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– NICHT ZUM VERSAND –

beryls
STRATEGY ADVISORS

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Automotive lightweight – Heavy impact

Economic Symposium, Alpbach

A definition: Automotive lightweight – from lightweight material to lightweight design …

A „LIGHT CAR" makes use of …

… and requires not only material and product application know-how, but processing and joining know-how as well.

Source: Berylls Strategy Advisors

… with heavy impact – the 3 key drivers for lightweight design in Automotive (1/3)

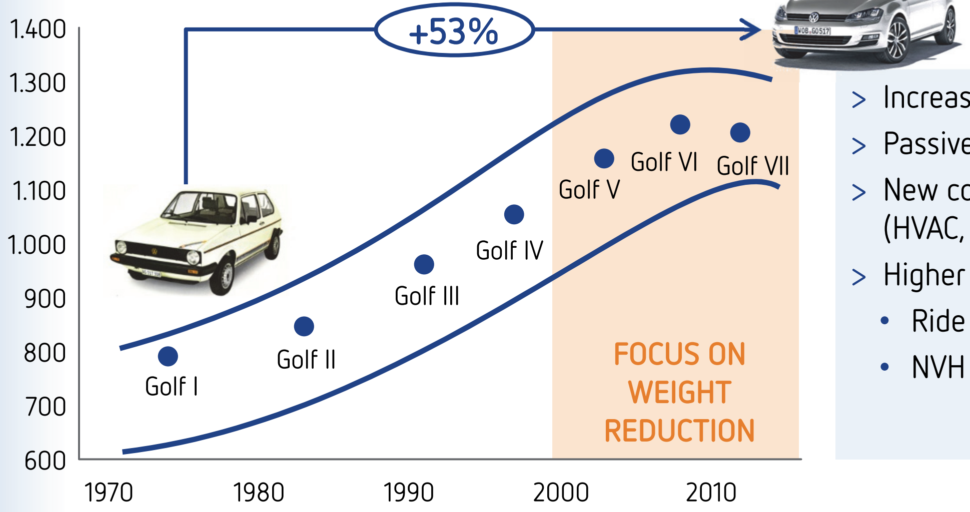
VEHICLE CONTENT & FUNCTIONS

CO_2 EFFICIENCY

POWERTRAIN ELECTRIFI-CATION (xEV)

