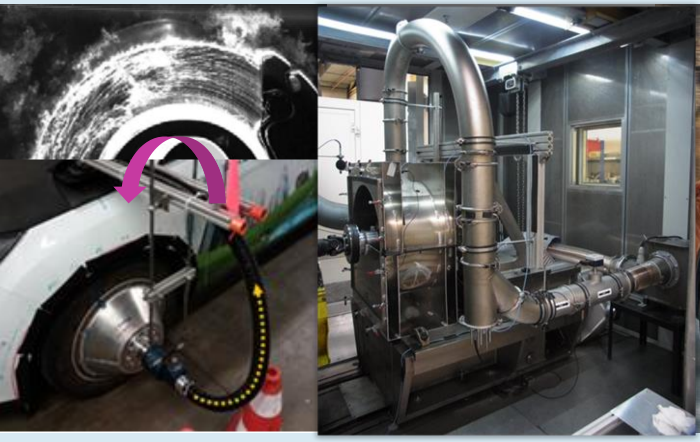
Electrification | **Driver Assistance Systems/ Autonomous Driving** | **Connectivity**

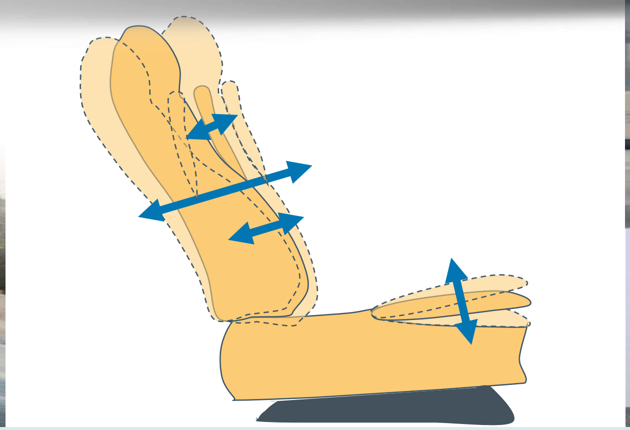
Weight & Cost Increase of Cars

Electrification

Driver Assistance Systems/ Autonomous Driving

Connectivity





Emissions

Safety

Comfort

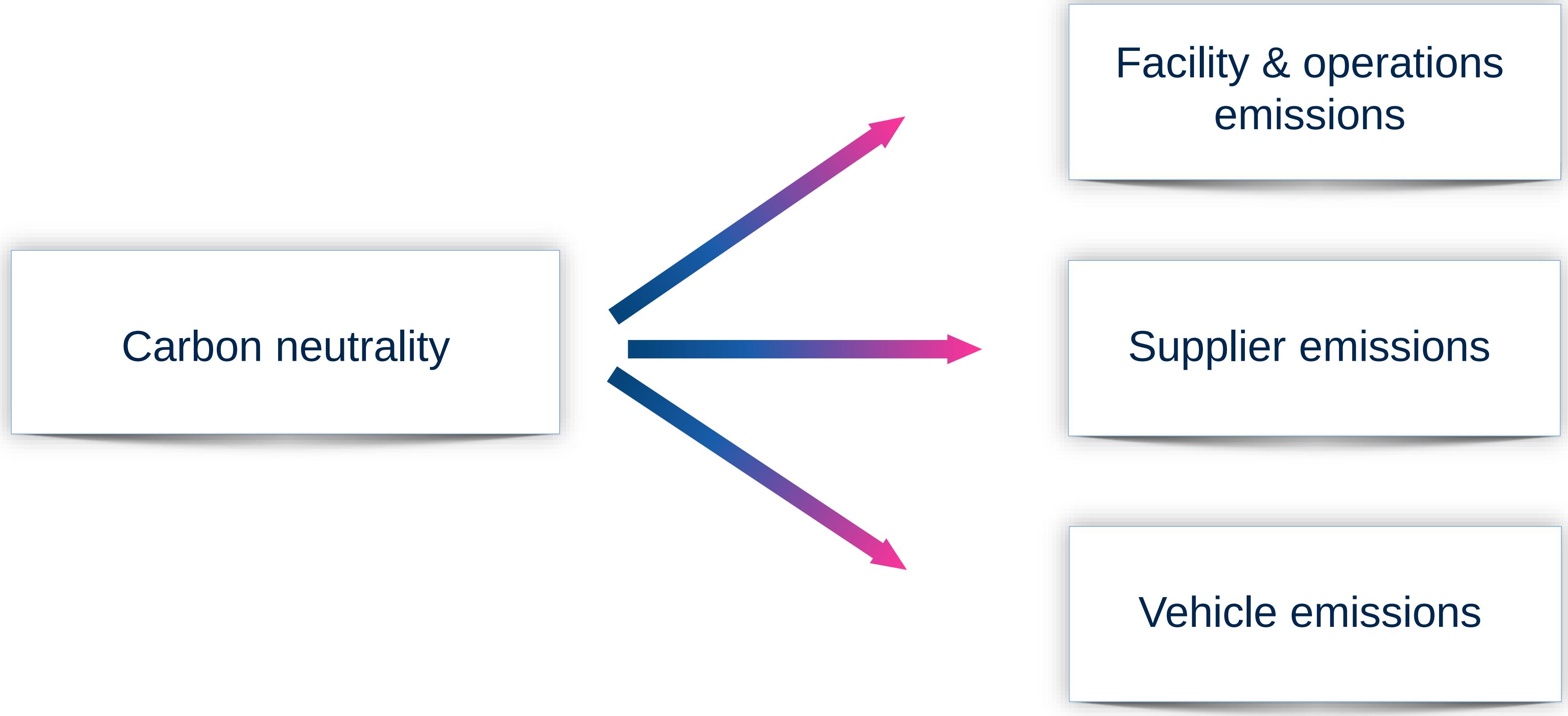
Size

Sustainability Goals and Cost Challenges

Carbon neutrality

- Facility & operations emissions
- Supplier emissions
- Vehicle emissions

Sustainability Goals and Cost Challenges

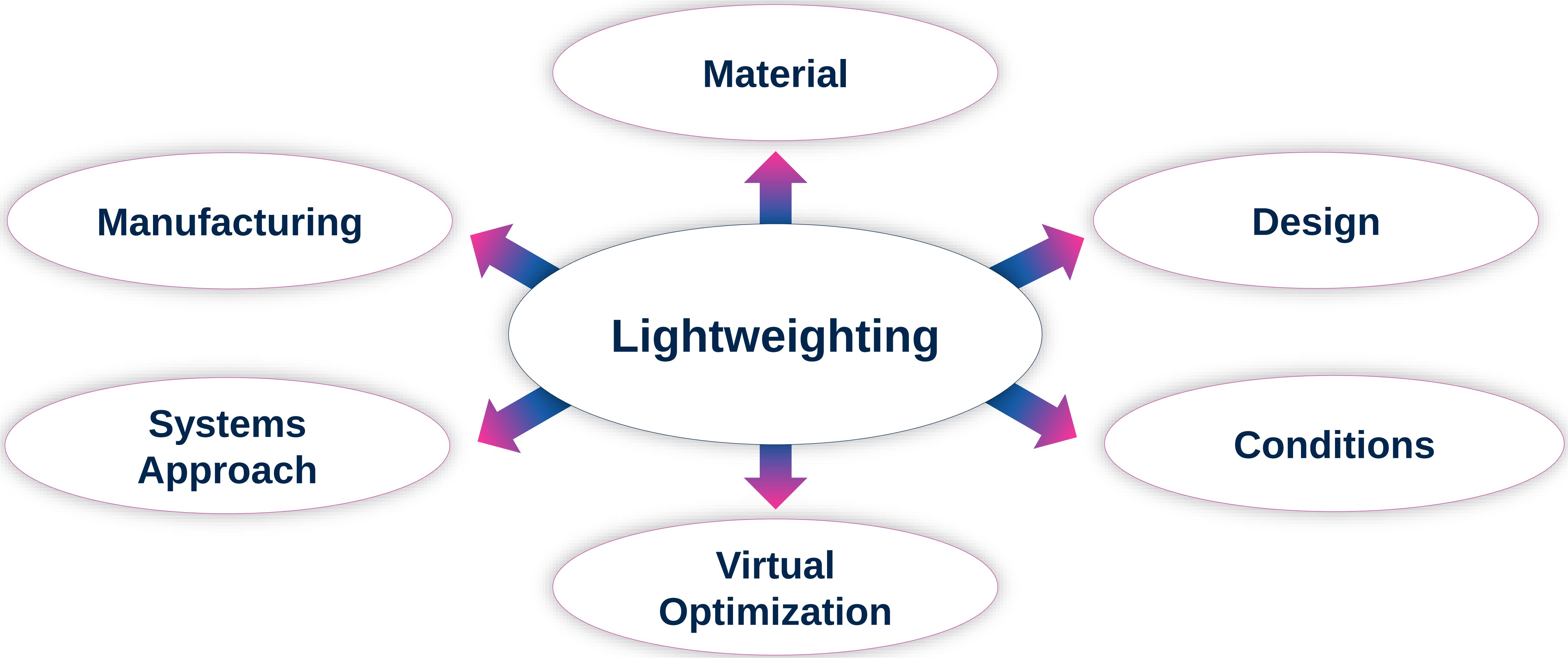


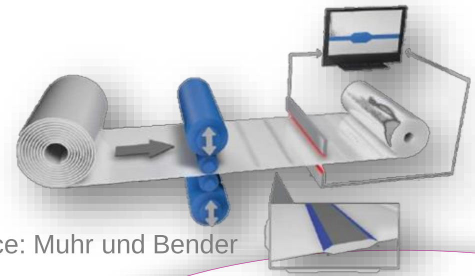
Ford strives for carbon neutrality causing additional cost challenges → **Strong demand for technologies supporting weight, cost as well as carbon emission reduction**

Henry Ford about Lightweighting

Henry Ford, 1923

"Saving even a few pounds of a vehicle’s weight [...] could mean that they would also go faster and consume less fuel.
Reducing weight involves reducing materials, which, in turn, means reducing cost as well."


