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AffordabLe LIghtweight Automobiles AlliaNCE

Accelerating the decarbonisation of transport

Roadmap on the future of European lightweighting

FINAL EVENT, September 19th 2019

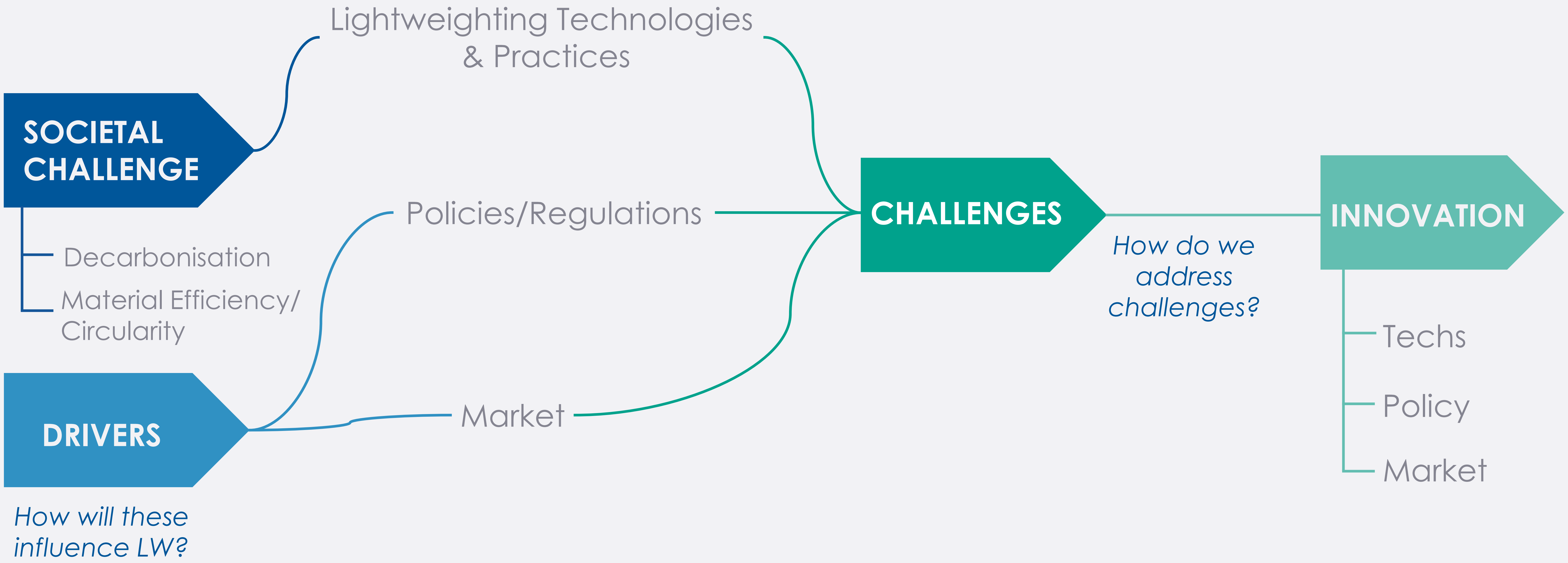
Marcos Ierides; **Bax & Company**

Agenda

Methodology

Methodology

From Societal Challenge to Innovation



How do we address the challenges while taking the influence of the drivers into consideration?

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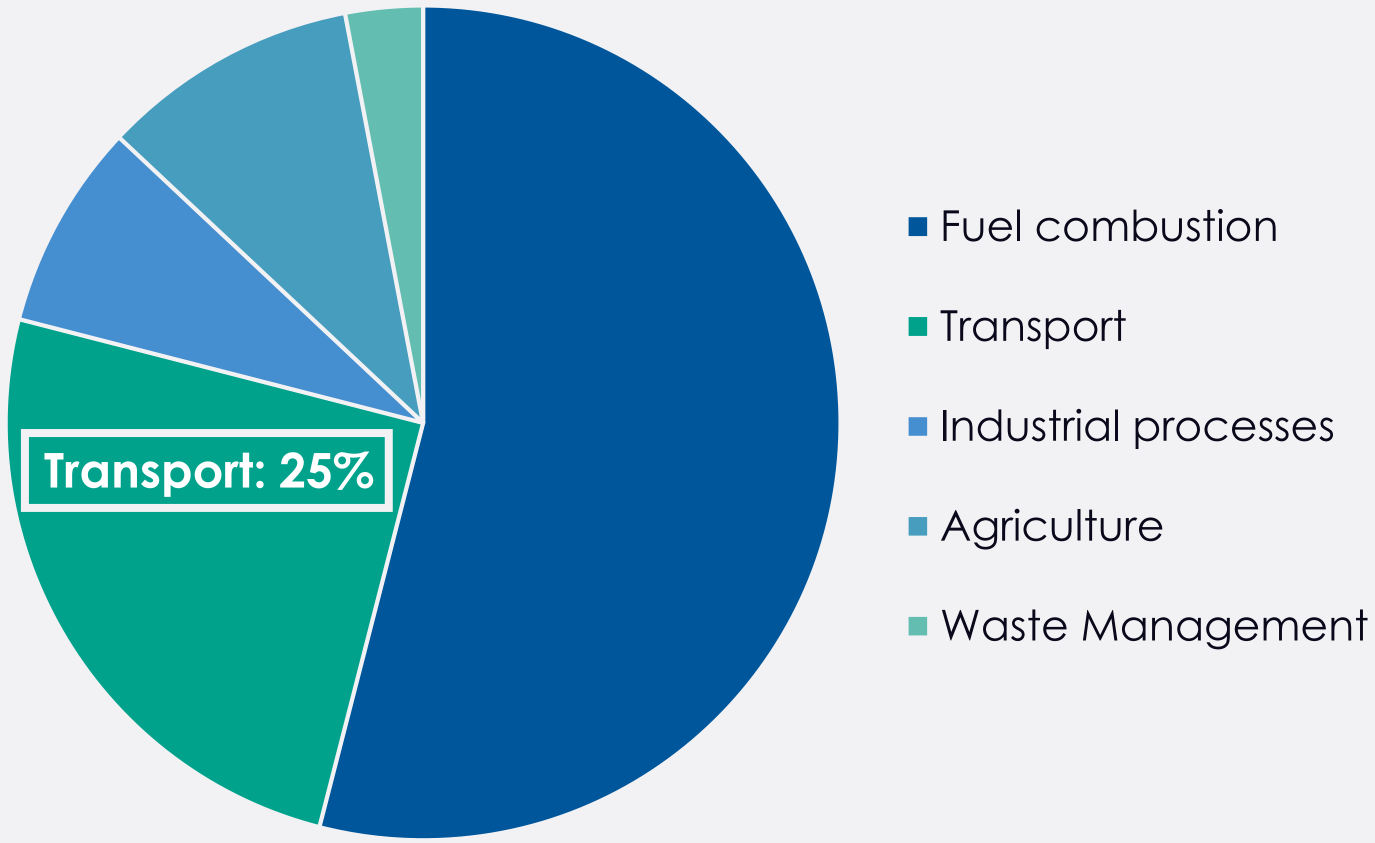
Methodology