EXAMPLE: VW GOLF – VEHICLE WEIGHT INCREASE ACROSS GENERATIONS

kg, standard equipment, basic performance engine

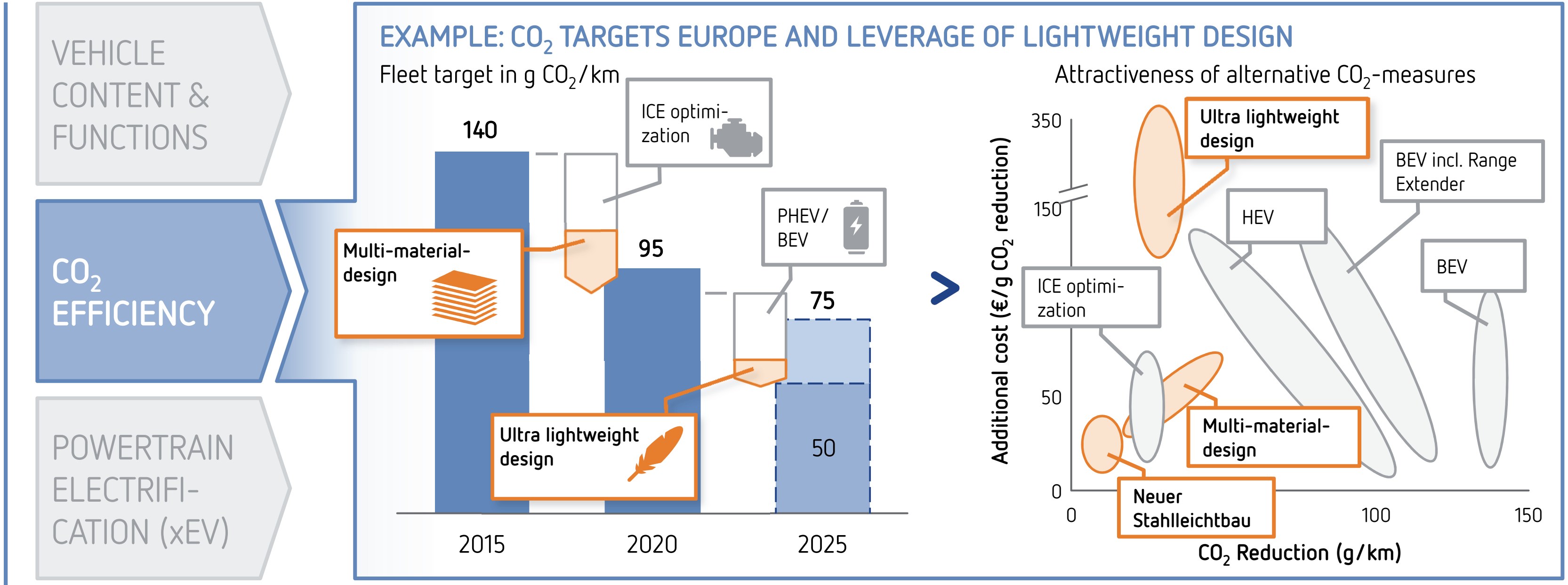


- Increase of vehicle size
- Passive safety (NCAP rating, …)
- New comfort functions (HVAC, power seats, …)
- Higher requirements on
  - Ride & handling (controls, …)
  - NVH (glass, insulations, …)

> Lightweight design needed to reverse the weight spiral of additional vehicle content and functions!

Source: Volkswagen, Berylls Strategy Advisors

… with heavy impact – the 3 key drivers for lightweight design in Automotive (2/3)



Lightweight design as an important lever to apply to future CO_2 emissions regulations (2020 and beyond)

Source: Berylls Strategy Advisors

... with heavy impact – the 3 key drivers for lightweight design in Automotive (3/3)

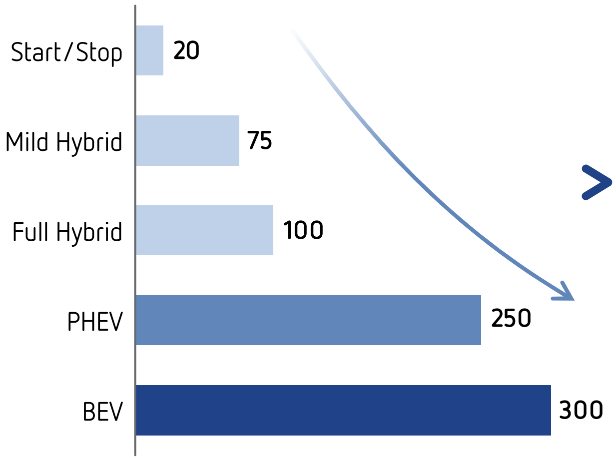
VEHICLE CONTENT & FUNCTIONS

CO_2 EFFICIENCY

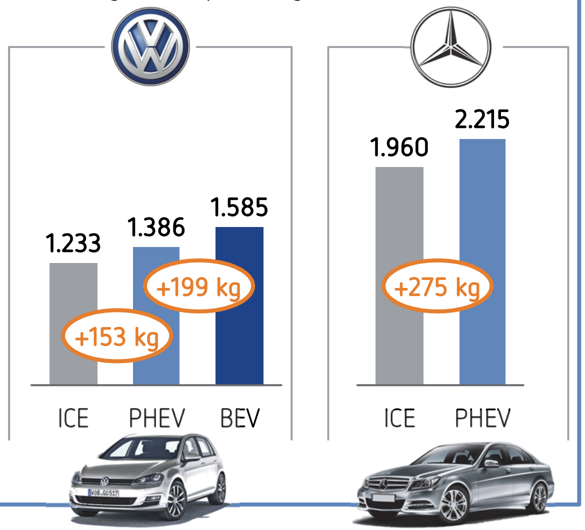
POWERTRAIN ELECTRIFI-CATION (xEV)

