AMAP Colloquium

37.5 % CO_2 reduction target for 2030 – Technological implications of the tightening CO_2 regulation

Aachen, March 21st 2019

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fka GmbH

fka- creating ideas and driving innovation

- Research partner for the automotive industry since 1981
- Innovative solutions and strategic consulting

- The holistic approach and unique infrastructure for simulation, testing and evaluation allows us to see the big picture and be your specialist for details at the same time.

Competences(excerpt)

Automated Driving fka

Benchmarking fka

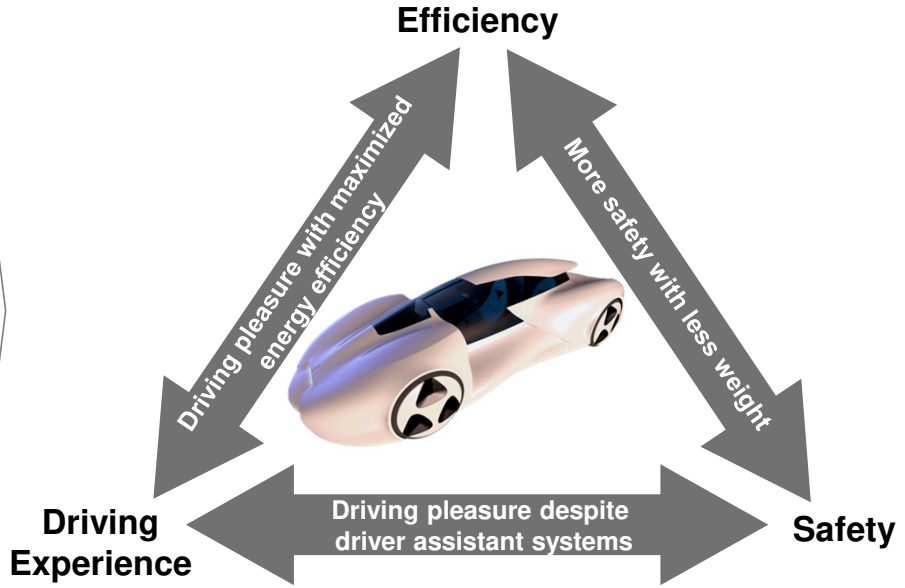
Strategy & Consulting fka

Environmental Protection, Urbanization und Cultural Change will shape future research topics…

Megatrends in the Automotive Industry

Outlook

- Research for upcoming generations of vehicles will concentrate on improvements in **EFFICIENCY** and **SAFETY** while having a high quality **DRIVING EXPERIENCE.**



- The **CO_2 legislation** demands a significant **increase in efficiency**, that can be achieved e.g. due to **electrified vehicle concepts**.
- Central question: What are the **implications** for vehicle manufacturers and especially the **supplier industry**?

Image sources: fka, FZ Jülich, PIXELIO

CO_2 and Fuel Economy Legislation is embedded in regulatory landscape which includes some target conflicts

Safety regulations

Autonomous driving regulations

Focus

CO_2 and Fuel Economy

- National and international **regulations** concerning CO_2-emissions

- Different **driving cycles** for CO_2-emission testing
  - Europe switches to **WLTC** test cycles
  - USA testing is simultaneously based on **two different cycles**
  - European and Japanese regulations are based on **vehicle mass**, while American regulation bases on the **vehicle's footprint**

Emissions

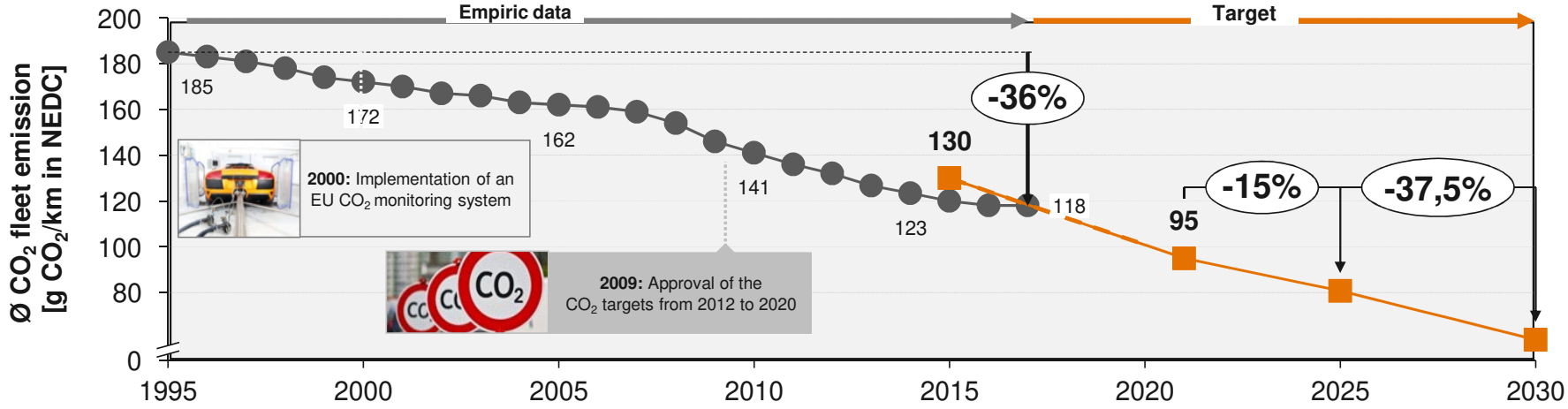
- National and international regulations concerning **NOx, CO, xHC and Particle emissions**
- Europe introduces **Real Drive Emissions (RDE)** as binding test procedure

Governmental incentives & regulations

Image source: AVL, Nevada DMV,

Future CO_2 targets for OEM now fixed: -37.5 % until 2030, compared to 2021!