Who and how where they involved

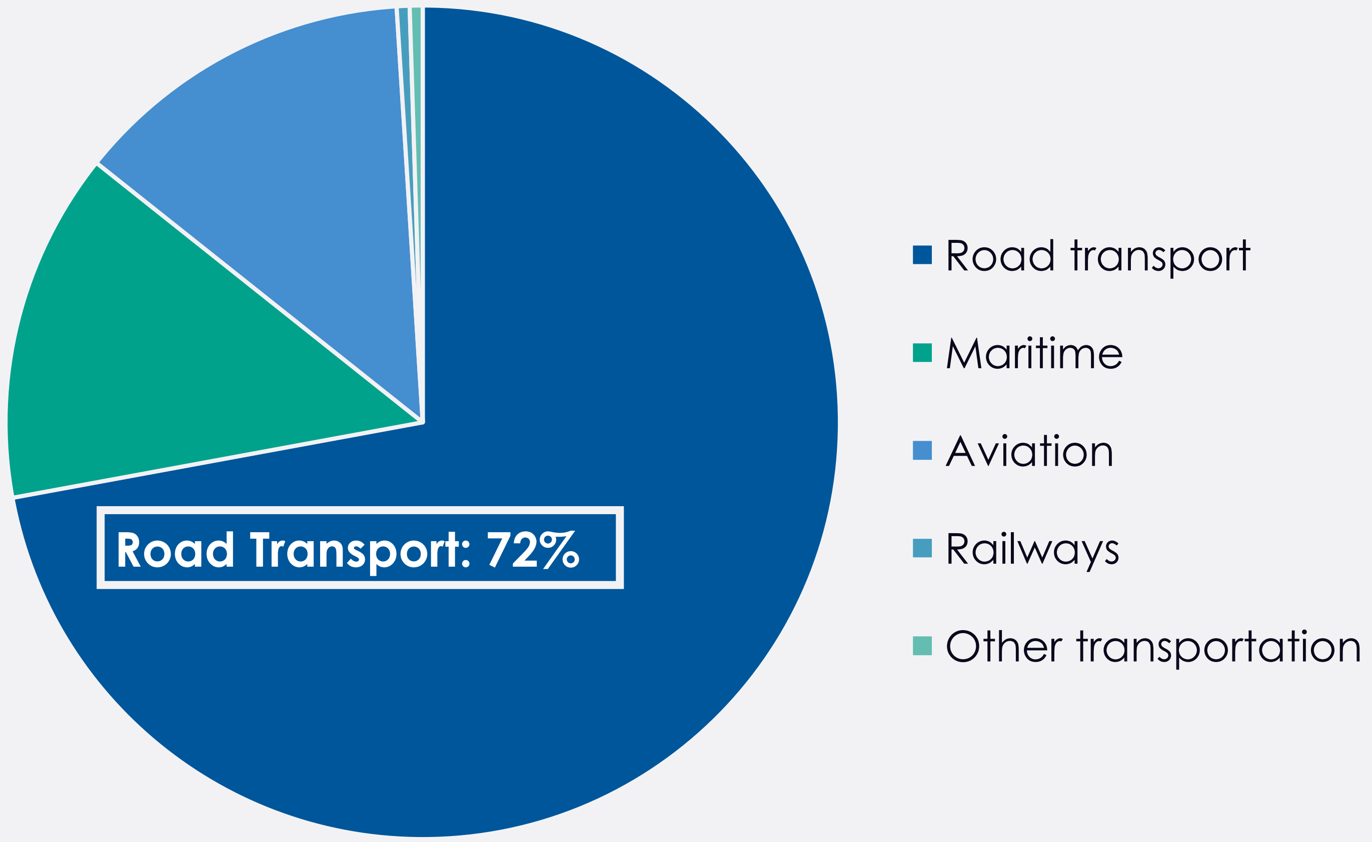
The bigger picture

Background
The bigger picture

GHG emissions shares in the EU (2017)



Share of total emissions by activity



Share of transport emissions by transport mode

Background
From UN Sustainable Development Goals to Automotive Lightweighting

UN Sustainable Development Goals

The 2030 Agenda for Sustainable Development highlights transport as important cornerstone.

Paris Climate Agreement

The signees recognize that the transport sector plays a particularly important role in the achievement of the **2-degree target.**

EU decarbonisation targets

The 2050 long-term vision aims to achieve **net-zero greenhouse gas emissions**.

Clean mobility "by means of alternative transport, connected and automated driving and the roll-out of electric and alternative fuels vehicles" is highlighted.

