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Accelerating the Decarbonisation of Automotive Mobility by Means of Lightweighting

A Vision on the Future of Automotive Lightweighting

BAX & COMPANY
VALUE FROM SCIENCE AND TECHNOLOGY

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AUTHORS

Bax & Company

Johanna Reiland
Consultant

Laszlo Bax
Founding Partner

Marcos Ierides
Consultant

CONTRIBUTORS/ REVIEWERS

Benteler	*Christian Hielscher, Joern Toelle, Friedrich Bohner*
Batz	*Iratxe Lopez*
CRF	*Andrea Pipino, Daniele Bassan, Daniele Pullini, David Storer, Fabrizio Urbinati, Vito Guido Lambertini*
Daimler AG	*Sama Mbang*
Fraunhofer LBF	*Christoph Tamm, Thilo Bein*
Inspire	*Michael Grubenmann*
KIT – IPEK	*Markus Spadinger, Sven Revfi*
Novelis	*Jean-Francois Despois*
Ricardo	*Neil McGregor*
RWTH Aachen – IKA	*Dinesh Thirunavukkarasu, Kristian Seidel*
Swerea	*Joakim Hedegård*
thyssenkrupp Steel Europe	*Andreas Breidenbach, Erik Hilfrich*
Volkswagen	*Andreas Gebauer-Teichmann, Jens Meschke*

ALLIANCE consortium
EUCAR members

The present document summarizes the ALLIANCE roadmap on the future of automotive lightweighting. The full roadmap is available at lightweight-alliance.eu.

Prof. Dr.-Ing. Sama Mbang
ALLIANCE Coordinator/ Daimler AG

INTRODUCTION

Transport is one of the most important building blocks for society and its growth. This is particularly true for road transport, which is an essential pillar of European employment, trade and economic productivity, and development.

The three catalysts, accelerated technological advancement, deep societal change (e.g. environmental awareness), and effective public policy currently revolutionize the way people and goods are moved. Using minimum energy, at minimum costs, with maximum efficiency, while guaranteeing safety and comfort is the major task that OEMs and their partners currently face.

The roundtable discussion at the ALLIANCE Future Lightweighting Day in Aachen in September 2018, showed an aligned understanding of this major task with its current and future challenges. However, the priorities and strategies on how to address those are not always aligned between the different automotive lightweighting stakeholders, not excluding their future vision on lightweighting.

Therefore, this document's objective is to outline a common vision for European automotive lightweighting with the aim of reducing the environmental impact of the road transport sector, and increasing Europe's competitiveness in the field. It will provide an understanding of the challenges and future/ evolution of lightweighting in Europe.

This vision is based on input from stakeholders of the European automotive lightweighting industry and completed with knowledge compiled from current market research reports, technology studies and impact assessments.

ALLIANCE

Affordable Lightweight Automobiles Alliance

ALLIANCE is a research and innovation project on automotive lightweighting, co-funded by the European Commission's Horizon 2020 programme and supported by EUCAR, the European Council for Automotive R&D as well as EARPA, the European Automotive Research Partners Association.