EXAMPLE: ADDITIONAL WEIGHT BY ALTERNATIVE POWERTRAIN

Additional powertrain weight in kg – exemplary



Vehicle weight examples in kg

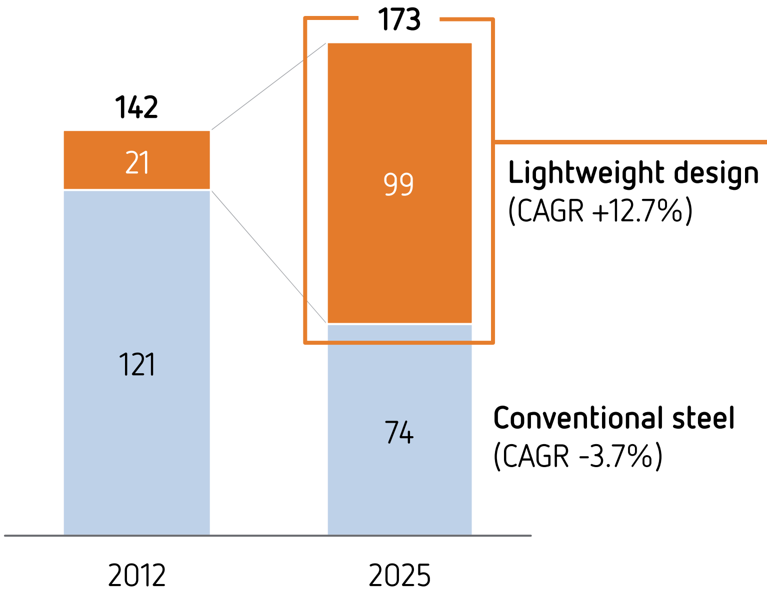


> Lightweight design crucial for xEV performance, to limit weight increase with direct impact on vehicle reach and/or battery site and cost

Source: Berylls Strategy Advisors

Example – The future market for "lightweight body design" will grow fivefold to almost €100bn (2025)

Lightweight Body Design – Market Growth…
in bn €, light vehicles, global



1 High-strength steel (HSS), Advanced high-strength steel (AHSS), Ultra high-strength steel (UHSS)
2 "Light vehicles" definition: including passenger cars, pick-ups and light trucks (up to 3.8 tons)
Source: Berylls Strategy Advisors

COMMENT

> **Global vehicle market[1] to grow by almost 50% until 2025**
- from 79 mn. units (2012) …
- … to 118 mn. units (2025, expected)

> **Strong shift to lightweight design**
- Lightweight design market growth in all regions, including China
- Diffusion into small vehicle segment – lightweight material to almost catch-up with conventional steel