Material
Manufacturing
Design
Lightweighting
Systems Approach
Conditions
Virtual Optimization



Source: Muhr und Bender

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Manufacturing

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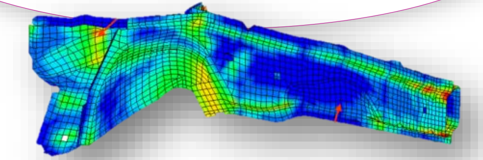

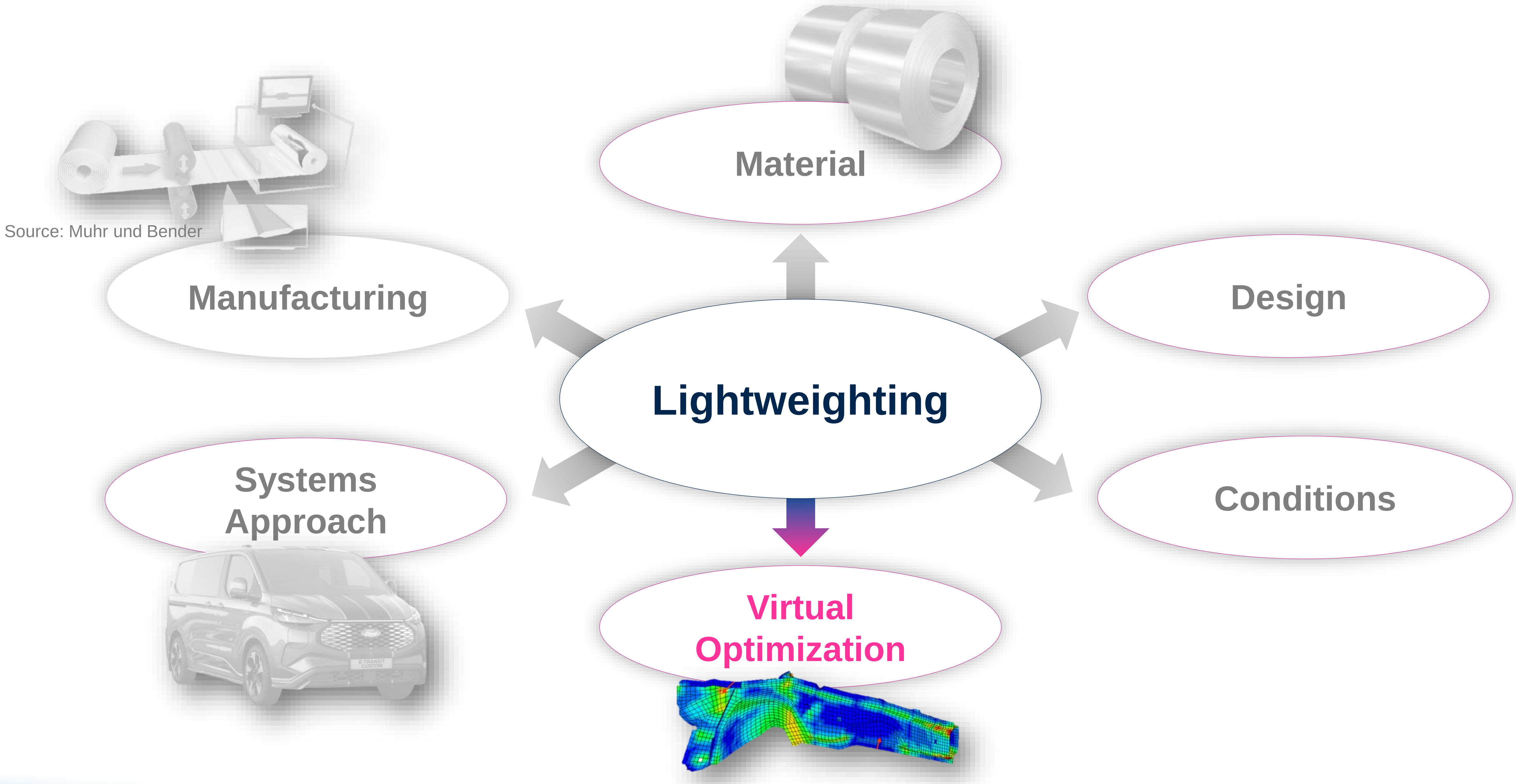
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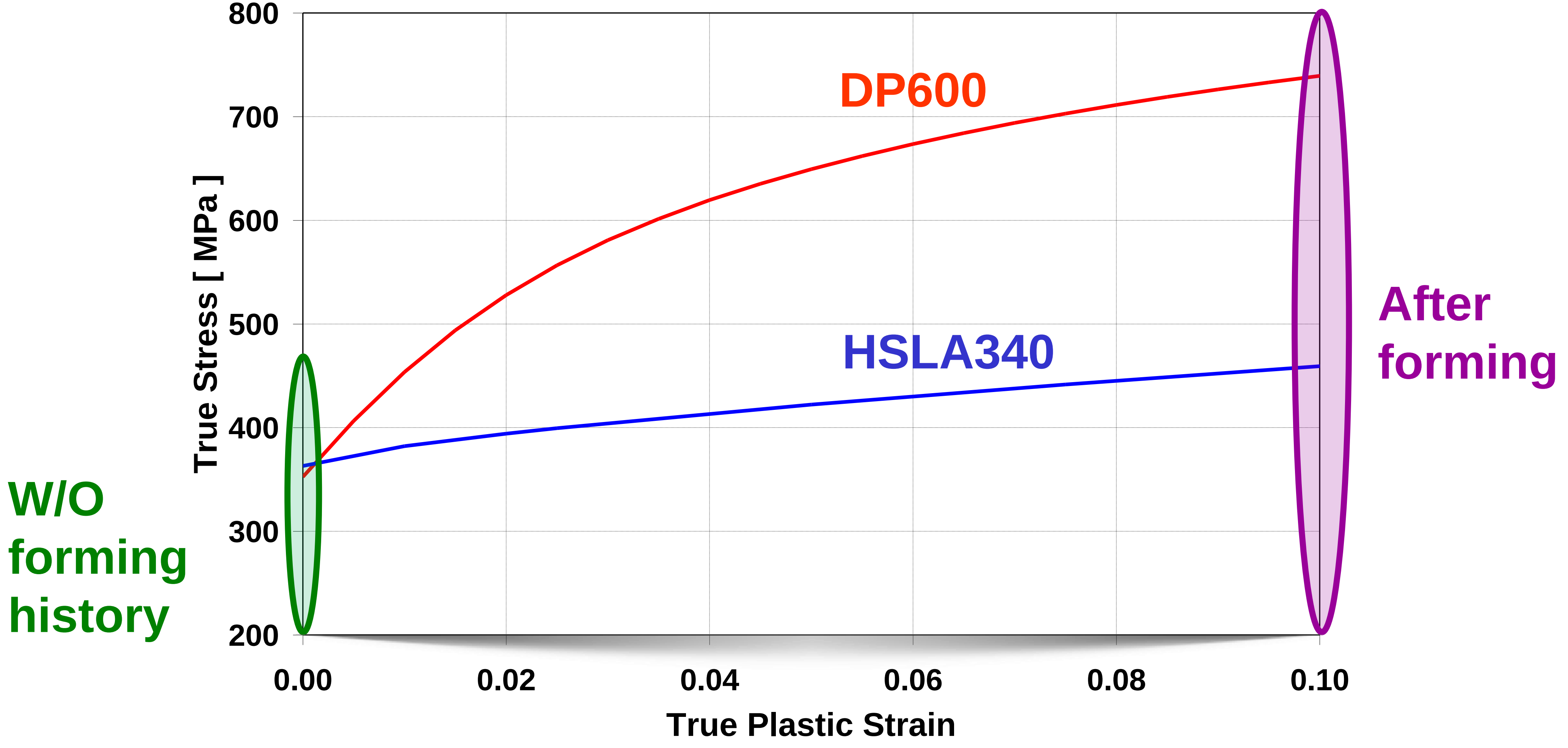
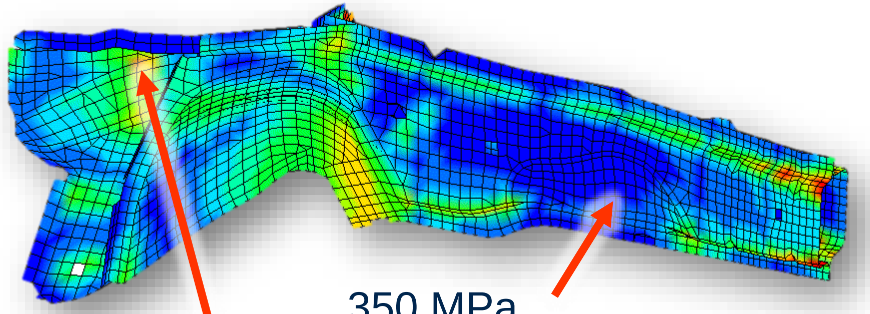
Virtual Optimization