Future CO_2-regulations



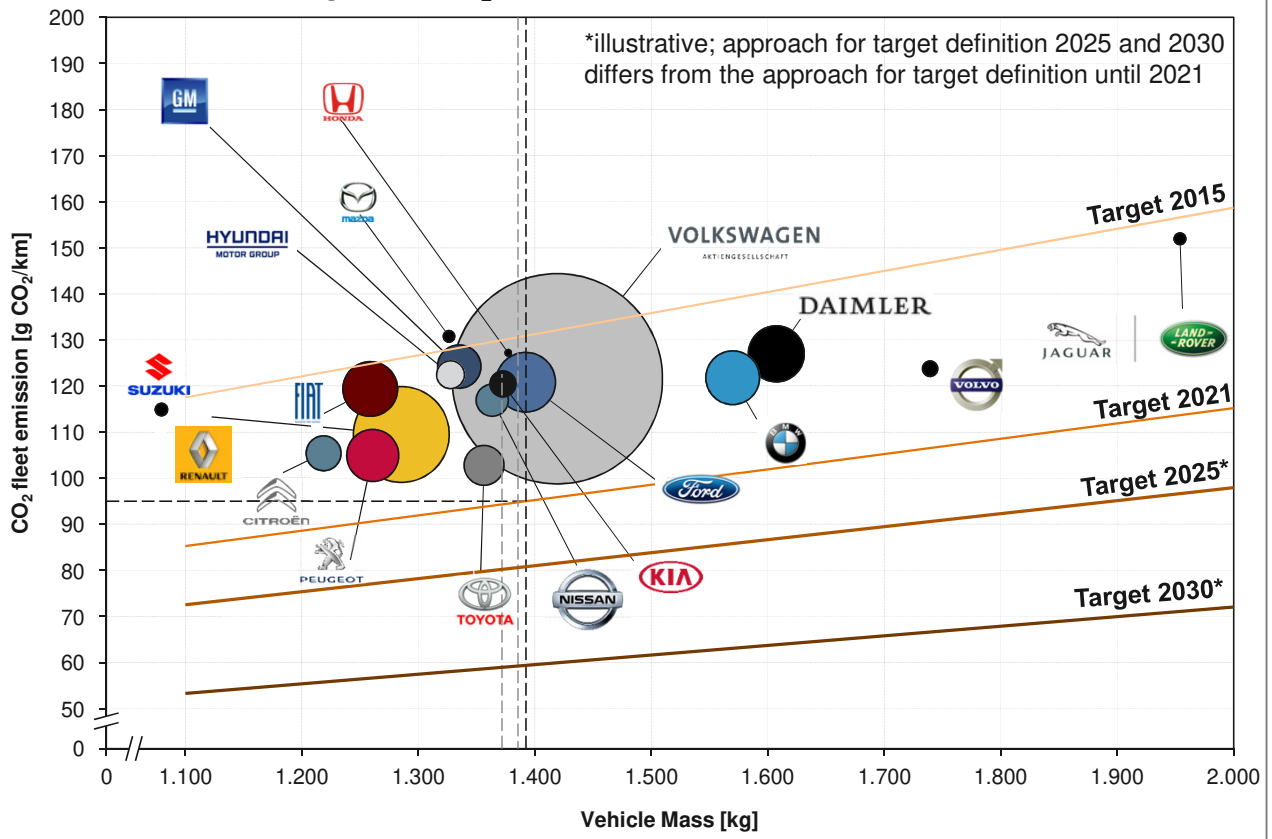
- **Reduction of 15% (2025) and 37,5% (2030) respectively**
- Switch to WLTP testing cycle in 2020 **does not** necessarily lead to an increase of target values

Conclusion

- CO_2 target values for 2025 and 2030 **defined** by EU Commission **to be formally approved: 15% reduction for 2025, 37,5 % reduction for 2030, Base: Measured CO_2 emissions per OEM in 2021.**
- **The European legislation is formulated "technology neutral", but includes some incentives for BEV and PHEV**

Target compliance is highly challenging, even regarding the 2021 legislation

Status Quo of Passenger Car CO_2-Emissions in the EU (2017)



Delta to Targets

	2021		2030	
	[g CO_2/km]	[%]	[g CO_2/km]	[%]
JLR	-38,2	-25,2 %	-95,0	-62,7%
Suzuki	-30,3	-26,4 %	-73,3	-63,9%
GM	-31,1	-25,1 %	-77,6	-62,6%
Honda	-32,7	-25,7%	-80,4	-63,2%
Ford	-28,8	-24,1 %	-73,6	-61,6%
VW	-25,7	-21,1 %	-71,4	-58,6%
Daimler	-24,8	-19,6 %	-72,2	-57,1%
BMW	-20,9	-17,1 %	-66,7	-54,6%
Toyota	-9,0	-8,7 %	-47,8	-46,2%
EU avg.	**-23,2**	**-24,7 %**	**-58,4**	**-62,2 %**

Non-compliance fees are ruinous!

If Volkswagen **did not lower their emissions further**, they would have to pay **€ 8,6 bn / y.** from 2021 on!

25,7 g CO_2
* 95 € / g CO_2
* 3.540.000 vehicles / year

8.642.910.000 € / year

Key learning

CO_2 targets will be drastically tightened, imposing extreme challenges to OEM!

- ***What is the favored / ideal technological option?***

Facing the CO_2 requirements, OEM are heavily promoting electric mobility

Mercedes-Benz

"We **intensively work on increasing the rate of electric vehicles** up to 20 percent of production in 2025. We oblige ourselves to this task **and are convinced that we succeed"**

In 2025, 15 to 25 percent of our sales should be electric and plugin hybrid vehicles."