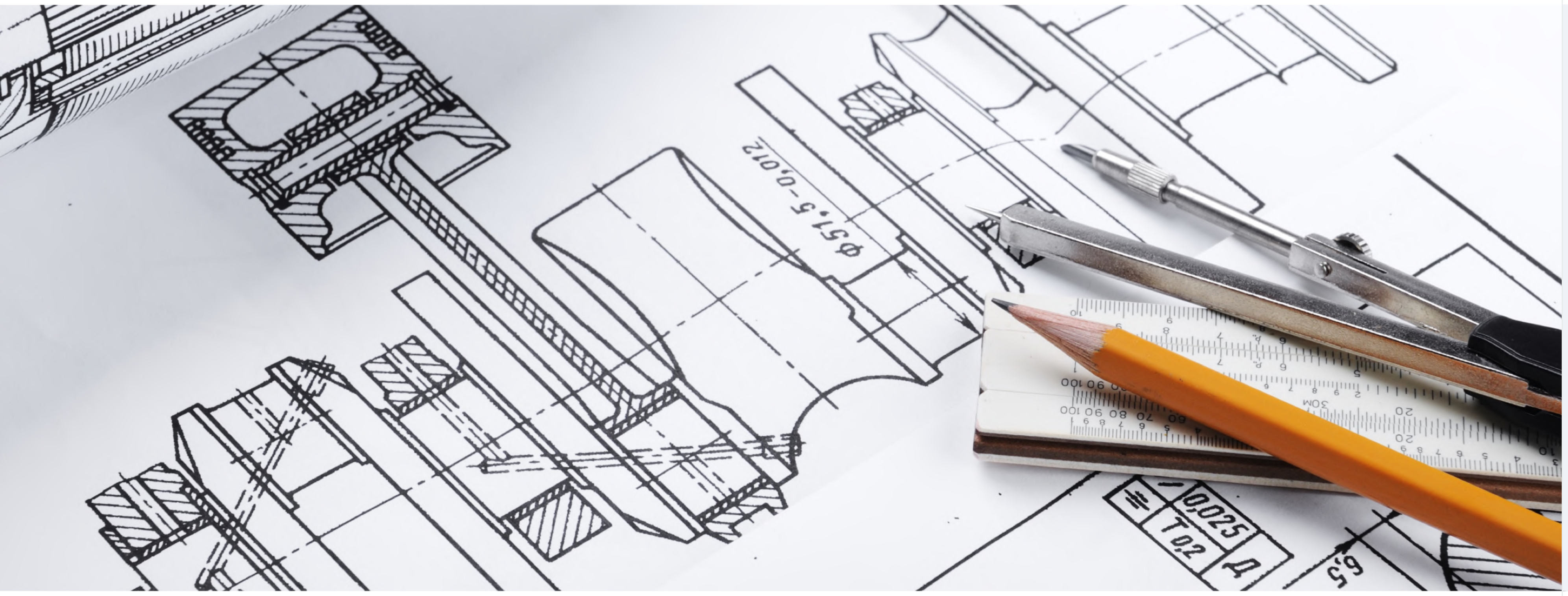
Six leading European carmakers (Daimler, Volkswagen, Fiat-Chrysler Research Centre, Volvo, Opel and Toyota) joined forces to address the need for more efficient vehicles. Together with four suppliers (Thyssenkrupp, Novelis, Batz, Benteler) and eight knowledge partners (Swerea, Inspire, Fraunhofer LBF, RWTH-IKA, KIT-IPEK, University of Florence, Bax & Company, Ricardo) they formed the ALLIANCE consortium.

ALLIANCE developed and demonstrated technologies with the primary purpose to holistically optimize fuel and energy consumption in both conventional and electric vehicles. This resulted in several demonstrators of real vehicle models, aiming at market application by 2025.

To ensure the market viability of the developed technologies as well as to accelerate pre-assessment of technologies over existing designs, several support tools have been developed.

The main objectives of the ALLIANCE project were to enable a reduction of energy consumption by 10% and global warming potential (GWP) by 6%, compared to a conventional vehicle by decreasing the vehicle's weight by 21 to 33%. All of this while keeping the cost of lightweighting below 3€ per kilogram saved.

CONTENT



ABBREVIATIONS

(C)FRP	(Carbon) Fibre-Reinforced Polymer
EoL	End-of-Life
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
HSS	High-Strength Steel
ICEV	Internal Combustion Engine Vehicle
OEM	Original Equipment Manufacturer
TRL	Technology Readiness Level

THE BIGGER PICTURE

The reduction of GHG emissions has been on the global political agenda for many years expressed in several of the Sustainable Development Goals by the UN. But the climate deal that became known as Paris Agreement signed by 195 parties within the United Nations Framework Convention on Climate Change in 2016 was a clear push to go way beyond ongoing efforts. The agreement revolved around the clear target scenario to keep the global temperature increase below 2°C compared to pre-industrial levels to avoid a global climate crisis.[1]

When in March 2018 the European Council requested a long-term strategy for the reduction of GHG emissions in the attempt for compliance, the Commission reacted with a vision for climate neutrality by 2050. The related document outlines the deep economic and societal transformations and the close collaboration required to achieve this vision.[4]