Emission targets around the globe

A drive towards lighter cars

2015

National Emission Ceilings Directive
(130 gCO_2/km)

CAFE standard
(39.5 miles per gallon)

CAFC standard
(6.9 liters per 100 km)

2020

National Emission Ceilings Directive
(95 gCO_2/km)

CAFE standard
(48.5 miles per gallon)

CAFC standard
(5.0 liters per 100 km)

2025

Provisional agreement:
15% less CO_2 emissions compared to 2021

CAFE standard
(54.5 miles per gallon)

2030

Provisional agreement:
37.5% less CO_2 emissions compared to 2021

2050

2050 Long-term strategy
net-zero emissions

- EU **emission** regulations
- U.S. **fuel economy** regulations
- China's **fuel consumption** regulations

Beyond the National Emission Ceilings Directive:

- Agendas of European member states vary significantly
- Increasingly stricter implementation at city level (e.g. vehicle bans)

Sustainable production and circularity
EoL Vehicles Directive

Purpose:

- Make dismantling, recycling and reusing more environmentally friendly
- Minimize the presence of hazardous substances, to enable re-use and recycling.

2015 **targets** under the Directive seem to have been met:

95%
reuse & recovery

85%
reuse & recycling

Substantial reduction of hazardous substances

Beyond the EoL Vehicles Directive: *Review by 31 December 2020*

- Circularity targets will be on a more sophisticated level. This will require specific data on the environmental performance throughout the lifecycle.

Lightweighting often suggests a multi-material approach

But multi-materials solutions may not be optimal in terms of circularity

National Emissions Ceilings Directive

A drive towards lighter cars

Multi-material approach

offering optimum GWP emission reductions

vs.

EoL Vehicles Directive/ Circularity Targets

A drive towards easy-to-dismantle and recyclable cars

Few-materials approach

offering favourable end-of-life options/ circularity performance

Lightweighting – What has been achieved?

What has been done

EUCAR endorsed initiatives in Europe go way back

2005 — SuperLightCar

2005-09, *FP6*
19 M€, 37 partners

- **VW Golf Mk 5**
- **- 39% BiW Weight using: Al (53%), Steel (36%), Mg (7%), Plastics (4%)**

2010 — elva

2010-13, *FP7*
5 M€, 7 partners

- **Expand potential of vehicle architecture**

HIVOCOMP

2010-14, *FP6*
16 partners

- **Cost effective use of PU and PP matrices**
- **High volume production**
- **Tech-demonstration**

2012 — ALIVE

2012-16, *FP7*
13 M€, 23 partners

- **4 years to mass production**
- **-35% vehicle weight**

ENLIGHT

2012-16, *FP7*
11 M€, 21 partners

- **8-12 years horizon years**
- **-45/50% Weight (BiW)**

2013 — urban-ev

2013-16, *FP7*
3.6 M€, 10 partners

- **Hybrid material architectures**
- **Off-the-shelf technology**

epsilon

2013-16, *FP7*
12.5 M€, 9 partners

- **Novel body architecture – focus on comfort, safety, efficiency**

NewSpec

2013-16, *FP7*
13 partners

- **Low cost production of CF from PE precursors**
- **Pilot plant facility**

2014 — FS www.Fibralspec.net

2014-17, *FP7*
11 partners

- **New CF precursors**
- **Modelling and testing in LC**
- **Industrialisation of final CF composite**

carboprec

2014-17, *FP7*
14 partners

- **Low CF precursors from lignin and cellulose**
- **Medium mechanical performance**
- **New tech development**

2016 — alliance — AffordabLe LIghtweight Automobiles AlliaNCE

2016-19, *H2020*
9 M€, 10 partners

- **6 years to mass production**
- **-25% vehicle weight reduction**
- **<€3/kg saved**

2019

Europe: The largest market for automotive lightweight materials:

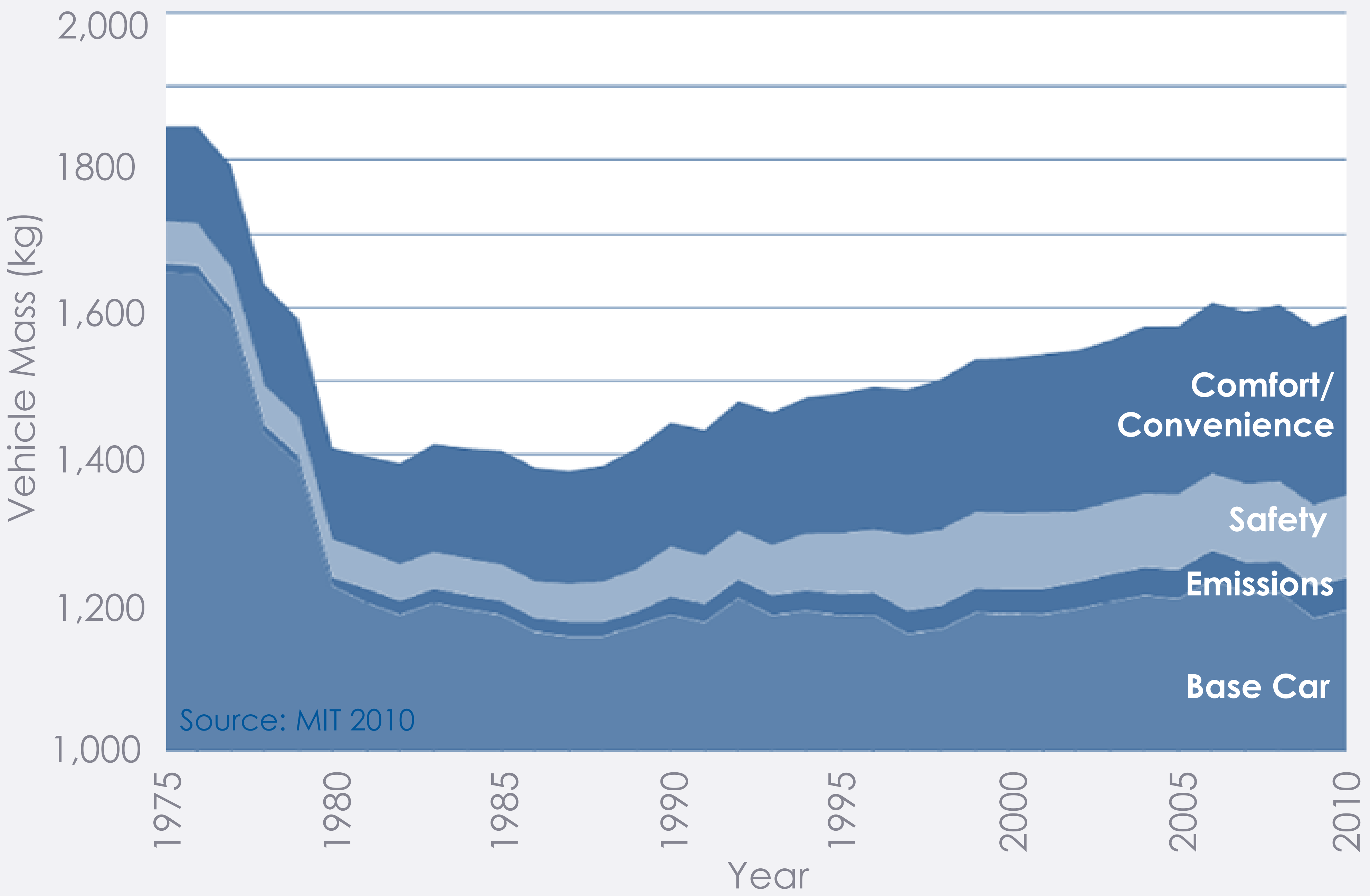
- Market growth in Europe is driven by investments of manufacturers and suppliers in the development of new and advanced lightweight materials