"Volkswagen Konzern will bei Elektromobilität bis 2025 weltweit führend werden. **Roadmap E:** In **2025 könnte jedes vierte neue Fahrzeug des Konzerns rein Batterie-elektrisch angetrieben sein."**

20 new electric driven models until 2023**. "We believe in the all electric future"**

Ford

Categorical concentration on **autonomous driving and electro mobility**.

Foundation of subsidiary for the development of battery electric vehicles
"The new organizational structure supporting **electric vehicles** is **part of our future"**.

TOYOTA

TESLA

"**In 10 years, more than a half of new vehicle production is electric** in the United States"

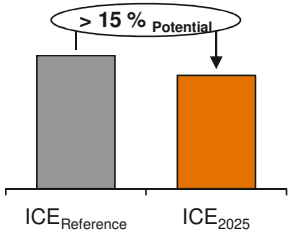
A significant electrification of the fleet is planned by all OEMs. Vehicle with electrification are a essential for their fleet strategy

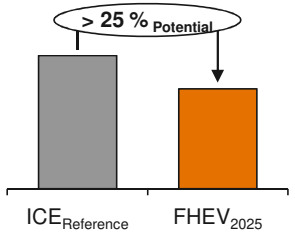
This strategy is backed up by the tailpipe CO_2 potentials of electrified vehicles.

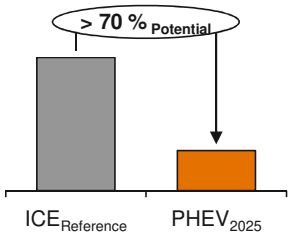
Example of optimization potential for a middleclass car by the year 2025

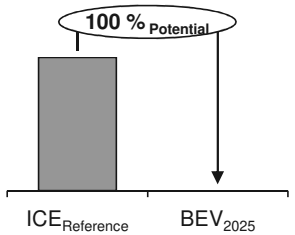
OEM perspective

- High potential for drive efficiency, even for powertrains with combustion engine.









Customer perspective

- **From an end costumer perspective only economic and "useful" technologies are critical factors for purchasing decision.**
- **Examples for critical factors:**

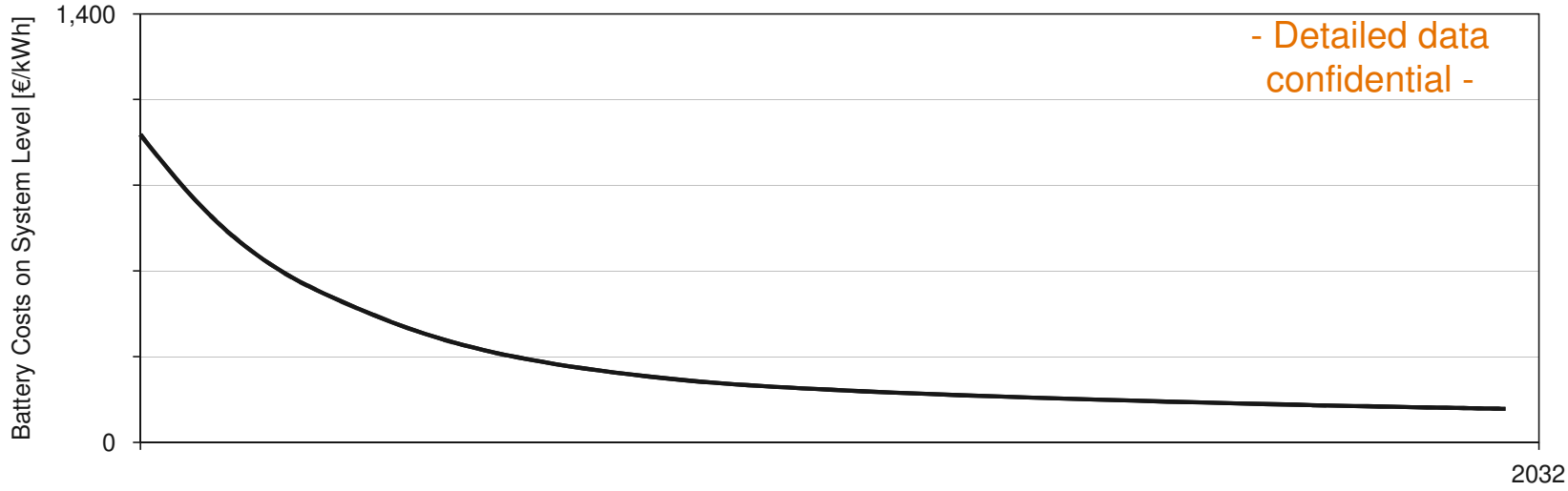
Challenges/ prospects

- Main challenge is cost efficiency
- Almost all CO_2- target values are possible technologically but **might not be feasible economically.**
- **Purchase decision from a customer perspective based on usability.**
- **Electrified powertrain variants** and **connectivity** have positive system based correlation and therefore **increase** the **customer benefits.**

Further progress regarding performance and costs of battery systems, but specific thresholds persist.