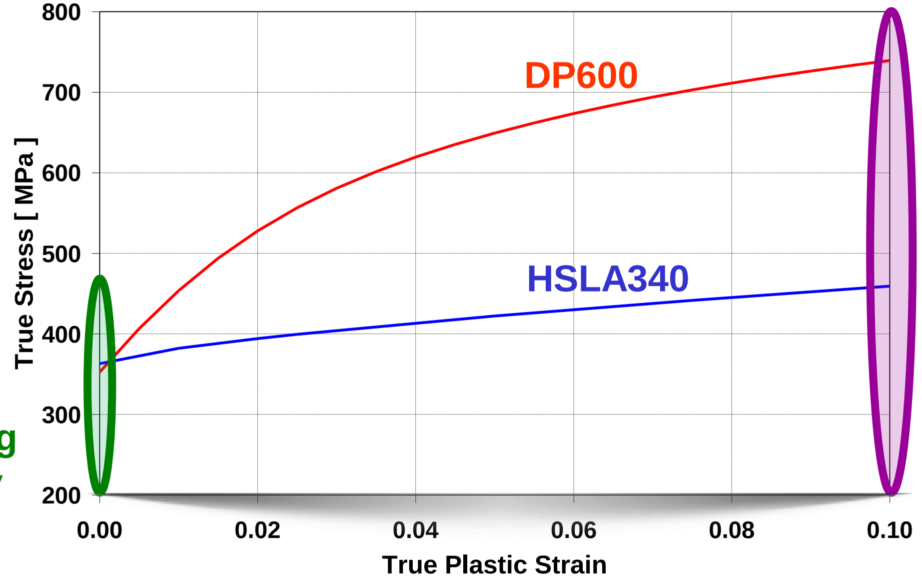


Virtual Optimization



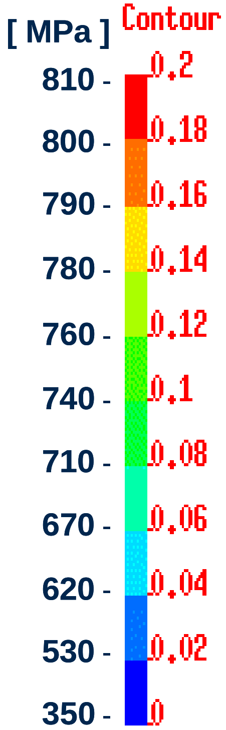
350 MPa
Local Yield Strength

> 750 MPa Local Yield Strength



W/O forming history

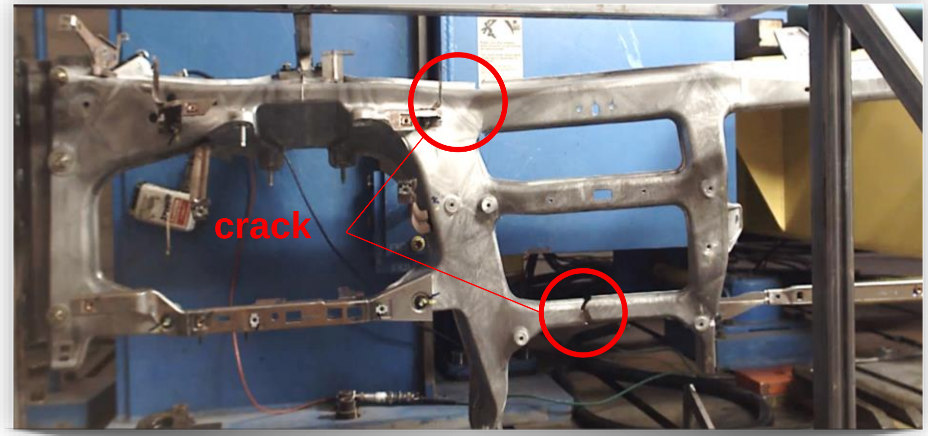
After forming



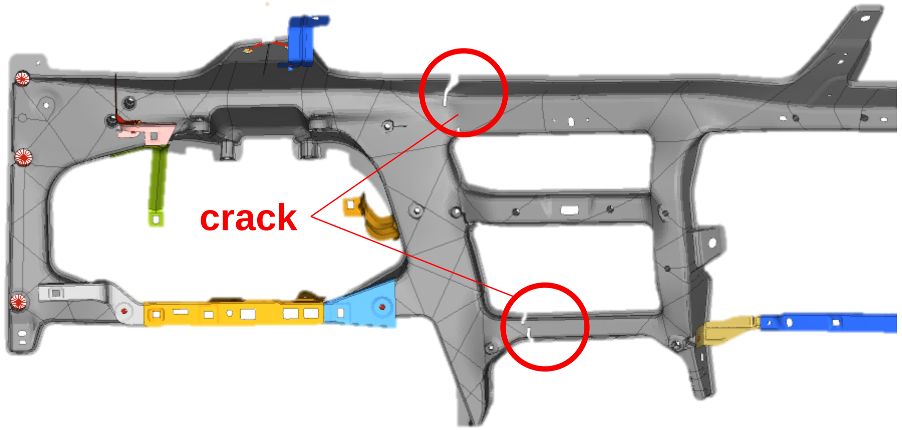
Yield Strength Plastic Strain

Virtual Optimization – Prediction of Material Failure

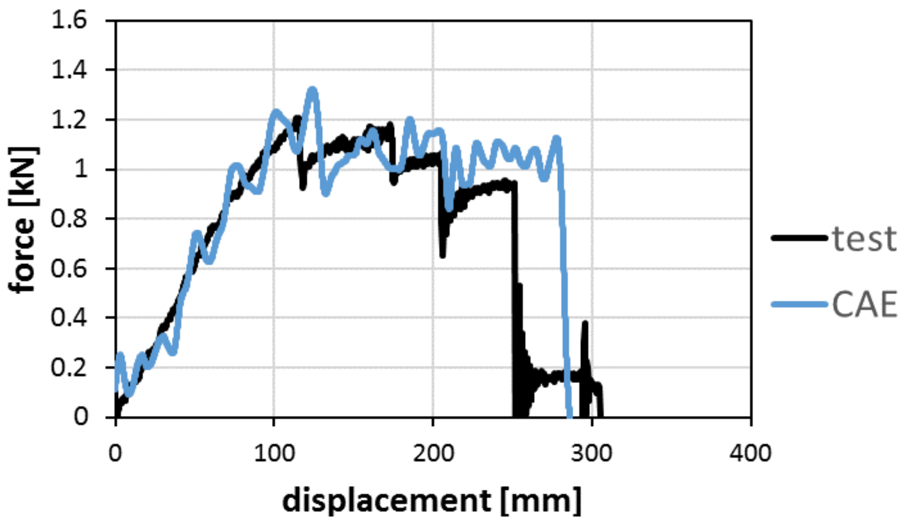
Test



Simulation

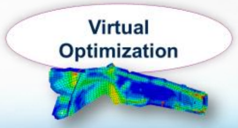


Correlation

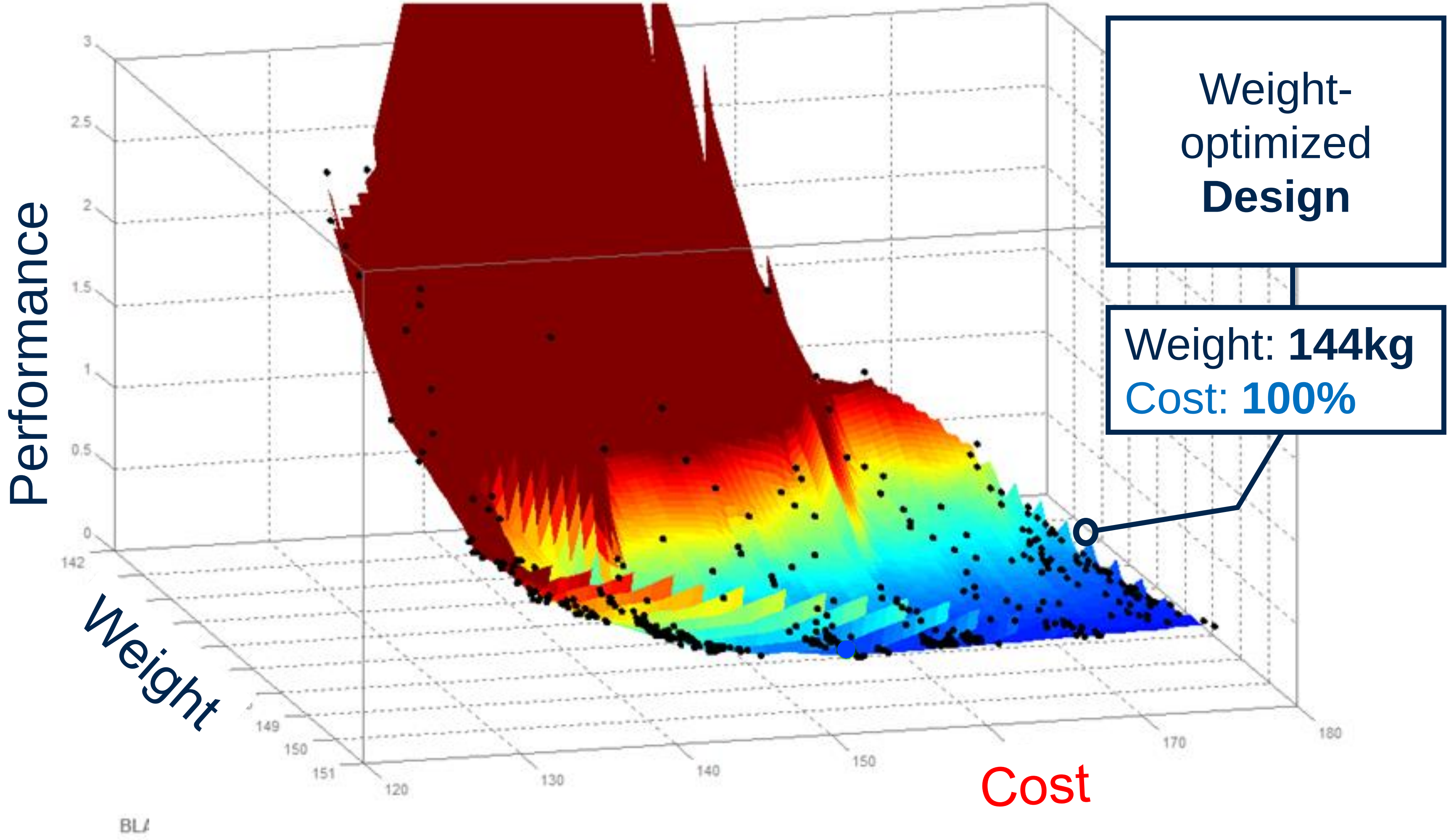


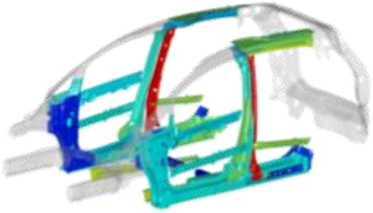
Virtual Optimization

1. Considering the influence of the **manufacturing process** on local properties for **crash CAE**
2. Integration of manufacturing CAE also for **NVH- and Durability**-simulations
3. Multidisciplinary Optimization (**MDO**): Crash, NVH, Durability