What has been achieved

The Evolution of Lighweighting Efforts and Vehicle Mass

- Although lightweighting efforts increased significantly **the mass of the base car** was **almost unchanged** since 1980
- The **total vehicle weight even increased** due to the integration of entertainment and safety features and measures to reduce exhaust emissions
- **Safety regulations** and **consumer preferences** for more spacious and comfortable cars led to increased vehicle sizes

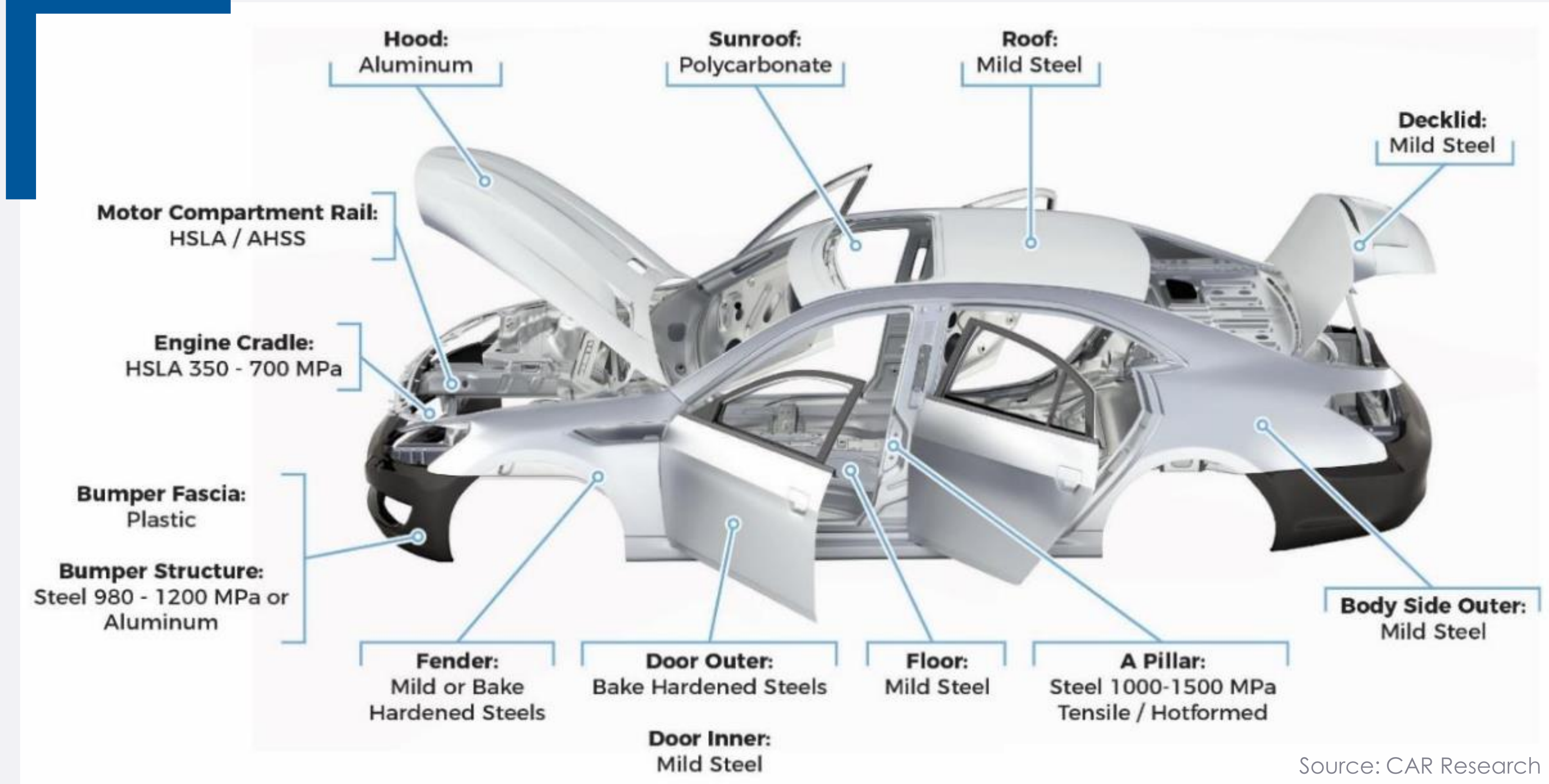
Passenger Car Mass (1975-2010)