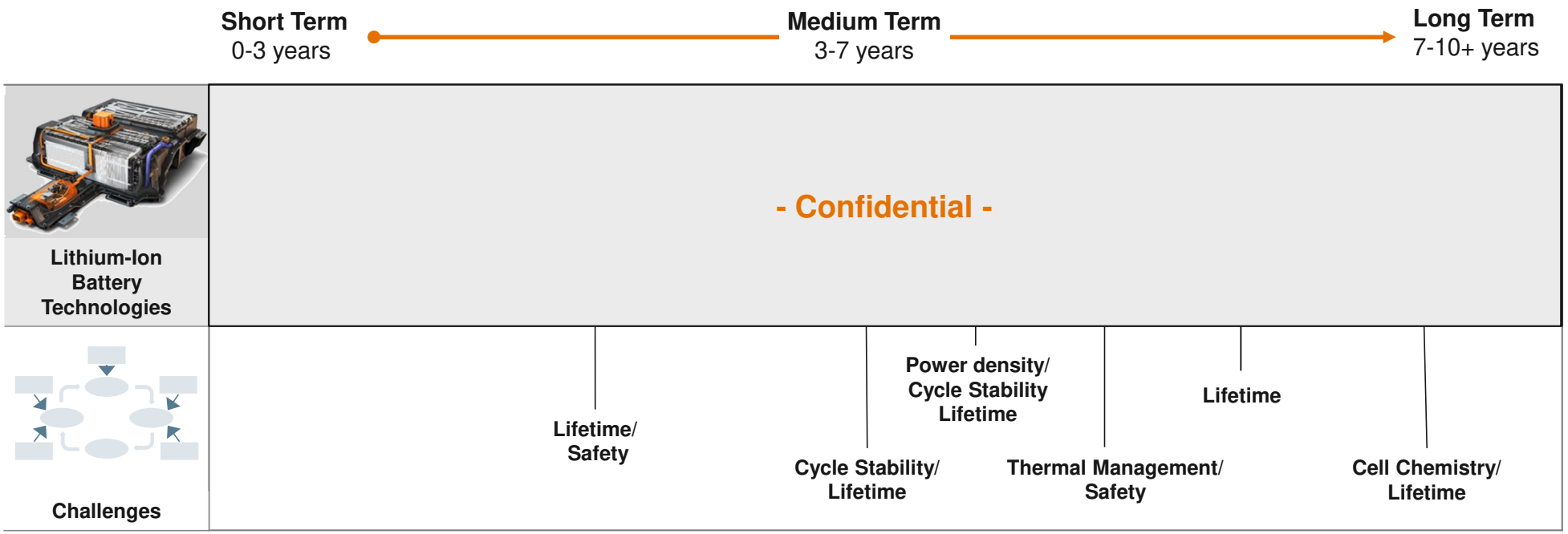
Cost Development of Battery Prices – Meta Analysis

- Li-Ion battery system costs will continue to fall, however battery system costs below 100 € / kWh on system level may not be reached even on the long term due to volatile raw material prices
- New battery generations (e.g. solid state battery) are promising, but still far away from series application



Electric mobility will remain challenging from a cost perspective.

Challenges have to be solved to bring new battery generations to the market.



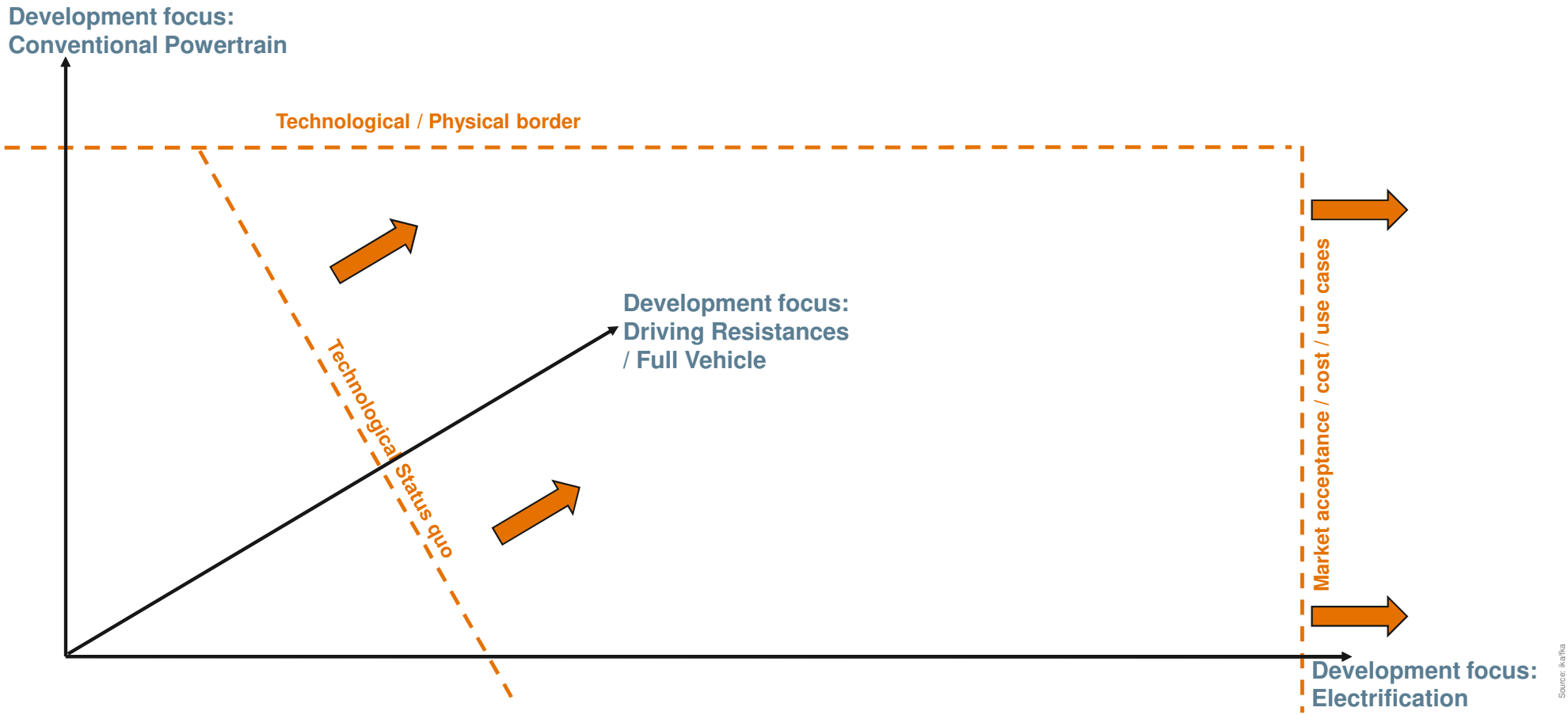
New battery generations are on the horizon, but the development remains an evolutionary process.