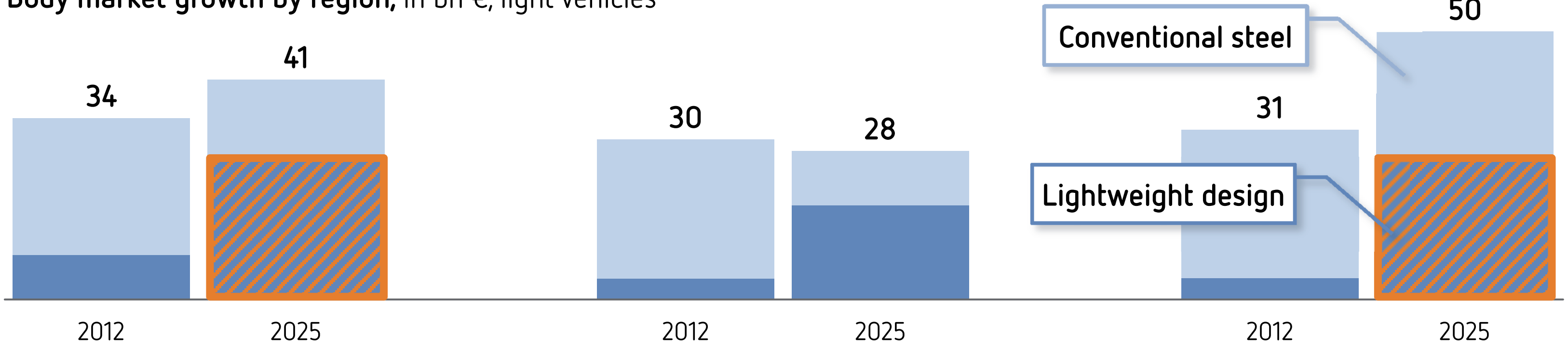
> **Multi-material design on the rise**
- In 2025, almost 1/3 of all vehicles will apply multi-material solutions (steel- or aluminum-intensive)

> **Lightweight design still a steel market in the future**
~75% of market will be high- to ultra-high-strength steel

Example – Continued high growth potential for lightweight body design in Europe, and China will almost have caught up with Europe by 2025

EUROPE | NAFTA | CHINA

Body market growth by region, in bn €, light vehicles



EUROPE

- European OEMs/suppliers as innovation leader since years
- European Premium segment as key driver
- Tight European CO_2 regulations

NAFTA

- Big 3 (FCA, Ford, GM) need to catch up on vehicle weight
- European transplants to introduce lightweight value creation

CHINA

- By far strongest production growth
- Strong and fast catch up with state-of-the-art technology
- Local investments by all international OEMs/suppliers

Comment: Regions correspond to vehicle production location
Source: Berylls Strategy Advisors

Know-how requirements for lightweight design innovations – 3 dimensions

MATERIAL

- New alloys, new composites
- New material combinations
- Material treatment
- Etc.

PROCESS

- Semi-finished products
- Machining and joining technologies
- Process design and management
- Etc.

FUNCTION

- Requirements engineering
- Technical concepts and solutions design
- Application engineering
- Simulation and testing
- Etc.

FOCUS

SUPPLIER

COLLABORATION

OEM

Source: Berylls Strategy Advisors

How to exploit future lightweight markets – … and key success factors for all players

1. Mastering the diversity of light weight solutions –
INNOVATION CAPABILITIES!

2. Supply of global markets –
GLOBAL FOOTPRINT & BUSINESS PERSPECTIVE!

3. Leverage across the value chain –
INDUSTRIES NETWORK & PARTNERING!

Source: Berylls Strategy Advisors

1 Decade of diversity – both heterogeneity and individualization are still on the rise in lightweight body design solutions

1 Mastering the diversity of light weight solutions – INNOVATION CAPABILITIES!

EXAMPLE: LIGHTWEIGHT BODY DESIGN – A DECADE OF DIVERSTITY

LIGHTWEIGHT DESIGN "AT ITS BEST" – competition for the "best" lightweight design solutions of the future

Smart lightweight steel construction
E.g. VW Golf VII

CFRP
E.g. BMW i3 passenger cell

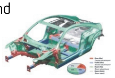
Topology optimization
E.g. Mercedes Benz SL

Load level concepts
E.g. weight spread of alternative drive systems

Tailored solutions
E.g. tailored welded blanks

Hybrid solutions
E.g. Audi A6 front roof frame

Multi-material design
E.g. Audi TT (2nd generation)