Lightweighting – an ongoing success story

Solutions in mass-produced mainstream cars

- At present, BIW material composition of an average passenger vehicle consists of a mix of various grades of **steel, aluminium** and **plastics**
- Applications for **composites** have become more prevalent at the upper end of the market
- Plastics represent about **50% of the volume** of today's vehicle but only about **10% of the weight**
- Success Story: SuperLightCar demonstrated a **reduction in the body weight of up to 35%** compared to the reference model
- Success Story: ALLIANCE achieved a **reduction of GWP by 24%** on average for the demonstrator modules



Source: CAR Research

Although the multi-material approach is highly discussed, promoted and invested in, metals and here mostly steels are today still the predominant material choice!

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Is Lightweighting still relevant?

The impact of future mobility trends

A shared, electrified and autonomous future

Shared mobility

Alternative power trains/ Electrification

Autonomous Driving/ Connectivity

How will we move people and goods in the future?

Are lightweight efficient cars still necessary in a 100% RES energy scenario?

What will the architecture of tomorrow's vehicles look like?

Will we see less cars on our roads?

Who will own the car in the future?

Will the car of the future have a (much) higher lifetime mileage?

What crash requirements will materials have to comply with?

What kind of lightweighting will be needed?

The impact of future mobility trends

A shared, electrified, autonomous and ***light*** future

Shared mobility

- Lifecycle impact changes: Counterbalancing higher utilisation (high use-phase impact of materials with high lightweighting potential)

Alternative power trains/ Electrification

- Counterbalancing additional weight of battery and battery protection
- Lifecycle impact changes: Counterbalancing CO_2 impact of battery manufacturing
- Reduce weight to reduce energy consumption to increase range

Autonomous Driving/ Connectivity

- Entertainment & information systems add weight: lightweight materials can partially compensate for this
- Need for multi-functionality of materials/ components leads to a shift in material preferences
- Lighter vehicles have better emergency brake performance at equal braking force

Lightweighting dilemmas

Lightweighting dilemmas

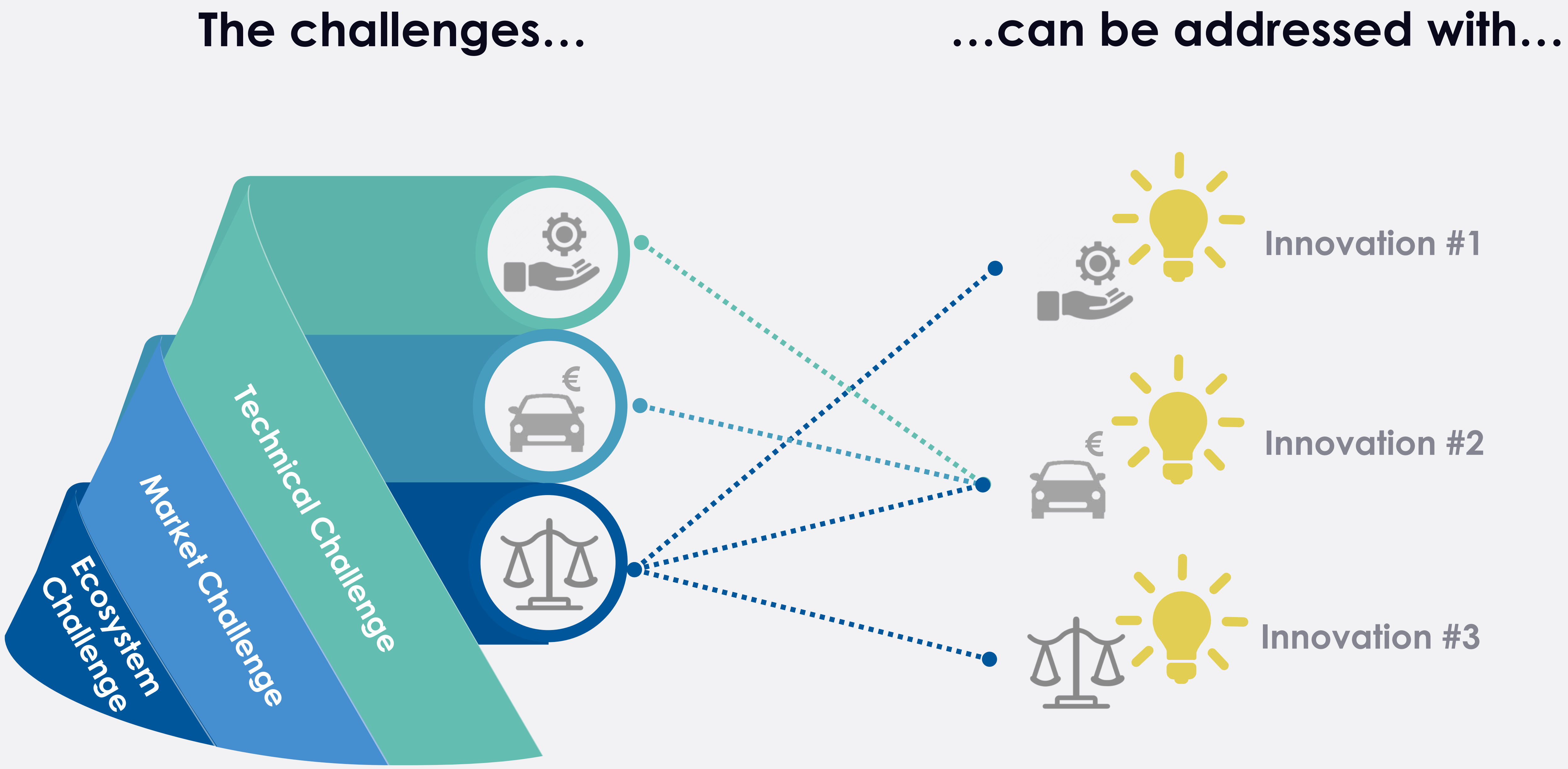
Controversies, discussions and uncertainties