Key learning

Obviously, the technological answers are not that easy!

- ***So how will the technological landscape look then?***

OEM use a multi-faceted strategy regarding powertrain technology to improve efficiency.



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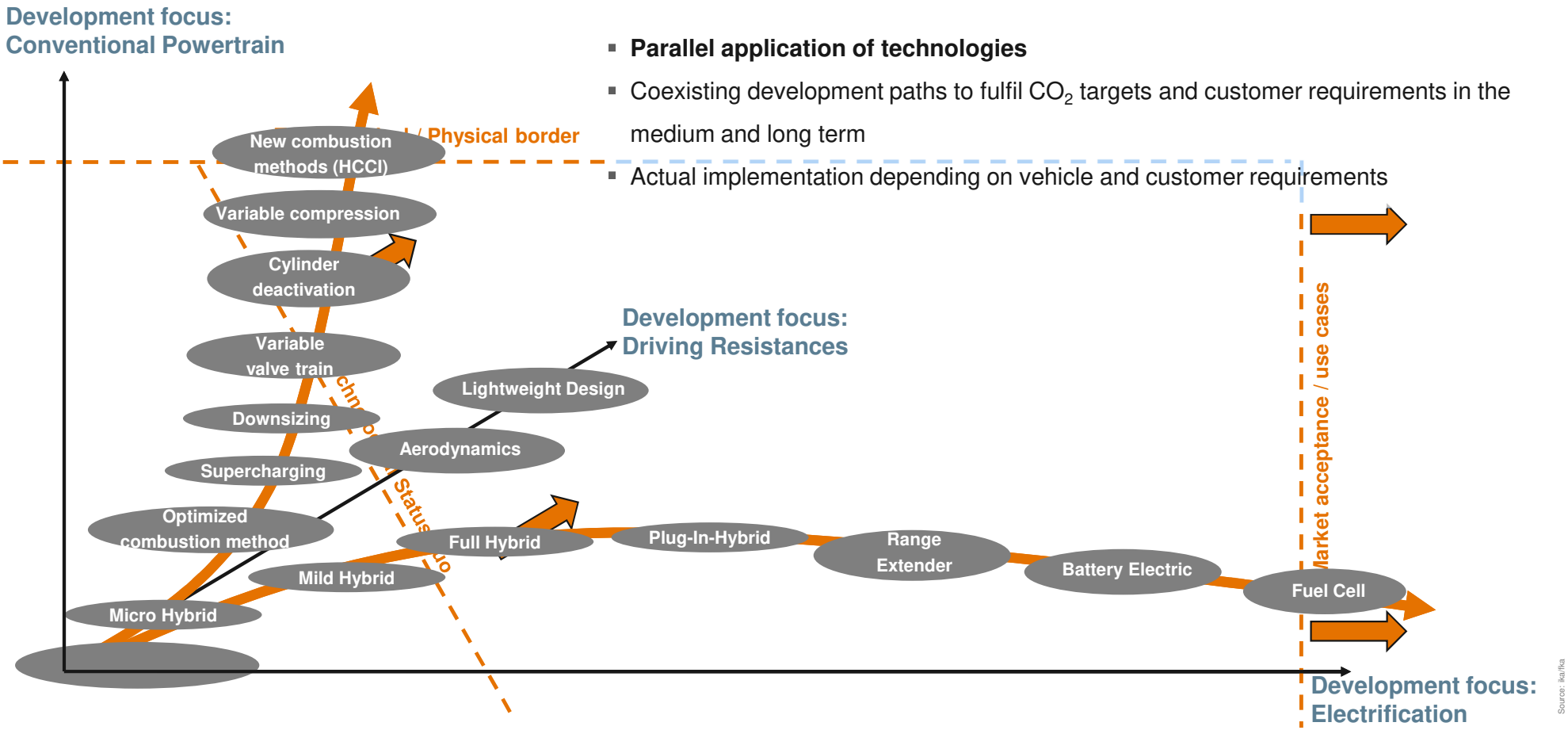


- **Parallel application of technologies**
- Coexisting development paths to fulfil CO_2 targets and customer requirements in the medium and long term
- Actual implementation depending on vehicle and customer requirements

Key learning

At least in the medium term, there will be a diversified technology strategy!

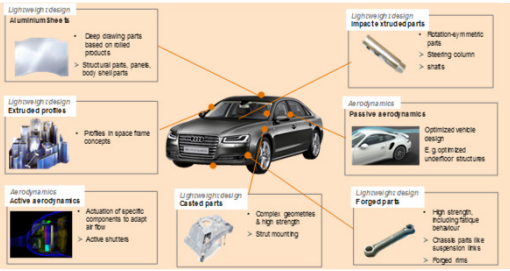
- ***So what's in there for material specialists?***

Three basic questions for material specialists

1

Implications on component level

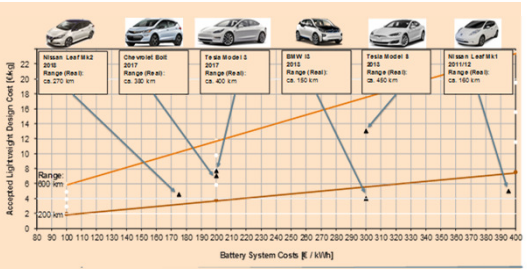
- How does the technology strategy of the OEM influence the demand for and the design of components?
- How can specific components contribute to the CO_2 reduction



2

Implications on full vehicle level / lightweight design

- How does the general demand for lightweight design solutions change in the context of the preferred technology strategy?