4. Integration of **manufacturing feasability and cost** in MDO



Optimization of Weight and Cost

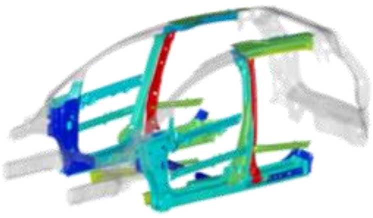


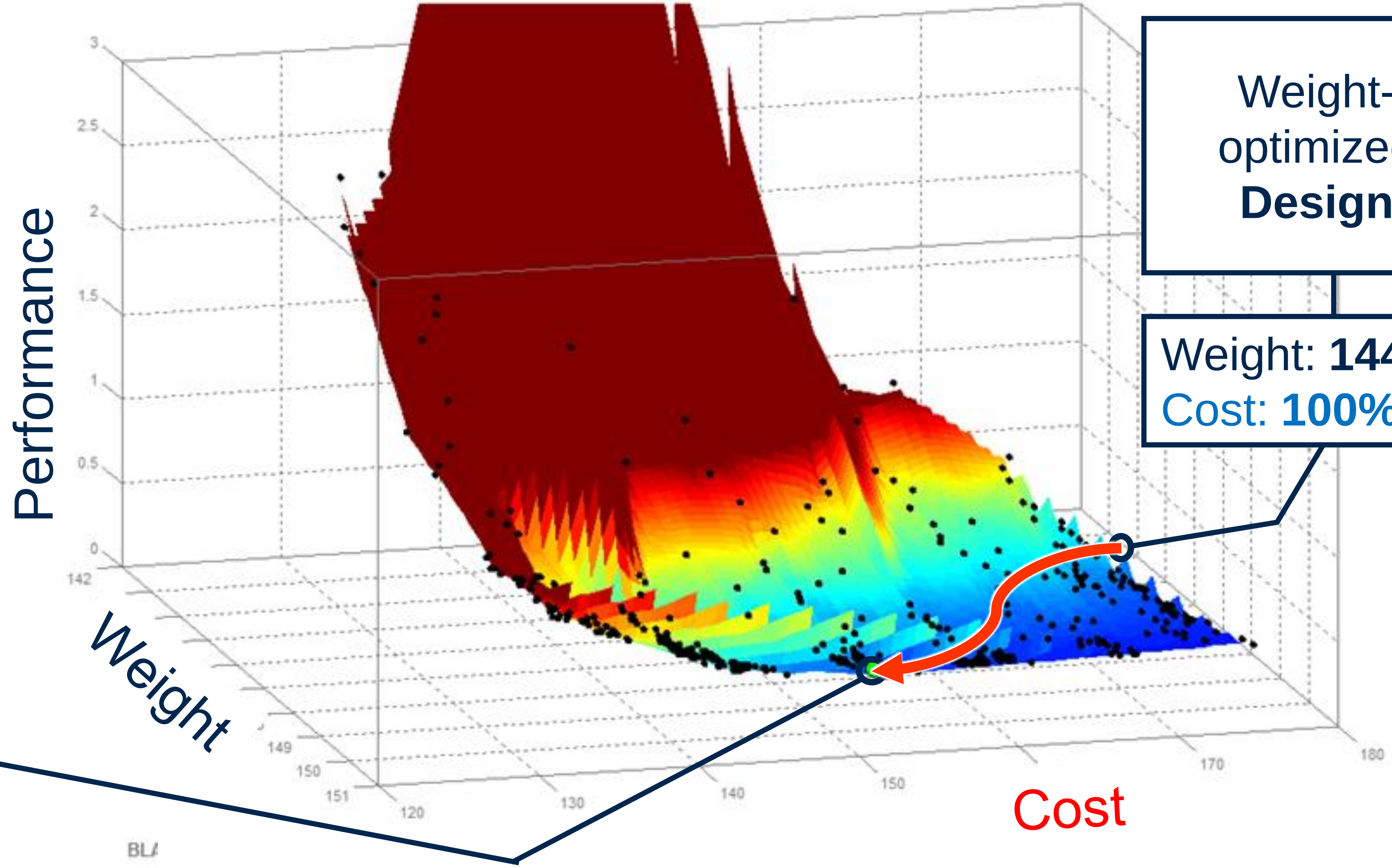


Optimization of Weight and Cost

Weight-optimized **Design** also considering **Cost**

Weight: **148kg**
Cost: **85%**

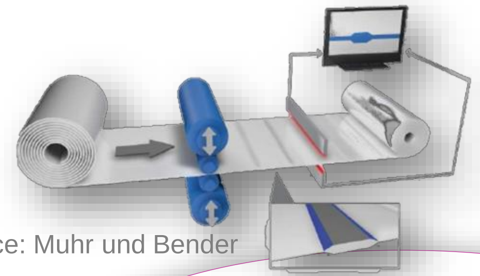




Weight-optimized **Design**

Weight: **144kg**
Cost: **100%**

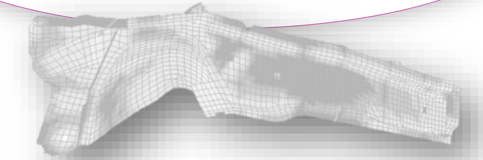
Virtual Optimization



Source: Muhr und Bender

Lightweighting

- **Material**
- **Manufacturing**
- **Design**
- **Conditions**
- **Virtual Optimization**
- **Systems Approach**



Materials and Manufacturing – Example: Body Structure

All car manufacturer:

>> 95% of all body structures are **steel based**

Materials and Manufacturing – Example: Body Structure

All car manufacturer:

>> 95% of all body structures are **steel based**

Ford:

< 85% of all body structures are **steel based**

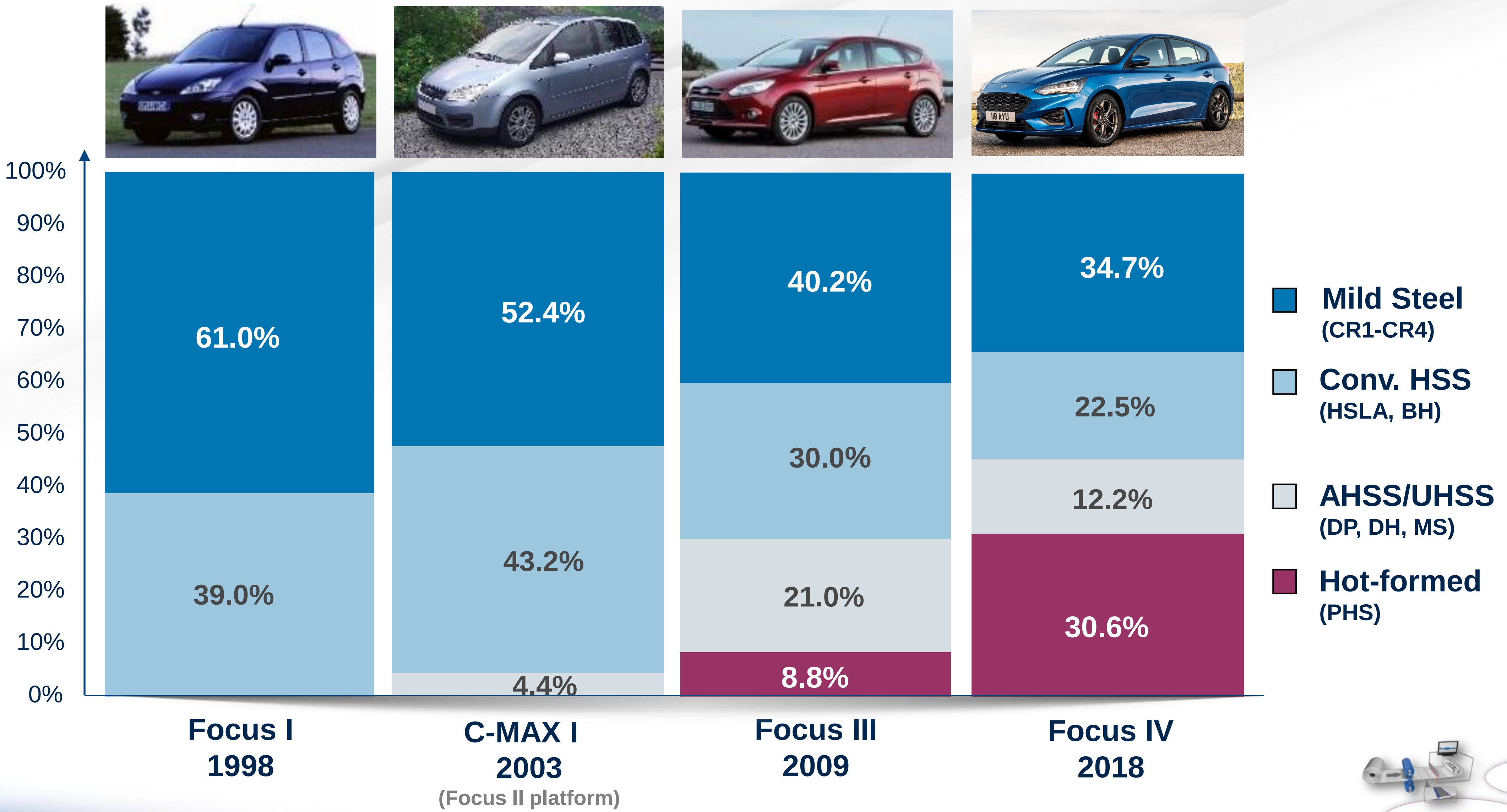
Steel- vs. Aluminium Architecture

Ford vehicles with steel architecture


Ford vehicles with aluminium architecture




Steel in the Body Structure



Hot-formed Steels (PHS)

PHS B-pillar

Tailor rolled B-pillar

Partially hardened rear side member

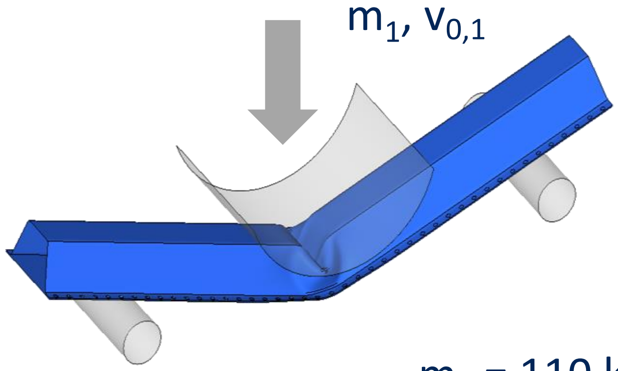
- high ductility
- transition zone
- high strength

Form blow hardening of tailor rolled tube

Study about Lightweight Potential of High Strength Steels

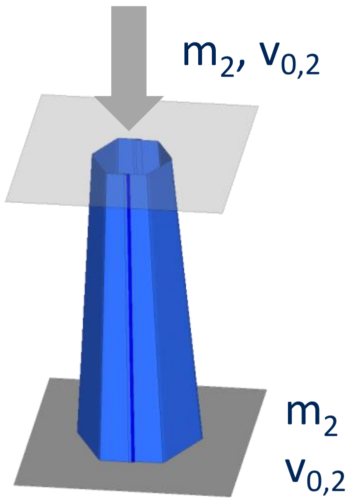
Goal: **Optimization of the sheet thickness** for given crash performance