- Multi-materials vs. ease of recycling
- Regen braking may reduce benefit of lightweight in cities?
- Heavier cars perform better during a crash
- Longer lifetime mileage increases use phase impact
- Impact of mixes of bio-based and fossil-based materials
- Biodegradable vs. non-biodegradable biomaterials
- Consumer preferences for spacious cars

Innovation actions under the microscope

Scoping Lightweighting

From Challenges to Innovation



Addressing the challenges while taking the influence of the drivers into consideration.

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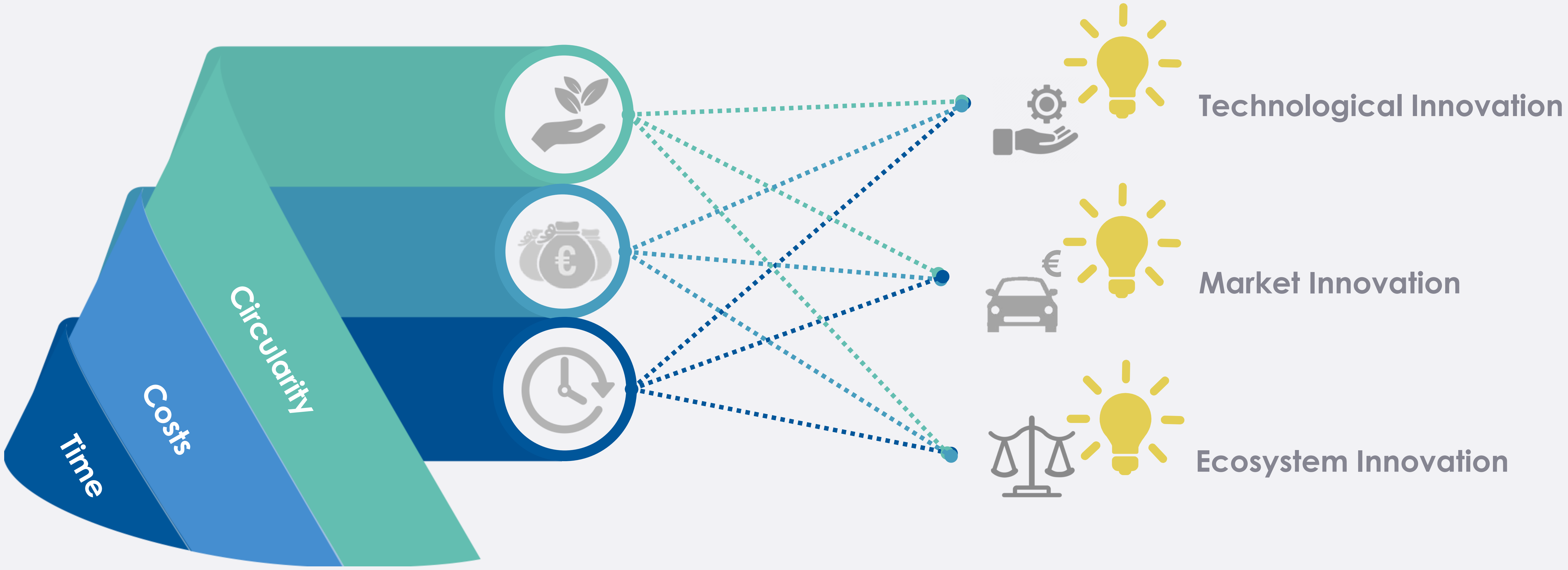
Scoping Lightweighting

From Challenges to Innovation

The challenges… | **…can be addressed with…**



Addressing the challenges while taking the influence of the drivers into consideration.

Challenge

Affordability remains an issue for many lightweighing solutions

The highest performing lightweight solutions suffer from high **raw material prices**, high **manufacturing costs** (tooling, equipment, machinery) and **long cycle times** (process and delay times) leading to overall higher costs in comparison to traditional solutions

- Innovate **raw materials processing** and **component shaping technologies**:
- **Simulation and semi-automated generation and assessment of design alternatives** allow to quickly and efficiently design, test, and validate new concepts that can go beyond basic material replacements
- Optimize production processes (increased level of **automation**, **agile production** lines, planning support tools)

- Enable **collaboration between stakeholders** to address some cost challenges (e.g. common digital interfaces, standardized material composition and material/process qualification processes)
- Enable the **use of secondary materials**: Develop new business models by coupling the return-to-producer principle with closed-loop recycling wherever possible

- Promote the **certification of secondary raw materials** (e.g. aluminium)

Optimized materials and processes to lower costs

Example: Composite materials with high lightweighting potential

What's challenging:

- High **material costs** (mainly carbon fibres)
- Slow production rates e.g. due to the difficult **handling of the flexible fibres** without the hardened matrix, the time-intensive **hardening process** and the **low level of automation**
- The industry's general **lack of experience** with the material

What still needs to be done:

- Develop concepts to integrate **secondary materials** (e.g. carbon fibre fillers) in components
- Innovate processes with **efficient and fast automation** for mass production
- Further **innovate material formulation**/ combinations to reduce costs while maintaining performance
- Making CF production **less energy intensive**

Challenge

Time for novel material qualification/ innovation mainstreaming

Industry reality: It's a **long voyage from R&D result to mass produced car design-in** of new (material) technologies. This is due to **the need to manage risks, ensure safety and maintain affordability and business viability and growth**.