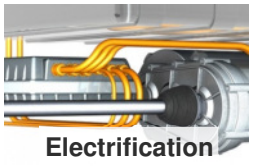
3

Change of evaluation criteria for materials

- Are there new requirements, in addition to the traditional performance, mass and cost parameters?

Largely material driven solutions in the conventional drivetrain

Trends / drivers



Technology examples: Conventional drivetrain

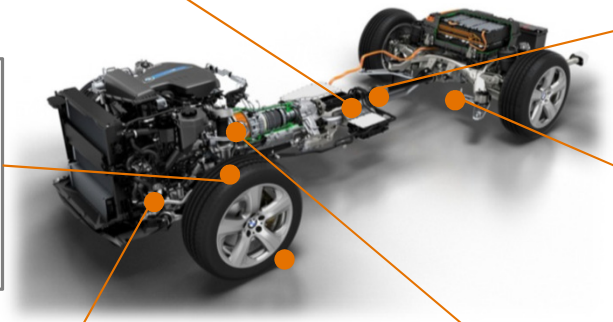
Exhaust gas treatment

SCR Technology

- Efficient removal of NO_x
- Engine in favorable operating point
- No increase of exhaust gas back pressure

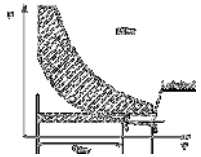
Particulate filter

- Efficient reduction of particulate mass and number
- Compliant with emissions limit Euro 6c, especially for direct-injection diesel- and gasoline engines



Combustion methods

Miller cycle



- Extended expansion within partial-load range
- Increased efficiency

Innovation / Driving dynamics

Torque-vectoring-differential

- Active torque distribution
- Higher curve speed

Lightweight & Friction Reduction

Pistons

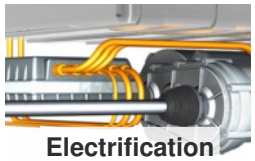
- Higher resistance
- Enables higher specific power
- Weight reduction

Turbocharging

- Conventional turbo or e-booster
- Responsiveness
- Elasticity
- Lightweight for minimization of turbo lag

Measures on the full vehicle to reduce driving resistances

Trends / drivers



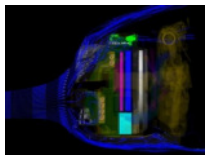
Lightweight design
AluminiumSheets

- Deep drawing parts based on rolled products
- ➢ Structural parts, panels, body shell parts

Lightweight design
Extruded profiles

- Profiles in space frame concepts

Aerodynamics
Active aerodynamics



- Actuation of specific components to adapt air flow
- ➢ Active shutters

Lightweight design
Casted parts

- Complex geometries & high strength
- ➢ Strut mounting

Lightweight design
Impact extruded parts

- Rotation-symmetric parts
- ➢ Steering column
- ➢ shafts

Aerodynamics
Passive aerodynamics

Optimized vehicle design

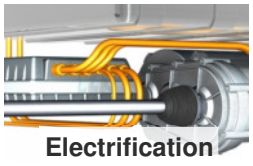
E.g. optimized underfloor structures

Lightweight design
Forged parts

- High strength, including fatique behaviour
- ➢ Chassis parts like suspension links
- ➢ Forged rims

For electrified vehicles, the battery case turns out to be the key component for material specialists.