3-Point Bending of hat-profile



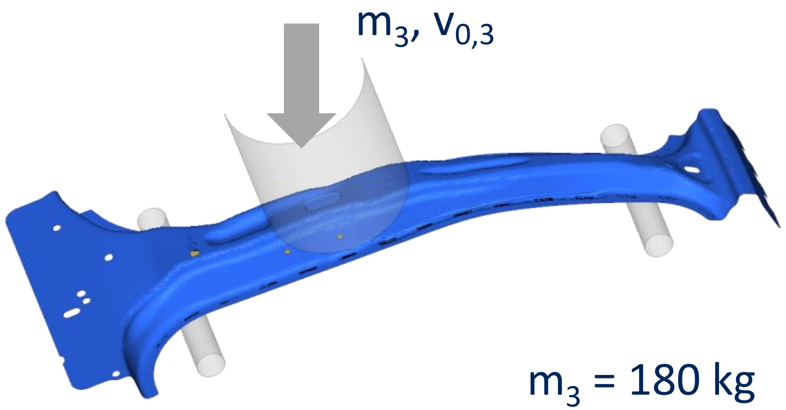
m_1 = 110 kg
$v_{0,1}$ = 6 m/s

Axial Crush



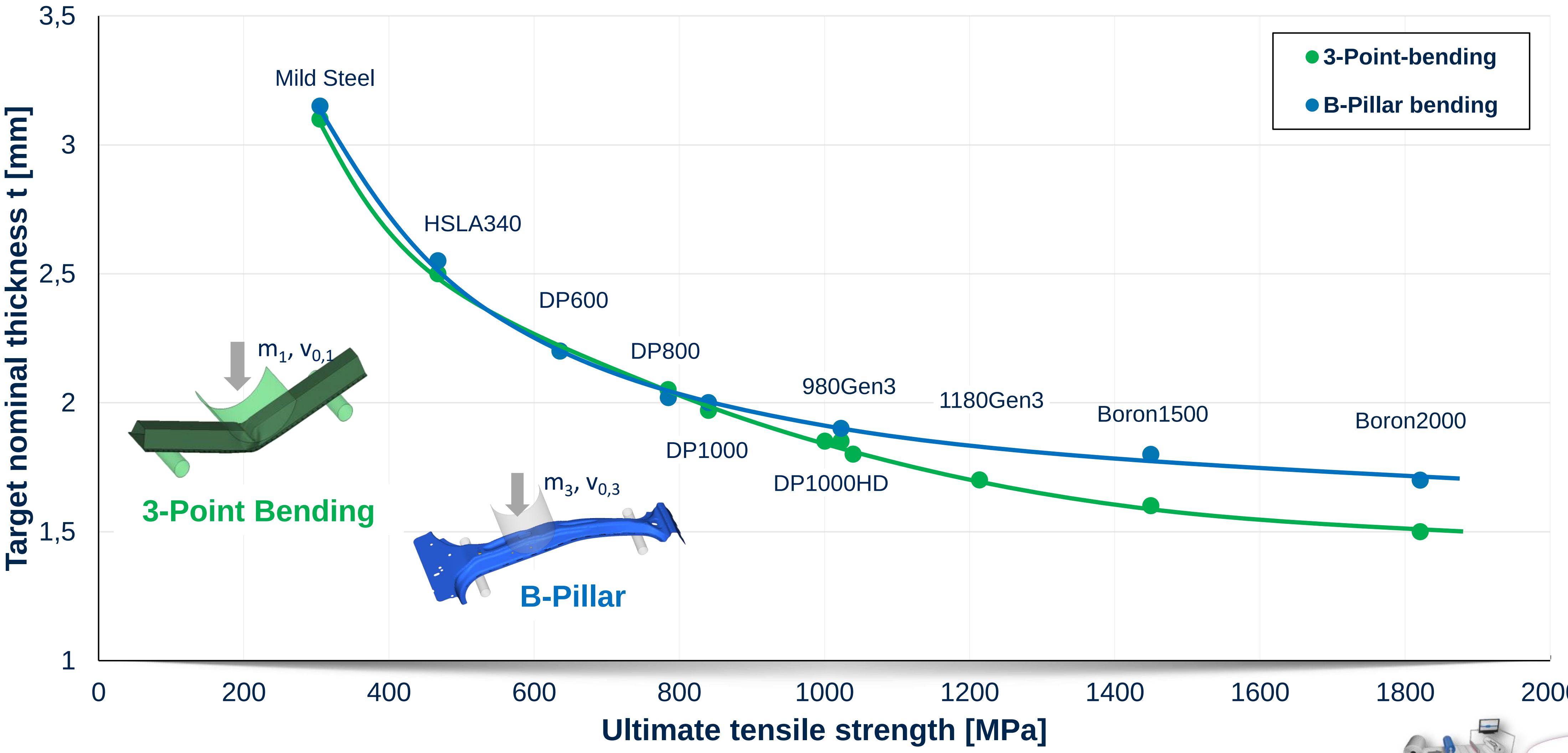
m_2 = 350 kg
$v_{0,2}$ = 14 m/s

3-Point Bending of B-Pillar

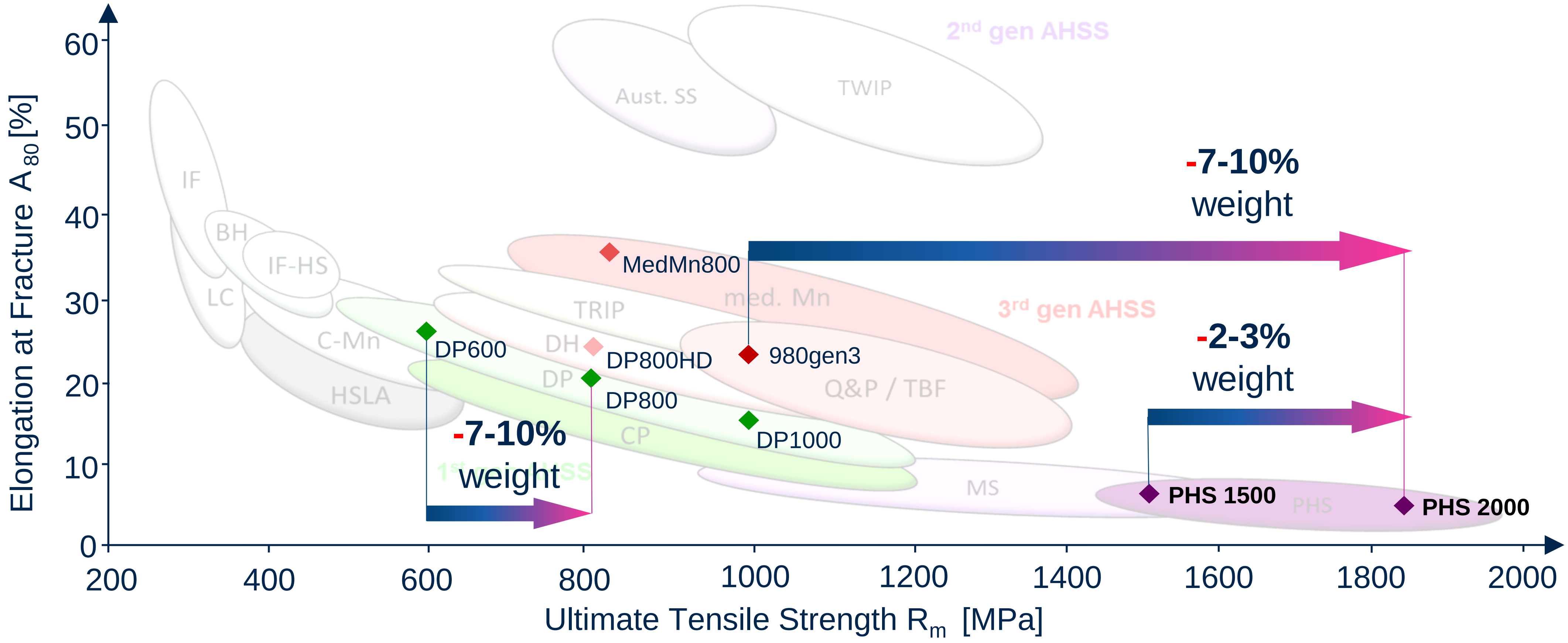


m_3 = 180 kg
$v_{0,3}$ = 5 m/s

Lightweighting Potential of High Strength Steels – B-pillar

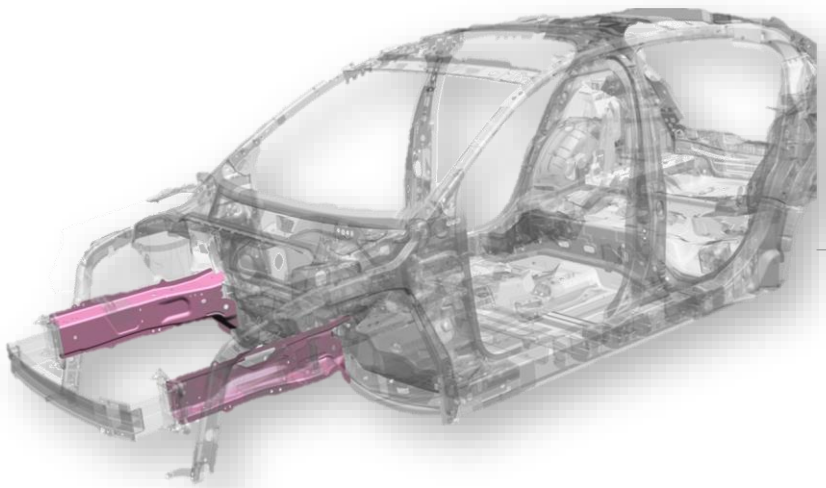


High Strength Steels and Lightweighting



Replacing DP600 by DP800 enables more weight reduction than the use of PHS 2000 instead of PHS 1500

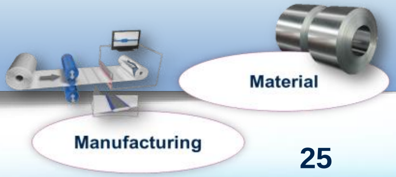
Lightweighting by DP Steel with Improved Ductility



FORD FOCUS

Higher Ductility of DP800HD compared to conventional DP800 enables the **use of 800 grade instead of DP600** for the front side member

7.5% weight reduction



FORD F150 with Aluminium Body

F-Series is the best selling **truck** in America since

47 years

F-Serie is the best selling **vehicle** in America since

42 years

The Road to the First Aluminum Body in High Volume

AIV Sable:

Al body-in-white, **Steel-design**

1992

Ford 2000:

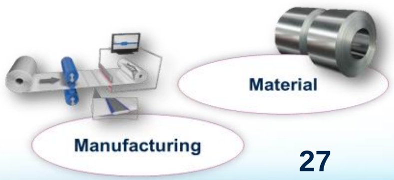
Al body-in-white, **Al-design**

1998

Jaguar XJ:

Al body-in-white, **advanced Al-design**

2003

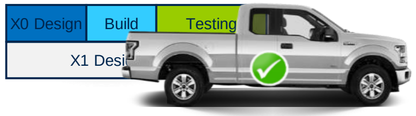


F150 – Key Aluminium Workstreams

F150 Prototypes

Jan. - Jun. 2010

X0 Design, Build, Testing, X1,



Al in Low Volume

1992

1998

2003

Al Readiness Workstreams for High Volume

Oct. 2009 – April 2010

- Marketing / Customer Acceptability ✓
- Service / Repair ✓
- Material Supply / Procurement ✓
- Manufacturing / Stamping ✓
- Engineering: Body / Vehicle ✓

High Confidence achieved!

April 2010

Ready to go for

High Volume

F150

Nov. 2014

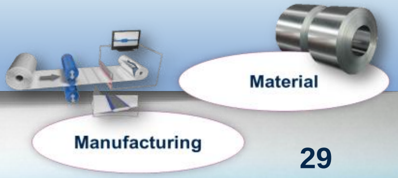
Job 1

F150

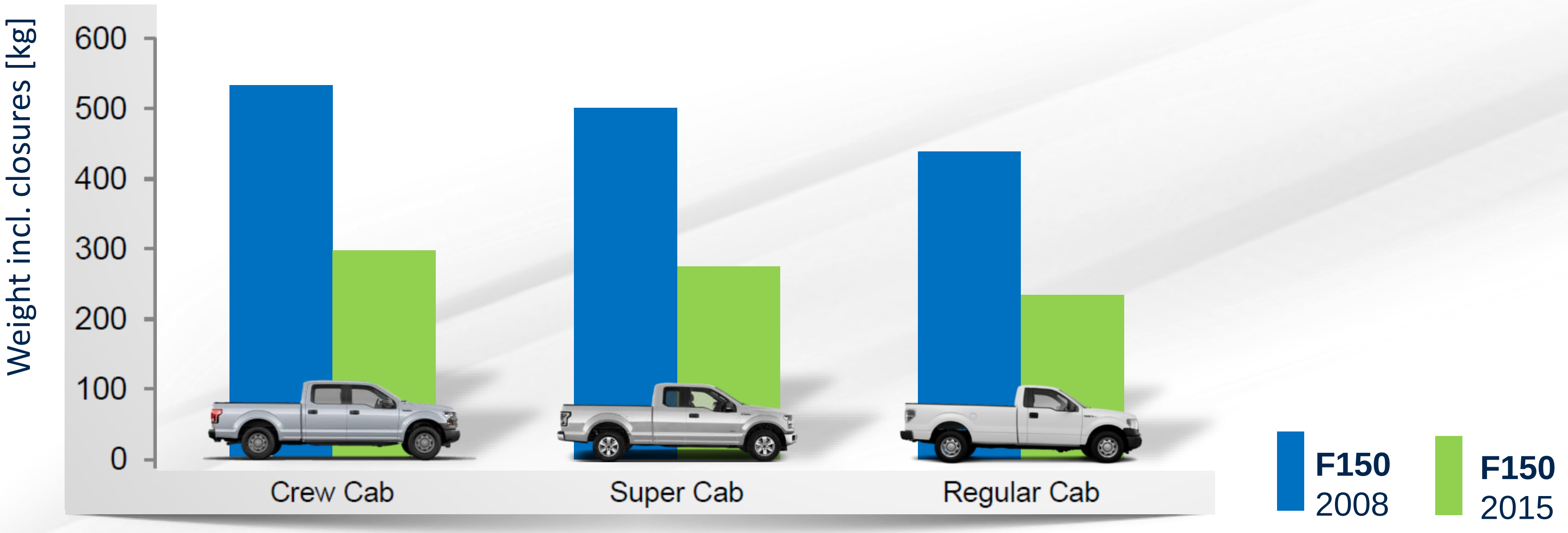
F150 – Why Aluminium?