Integral construction
E.g. suspension strut dome of the Porsche Panamera

- Innovations at the core
- Premium as front runner

- Focus on steel in the past
- Innovation invest to catch up

- Very strong material competence
- Volume applications in focus

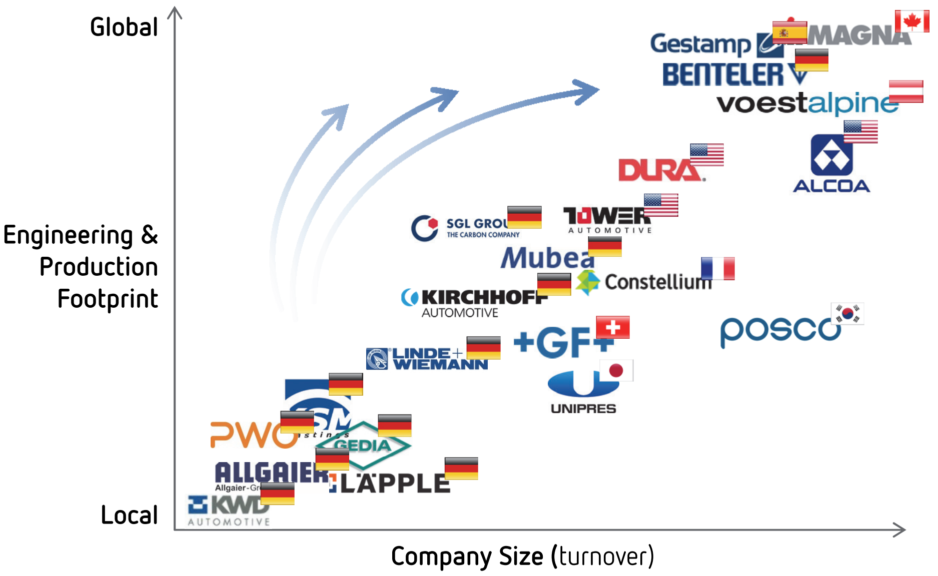
- Strong presence of steel sector
- Limited application innovation know-how

Source: Company information; Berylls Strategy Advisors

2 Global footprint – Localization of the engineering and production value chain becomes a must as markets for lightweight design go global

2 Supply of global markets – GLOBAL FOOTPRINT & BUSINESS PERSPECTIVE!

EXAMPLE: Metal forming companies – selected players



Source: Berylls Strategy Advisors

- Mid-sized to very large players
- Focused internationalization "with the customer"

- Larger players
- Internationalization, with focus on U.S. market, still

- Strong footprint home markets
- Some internationalization with Japanese (Korean) OEMs

- Business focus/footprint China
- Some M&A internationally expected

3 Collaboration – For lightweight design innovations, a comprehensive perspective across the whole value chain is needed, to bring in the right set of partners

3 Leverage across the value chain – INDUSTRIES NETWORK & PARTNERING!

EXAMPLE: LIGHTWEIGHT DESIGN NETWORK GERMANY

Materials/Alloys → Semi-finished products → Machinery equipment → Tooling → Forming & Joining → Assembly

EXAMPLES

OEM + SUPPLIERS

RESERACH INSTITUTES
- DLR
- Fraunhofer-Gesellschaft
- Laser Zentrum Hannover
- Leibnitz-Institute

CLUSTERS & NETWORKS
- CFK-Valley Stade e.V.
- Forschungscampus ARENA 2036
- Initiative Massiver Leichtbau
- Cluster Neue Werkstoffe (Bayern Innovativ)

UNIVERSITIES
- TU Bergakademie Freiberg
- RWTH Aachen
- TU Dresden
- TU München

ASSOCIATIONS
- VDI, VDMA, VDA, VCI
- Industrievereinigung Verstärkte Kunststoffe
- WV Metalle, WV Stahl