Trends / drivers



Thermal runaway

Packaging

NVH

Thermal management

Implications of future cell chemistries

Vehicle integration

Lightweight design

Safety

Production costs

Crash & Crush

Sealing

Recyclability

Corrosion

Battery System Mercedes-Benz EQC

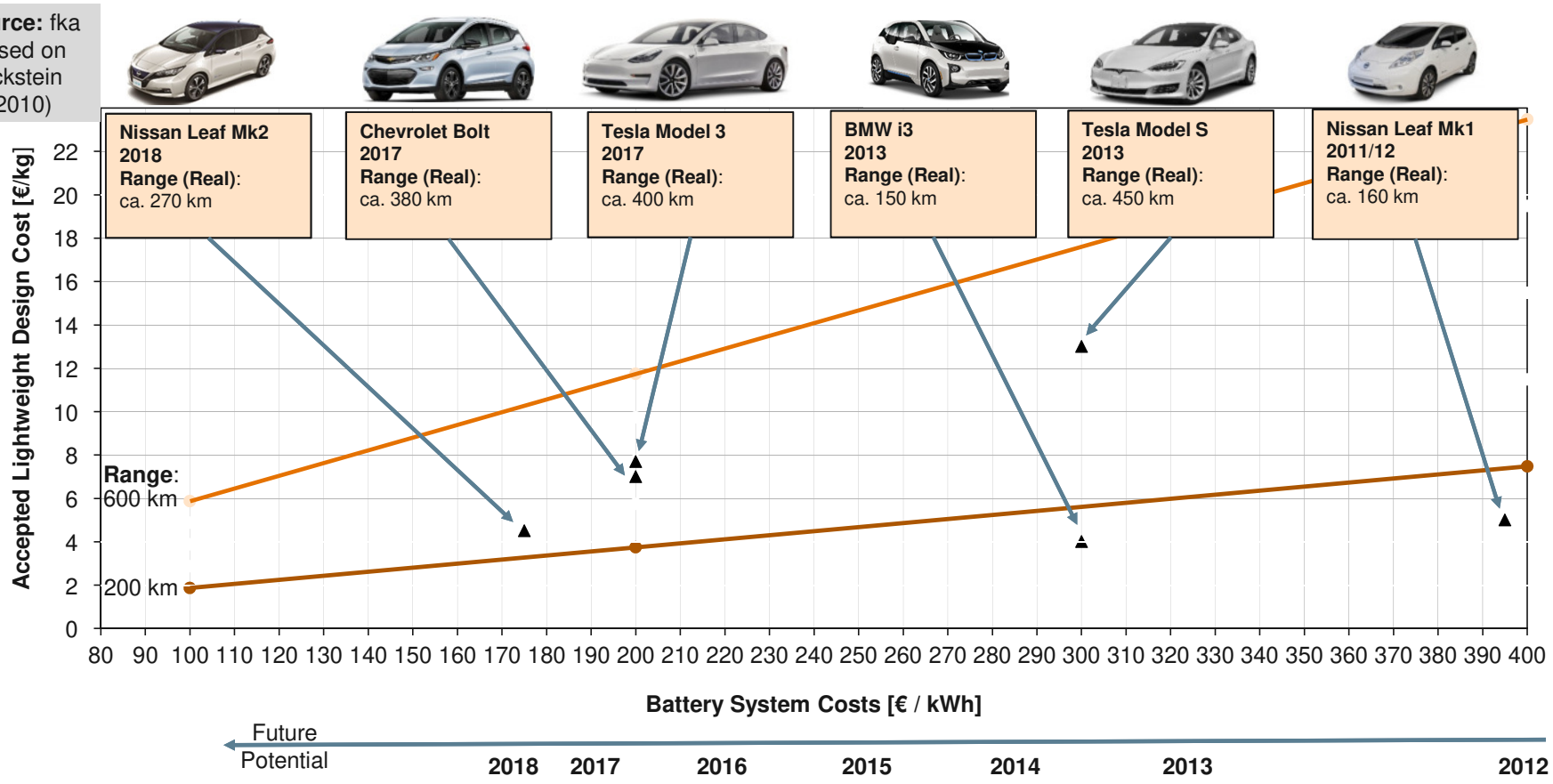
Key learning

All technology paths offer a wide range of applications on component level!

- ***But with a focus on lightweight materials, doesn't their relevance decrease in the context of electrification and recuperation capabilities?***

OEM face a trade-off between battery and lightweight design costs. Therefore, LWD has to keep up with cost efficiency improvements.

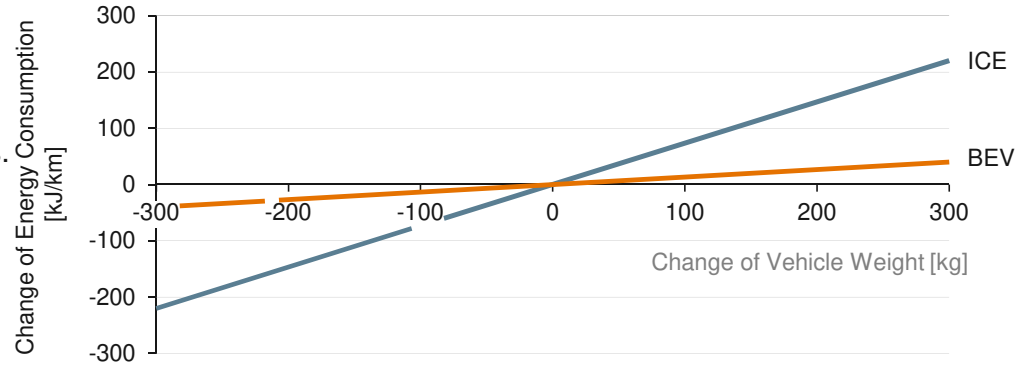
Source: fka based on Eckstein (2010)



Because of further vehicle development criteria, lightweight design will stay relevant for electrified vehicles

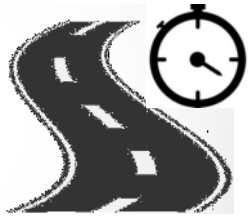
Energy Efficiency

- Indeed, lightweight has a less direct impact on energy efficiency of electrified vehicles due to their energy recuperation capabilities.
- Thus, the **lightweight design pressure** theoretically **decreases from a pure efficiency perspective.**



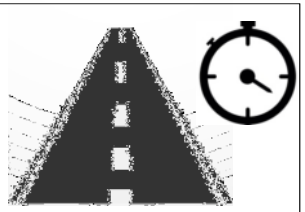
Lateral Dynamics

- Lightweight design enables **better driving dynamics** and increases **driving safety and comfort**
- **Fewer driver assistance system interventions needed.**
- **Lightweight design stays relevant** regarding customer requirements



Longitudinal Dynamics

- Lightweight design **reduces the power** to be **provided by the drivetrain** – regardless the concrete powertrain type.
- **Lightweight design** is n**ecessary** to **fulfill costumer requirements** concerning **acceleration capabilities** and **longitudinal vehicle dynamics**
- **Lightweight design stays relevant** regarding customer requirements



Key learning

Lightweight design will stay relevant even for electrified vehicles!

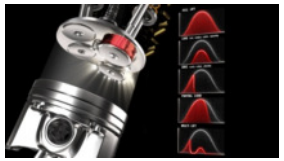
- ***But are there new requirements that may become more relevant in future?***

In the long-term, life cycle assessment could be a game changer for technological decisions

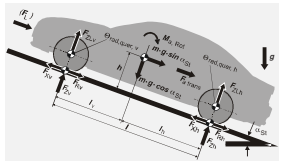
- Art. 7 (8): “The Commission shall **no later than 2023** evaluate the possibility of developing a common Union **methodology for the assessment** and the consistent **data reporting** of the **full life-cycle CO_2 emissions** of light duty vehicles that are placed on the Union market. The Commission shall transmit that evaluation, including where appropriate proposals for **follow-up measures, such as legislative proposals**, to the European Parliament and the Council.”