- **Efficiency**
- **Payload**
- **Driving Dynamics**
- **Body on Frame:**
  - Steel-Frame
  - Aluminium body

Aluminium is used where it is most efficient



Ford F150 – Weight Reduction



Box	51%
Doors and closures	39%
Body structure	43%

45%

Weight reduction in BiW

Aluminium Recycling Concept

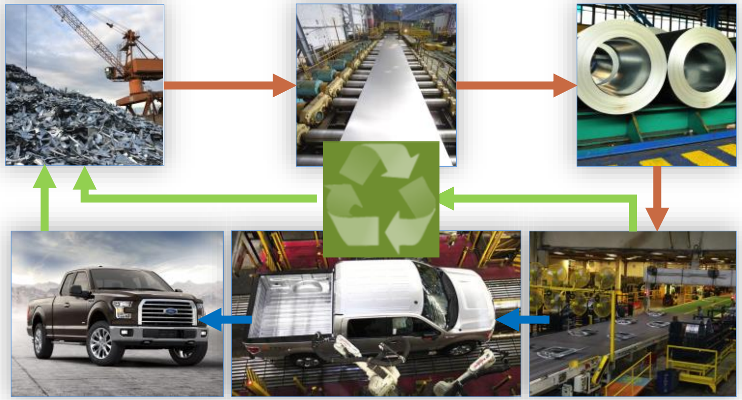
Mixing of Al-alloys

Low scrap value

Recycling one Al-alloy into itself

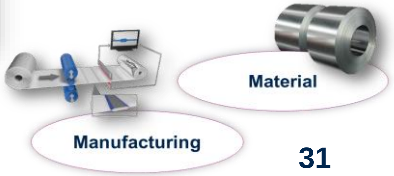
High scrap value

In order to enable the separation of the production scrap in the plant, **4 chemical compositions** were defined



„Multi Supplier Tolling“

10 different Al-grades



Current Use of CFRP

Current use of CFRP
in **car manufacturing**

Intensive CFRP use in **niche production**

CFRP use for **selected parts** in vehicles of low and medium volume

Current Use of CFRP in Car Manufacturing

2015

- Use of CFRP parts in light vehicles: **25.500.000 kg CFRP ***
- Global light vehicle sales: **88.000.000 vehicles ****

➡ **<0,3 kg CFRP-parts/vehicle**

Assumptions

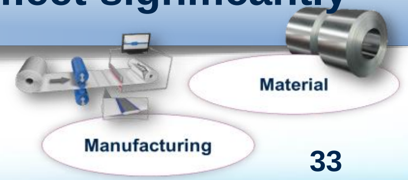
2025

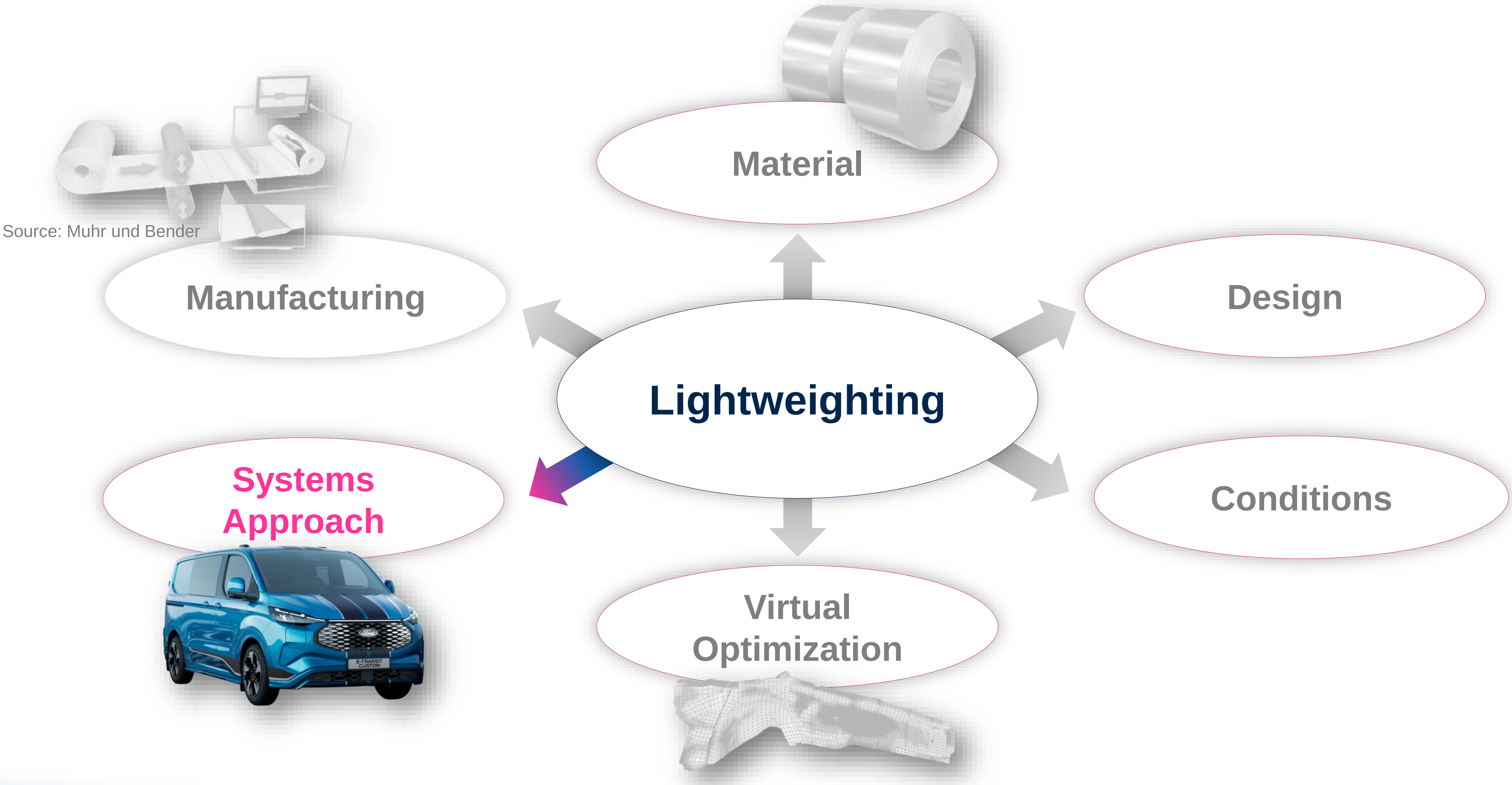
- Growth rate for the use of CFRP-parts in light vehicles: **20% per year until 2025**
- Global light vehicle sales: **110.000.000 vehicles**

➡ **<2 kg CFRP/vehicle**

* Source: Composites Marktbericht 2016, Nov 2016, T. Kraus, M. Kühnel/CCeV, E. Witten AVK, http://www.carbon-composites.eu/media/2448/marktbericht_2016_ccev-avk.pdf
** Source: Mike Jackson, IHS Automotive, Globalization of the Auto Industry, Ann Arbor, MI, 13 April 2016

In the foreseeable future CFRP parts will not contribute to the weight reduction of the vehicle fleet significantly

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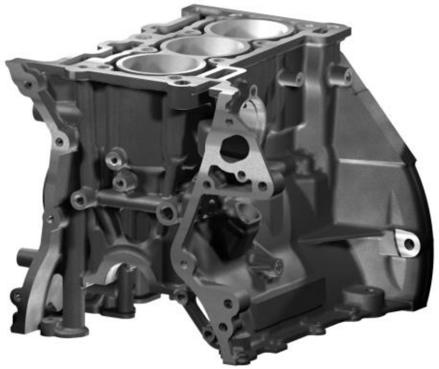
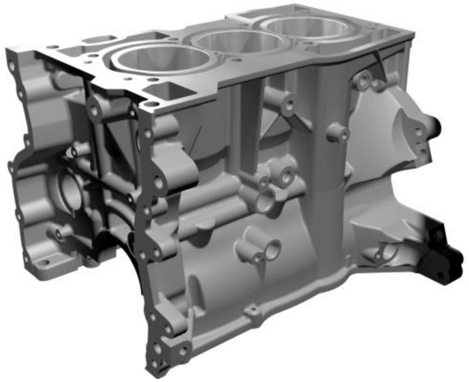
Source: Muhr und Bender

What is the Best Choice for Lightweight Engine Blocks?

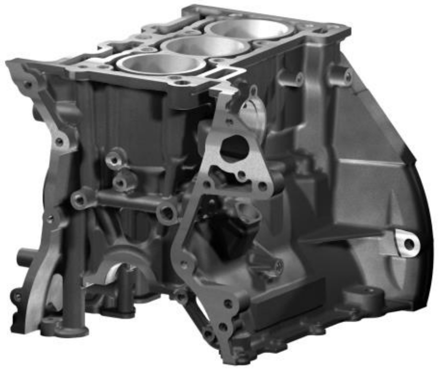


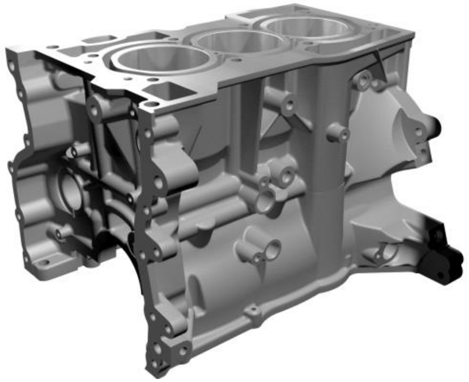


GCI-block		Aluminium-Block
100%	Block weight	**62%**

Therefore: Is Aluminium the **better material for lightweighting?**

What is the Best Choice for Lightweight Engine Blocks?