- Leading players across the value chain
- Strong research communities

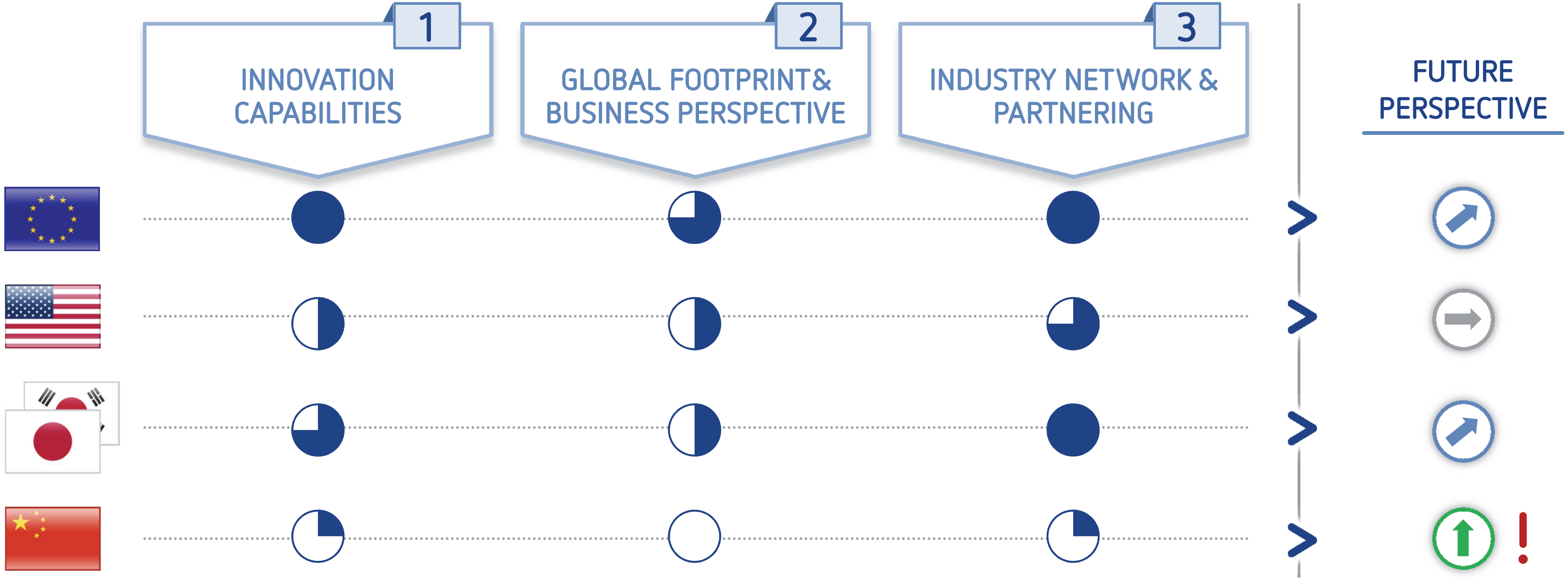
- Large steel/aluminum industries
- Comparatively high OEM in-house parts production

- Highly integrated value chains
- Tightened networks

- Almost no R&D history
- Technology networking not part of the DNA

Source: Berylls Strategy Advisors

Overall, Europe seems well prepared to master the future for lightweight design in Automotive



> As China is on the rise – both from a market as well as from an industry player perspective – European players will have to deal with a tightening competition

Source: Berylls Strategy Advisors

The future role of Europe – and the perspective for the Automotive lightweight industry

ESTABLISHED and WELL-KNOWN PLAYERS across the value chain

GLOBAL INNOVATION LEADERS with a TRADITION OF INNOVATION FOR DECADES

Coverage of the
WHOLE lightweight value chain ...

... from material disciplines to
MACHINERY & equipment to
PRODUCT & PROCESS SOLUTIONS

THE FUTURE OF LIGHTWEIGHT DESIGN:
Strategic (and operational) collaboration across the body value chain!

The MOST INNOVATIVE CAR SEGMENT (premium cars) right on the doorstep

AN UNRIVALED NETWORK OF R&D INSTITUTES AND FACILITIES

PUBLIC FUNDING AS ONE OF THE CORE INDUSTRIES

Source: Berylls Strategy Advisors

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