Currently the process only for material qualification takes up to **60 months**.

- **Advanced testing methods** and **standardized material qualification programs** to enable one program to satisfy the needs of many purchasers of the material
- Further develop and use **Modelling & Simulation tools** to minimize the need for physical tests to verify performance, tolerances, long term behaviour etc.

- **Coordinate closer collaboration between involved actors** to reduce the time needed to move through all the phases from R&D success to design-in into mass volume produced car models

- **EU wide coordination** among value chain stakeholders to **pool resources and data** where possible

Modelling & Simulation tools to shorten the time for material qualification

What's challenging:

- **Time** to design, collect information/data, build, execute, and analyse simulation models is too long.
- **Diversity of tools** (lacking compatibility of tools)
- **Standards** not sufficient to achieve seamless model transfer, coupling and co-simulation on different levels of detail

What still needs to be done:

- **Further improve models** representation of physical reality
- Innovate **data collection** processes
- Implement automated **workflows** that make the use of tools more efficient
- **Standardisation** for common interfaces (e.g. file formats) between tools

Challenge
Sustainability and Circularity

The reduction of the overall environmental impact e.g. **raw material extraction, energy use, emissions during processing** or **recyclability** at the end-of-life challenges several lightweight material technologies and especially the multi-material approach.

The **lack of data** on the lifecycle impact of technologies can lead to erroneous conclusions or guestimates.

- Develop/ make use of **design for circularity** methodologies and tools
- Further develop objective, data-driven tools **for Life Cycle Cost and Environmental Assessment**
- Develop reversible multi-material **joining technologies**
- **Bio-based material** solutions (natural fibres, bio-based matrices, wood laminates, bamboo)

- Create a holistic, objective understanding of the lifecycle impact of technologies with common **LCA databases**

- Harmonise **Emissions and End-of-Life expectations** based on objective holistic evaluations
- Promote the **certification of secondary raw materials** and the introduction of **material passports (?)**

Life Cycle Cost and Environmental Assessments

What's challenging:

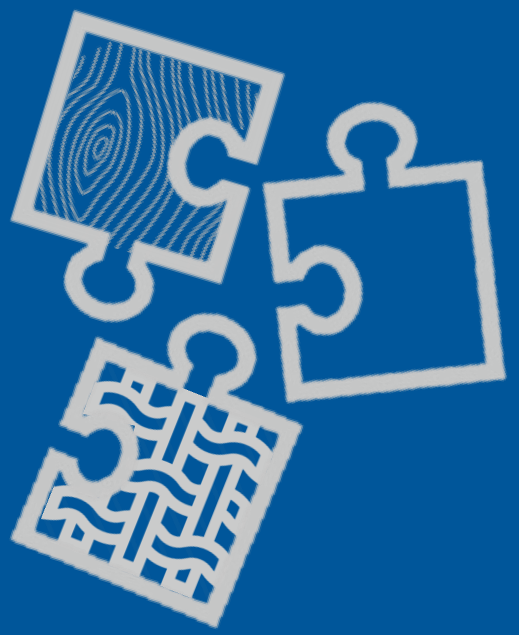
- **Complexity** (amount of data, criteria, risks) and **time-intensity** (data collection and evaluation) of assessment
- **Diversity of tools** (software, level of automation) and methodologies although standards exist
- High **costs** for acquisition of software and data sets
- **Lack** of reliable and **up-to-date data**

What still needs to be done:

- **Standardisation** and harmonization of approaches and definition of boundary conditions
- Create full **LCA databases**: Ensure that the data that is used is openly accessible and always up to date
- Increase **level of automation** of software

Reversible joining technologies for dissimilar materials

for example,
TP adhesives



What’s challenging:

- Existing thermoplastic adhesive formulations show **insufficient performance** for structural applications
- Higher **joining costs** compared to e.g. thermoset adhesives
- Application is fast but **drying processes** can be **time-intensive**

What still needs to be done:

- Further **optimize material formulations** of thermoplastic adhesives to enable structural joining while enabling separation of materials/ components at the EoL
- **Adapt process parameters** to reduce drying/ hardening time