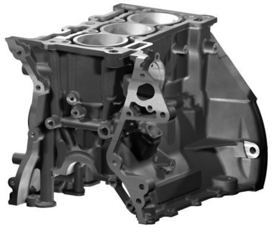




GCI-block		Aluminium-Block
100%	Block weight	**62%**
↓		↓
100%	Powertrain Weight	**100%**

Systems Approach

What is the Best Choice for Lightweight Engine Blocks?

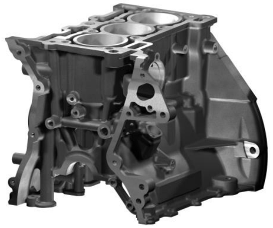


Block

GCI instead of Aluminium	→	Weight ↑ Size ↓ Cost ↓

Systems Approach

What is the Best Choice for Lightweight Engine Blocks?



GCI instead of Aluminium

Block

Weight	↗
Size	↘
Cost	↘

Powertrain

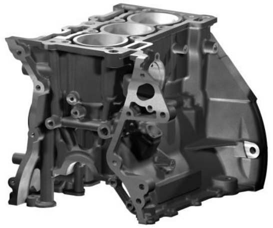
Weight	→
Size	↘
Cost	↘

Systems Approach

What is the Best Choice for Lightweight Engine Blocks?

GCI instead of Aluminium

Block



Weight ↑
Size ↓
Cost ↓

Powertrain

Weight →
Size ↓
Cost ↓

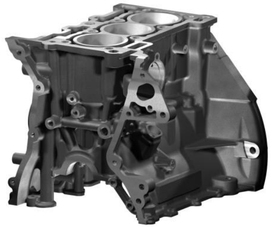
Savings will be invested in lightweight parts (Aluminium hood, knuckle,…)

Vehicle

Weight ↓
Cost →

Systems Approach

What is the Best Choice for Lightweight Engine Blocks?



GCI instead of Aluminium

Block

Weight
Size
Cost

Powertrain

Weight
Size
Cost

Savings will be invested in lightweight parts (Aluminium hood, knuckle,…)

Vehicle

Weight
Cost

Powertrain is the biggest of the carline

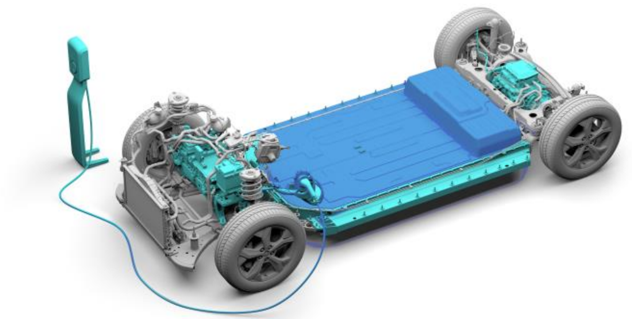
Vehicle

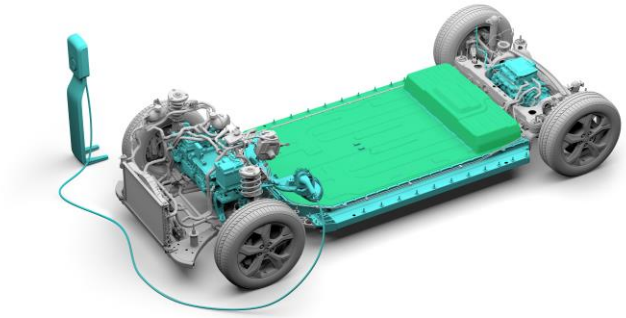
More efficient package
Shorter frontend

Weight
Cost

Systems Approach

Batteries and Lightweighting





Battery 1

62%

Weight per kWh

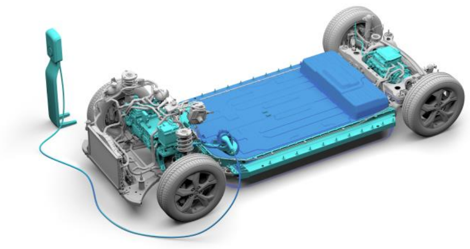
Battery 2

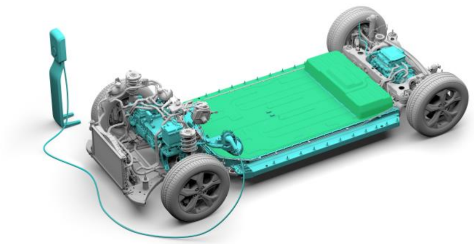
100%

Which one is the **better choice for lightweighting?**

Systems Approach

Batteries and Lightweighting





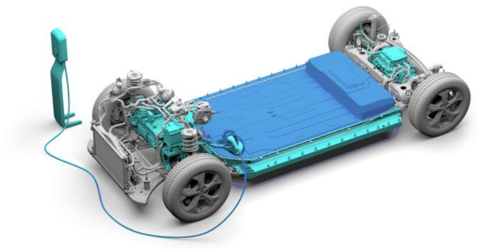
Battery assumptions:

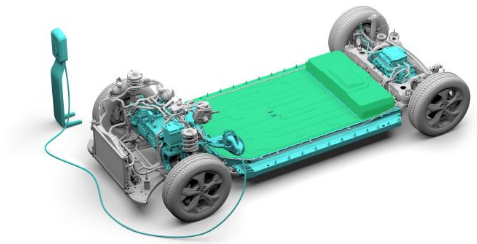
	Battery 1	Battery 2
Energy density	260 Wh/kg	160 Wh/kg
	500 Wh/l	250 Wh/l
Cost	$100/kWh	$70/kWh

Vehicle assumptions:

Energy consumption	25 – 40 kWh/100 km
Worst case range requirement	150 km

Batteries and Lightweighting





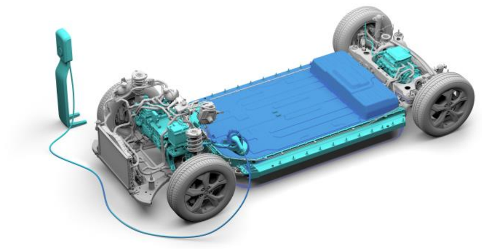
Battery assumptions:

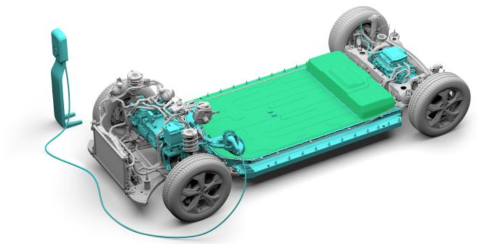
	Battery 1	Battery 2
Energy density	260 Wh/kg 500 Wh/l	160 Wh/kg 250 Wh/l
Cost	$100/kWh	$70/kWh
Weight for 60 kWh	231 kg	375 kg

Vehicle assumptions:

Energy consumption	25 – 40 kWh/100 km
Worst case range requirement	150 km

Batteries and Lightweighting





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	Battery 1	Battery 2
Energy density	260 Wh/kg	160 Wh/kg
	500 Wh/l	250 Wh/l
Cost	$100/kWh	$70/kWh
Capacity loss at -20°C	40%	10%

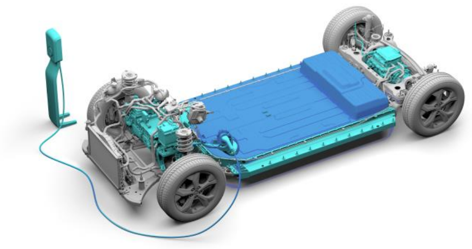
Vehicle assumptions:

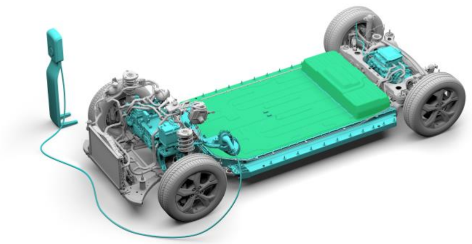
Energy consumption	25 – 40 kWh/100 km
Worst case range requirement	150 km

Systems Approach

Batteries and Lightweighting

Requirement of
150 km range at -20°C



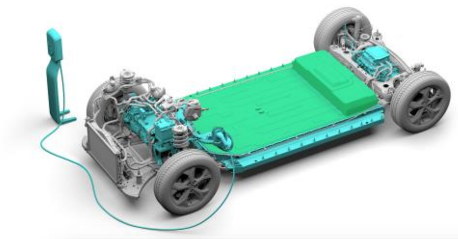


	Battery 1	**Battery 2**
Required capacity at -20°C	60 kWh	60 kWh
Required capacity installed	100 kWh	67 kWh
Battery volume	200 l	268 l
Battery weight	385 kg	419 kg
Cost	$10.000	$4.690

Battery 1 ist 34 kg lighter than battery 2, however > $5.000 more costly

Investing a minor part of the $5.000 will lead to lower weight and lower cost on vehicle level

Battery 2 – The Lightweight Option for the Specified Use Case



Battery 2
instead of 1

w/o LT range requirement

Weight	↑
Size	↑
Cost	↓

With -20°C range requirement

Weight	↑
Size	→
Cost	↓

Cost savings partially invested in weight saving (aluminium hood, knuckle,…)

Vehicle

Weight	↓
Size	→
Cost	↓

Systems Approach


Thanks for your interest!