Vehicle development

- **Efficiency improvement of the energy conversion:**
  - Engine measures
  - **Electrification of the drivetrain**
  - Auxiliary users optimization



- **Reduction of the driving resistances:**
  - Rolling resistance
  - Aerodynamic optimization
  - **Lightweight design**

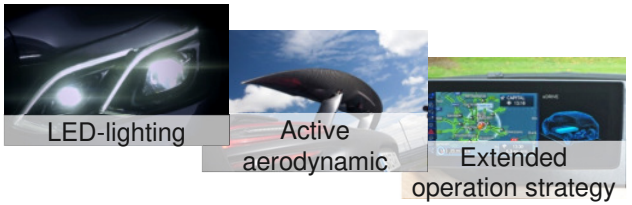


Vehicle production

- **Material:**
  - Steel, aluminium, composites
- **Production process:**
  - Cast, forming, hardening, assembly, ...
- **Joining process:**
  - Assembling, pressing, welding, bonding, screws, rivets, ...
- **Location:**
  - Europe, America, Asia, ...
- **Transportation route**
- **Recycling:**
  - Decomposability, material separation, ...

Vehicle use

- Driver behavior (dynamic – conservative)
- Environmental factors
- Air Conditioning
- Partly captured via „Eco innovations “

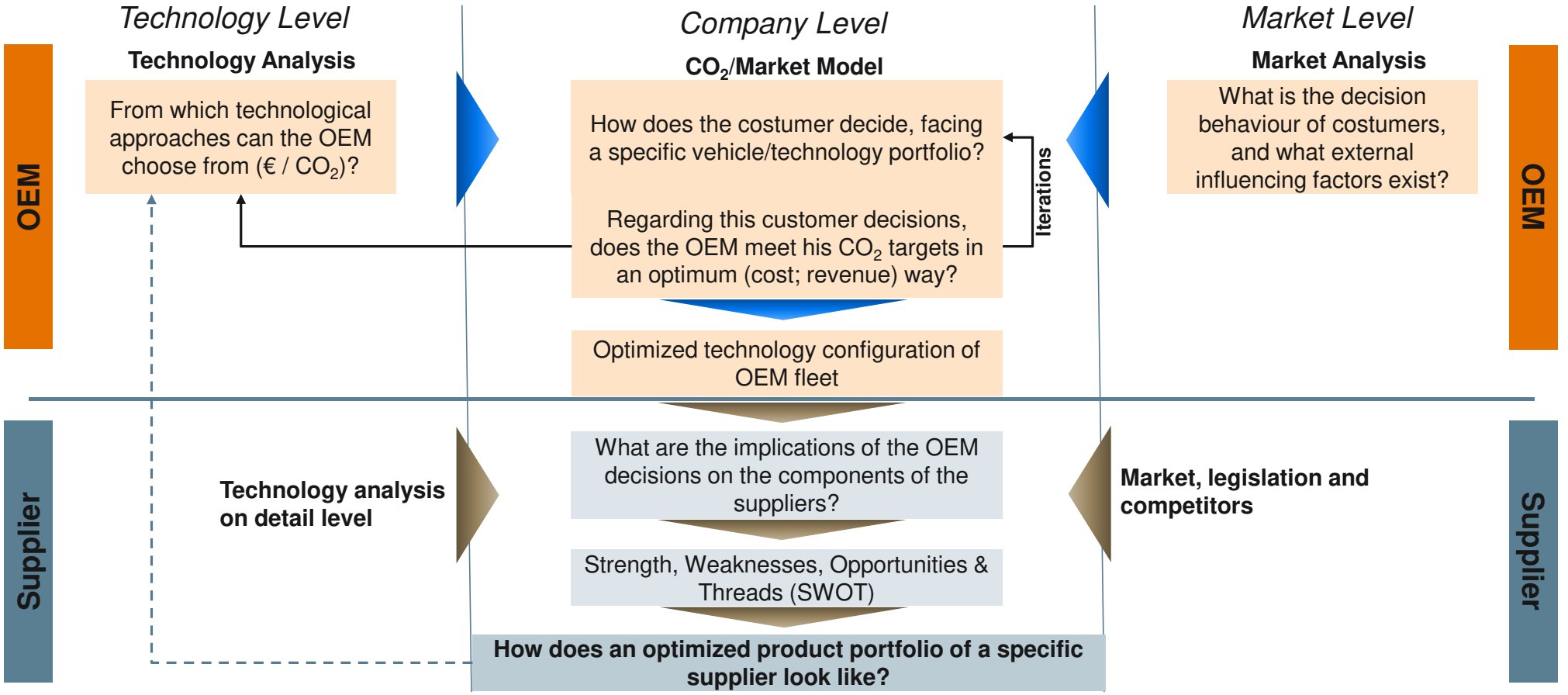


Key learnings / Summary

CO_2 targets are extremly tightening and challenging.
Electrification is an ideal solution, but development is evolutionary.
Thus, a variety of technologies will persist.
Chances for material specialists on component and system level in all technology paths.
Lightweight design stays relevant also in the context of electrification.
Lifecycle assessment (LCA) is drawing more attention, even from the legislator.

- Anticipate developments precisely on the level of detail required for each player?
- How to react to this development as a specific player?

Integrated methodology to optimize supplier product portfolio strategies with a focus on future CO_2 targets



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