Addressing challenges

Objectives around the lifecycle

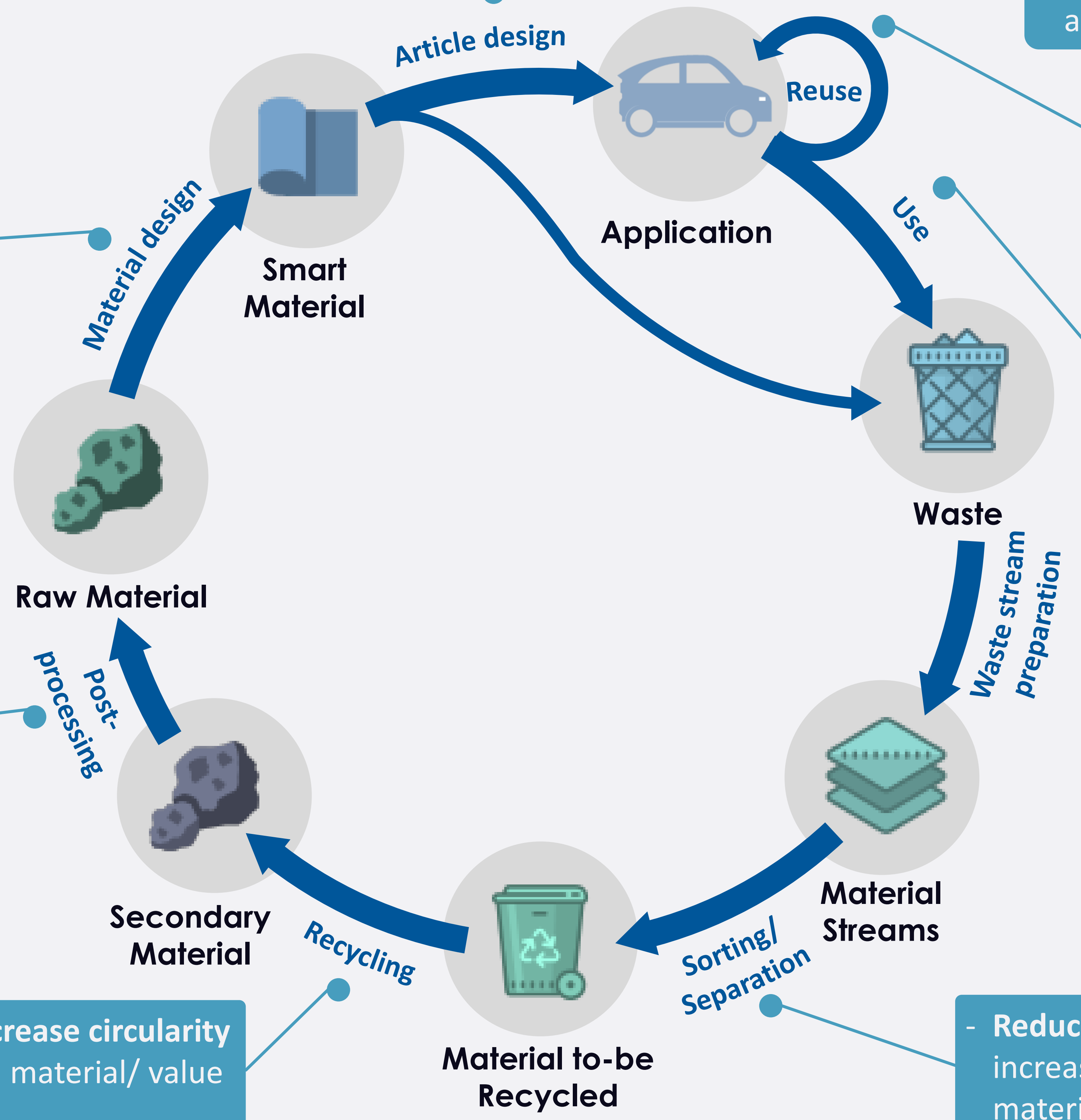
- **Reduce cost** by optimizing material use
- **Increase circularity** by designing for recycling and reuse
- **Increase circularity** by using reversible joining technologies
- **Reducing cost** by increasing level of automation

- **Reduce material qualification times** by improving M&S tools and using common digital interfaces
- **Reduce cost** by introducing secondary materials
- **Reduce cost** by increasing level of automation

- **Reduce cost over the lifecycle** by reusing parts and components

- **Reduce cost over the lifecycle** by extending the use-phase

- **Reduce cost** by introducing secondary materials



- **Reduce cost and increase circularity** by enabling (higher) material/ value recovery

- **Reduce cost and increase circularity** by increasing the value of retrieved material

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KPIs - Measuring lightweighting

Moving forward

KPIs 2019 to 2030

	KPI	Unit	2018/2019	2025	2030
Vehicle	Energy consumption	kWh/pkm	0.5	0.4	0.3-0.35
	Recycled content	% per mass	15-20	25	>35
	Cost of lightweighting	€/kg saved	3	2.5	1.5
Vehicle Module	Lifecycle performance*	gr of CO_2eq/pkm	?	?	?
	Recycling	% per mass	80-85	90	>95

* Uncertain if this KPI would be useful; difficult to define well

Moving forward

KPIs 2019 to 2030

	KPI	2019							2030						
Mono-material Part		Steel	Aluminium	Magnesium	FRP	Ceramics	Polymers	Glass	Steel	Aluminium	Magnesium	FRP	Ceramics	Polymers	Glass
	Cost compared to steel part	1	1.5-2.3	N/A	7-9	N/A	1-10	N/A	1	1.2-2	3-5	3-7	<10	1-7	N/A
	Degree of downcycling *	4-5	4-5	4-5	1-3	1-2	1-5	4-5	5	5	5	4-5	3-4	4-5	5

* using commercially available recycling technologies; scale of 1-5 where 5 is no downcycling, 1 is complete loss of material properties

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Open Discussion

How can lightweighting be measured?

Are presented values feasible, too ambitious, not ambitious enough?

Which additional KPIs should be taken into consideration?

Findings & Conclusions

- Lightweighting continues to offer many benefits **but must be affordable** to reach mainstream adoption;
- **Lightweighting efforts are expanding far beyond the BiW;** focussing now also on interiors, auxiliary systems
- Lightweighting efforts are **influenced by regulations** which will play a crucial role also in the future
- **EU funding of lightweighting research** has improved the impact of very substantial value chain player R&D investments in lightweighting making real impact
- The **introduction** of novel lightweighting technologies in **mass produced cars necessarily takes a long time,** with associated risks carried by carmakers/ suppliers over several years
- **Multifunctionality** and material mixes (**multi-material approach**) will play an important role in delivering on emission targets and future mobility trends

Automotive lightweighting today is in many ways not **limited by technology** itself, but by a lack of **affordability, the necessity to avoid any safety or business risk** and by **supply chain / ecosystem complexity**.

Outlook

- Lightweighting should not be carried out for the **purpose** of making cars lighter but to **reduce emissions** (**LCAs** in early development stages)
- As the **boundary conditions** (regulations, crash requirements, material scarcity) evolve/ change constantly, lightweighting itself will continue to evolve
- **Dealing with the consequences that can be expected as a result of these ongoing changes** requires collaboration of all stakeholders including regulators and policy makers
- Holistic approaches are required to solve the issues around lightweighting: a combination of **technological, market awareness and ecosystem innovation** is crucial
- **Affordability and industrial compatibility** remain key challenges that require substantial R&D&I efforts that cover more than just technology
- **Digital technologies** in the design, testing, manufacturing and use phases will be crucial to accelerate innovation

Thank you

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