While carbon emissions are caused by all activities of industry and society, the transport sector specifically has a major impact; it produces a quarter of all GHG emissions. Within that large portion, the sub-segment of road transport accounts for more than 70%.[5] Therefore, the decarbonisation plans of the EU prioritise changes in the transport sector aiming to achieve clean, safe and connected mobility by means of alternative transport, connected and automated driving and the rollout of electric and alternative fuel vehicles.[4]

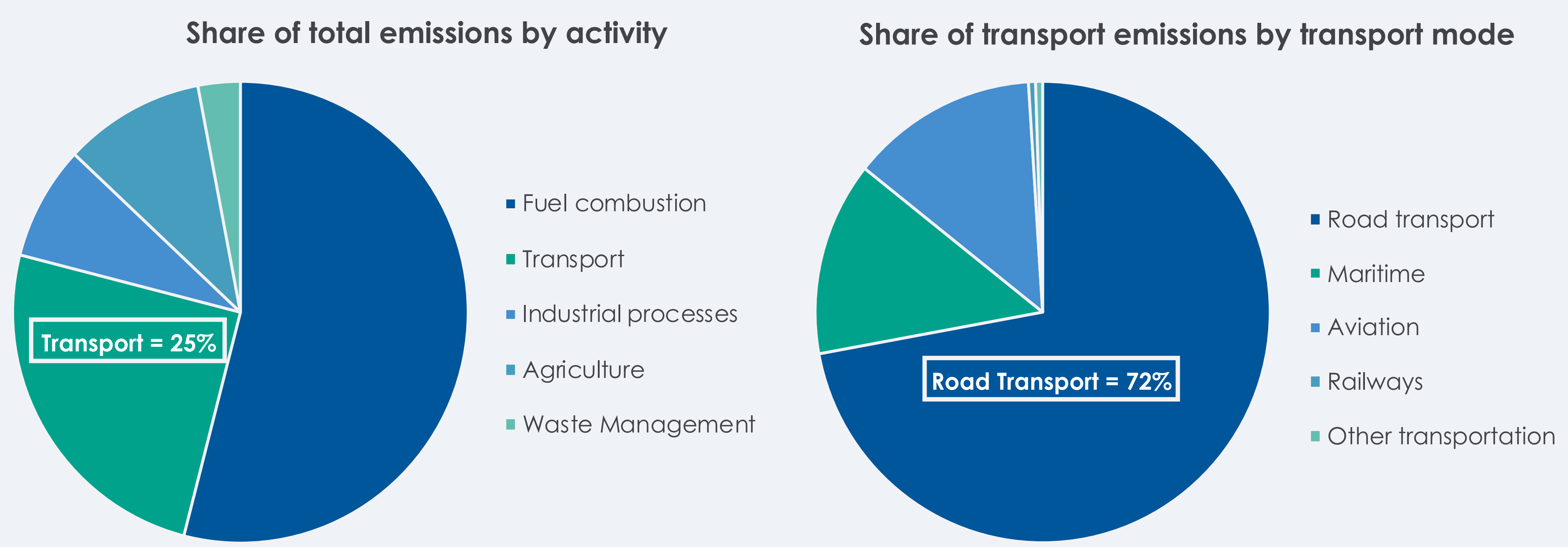


Figure 1: Shares of European greenhouse gas emissions in 2017[6]

With the European greenhouse gas emissions reaching 4.5 Gt CO_2eq only in 2017, the EU is a main contributor to the accumulation of GHGs in the atmosphere.[2,3] The European member states decided to sign the agreement not only individually but as a supranational confederation, expressing the ambition to jointly establish a strategy and the necessary regulations to execute the related action plan.

Automotive OEMs and their value chain partners currently follow two distinct approaches, in the attempt to deliver on the decarbonization targets of the European Commission: (1) using alternative energy sources with lower environmental impact and (2) improving the fuel efficiency of vehicles. Both benefit from lightweighting to increase the distance travelled per unit of energy.

[1] EASAC, Decarbonisation of transport: options and challenges, 2019
[2] IPCC, Special report - Global Warming of 1.5°C
[3] European Federation for Transport and Environment AISBL, How to decarbonise European transport by 2050, 2018

[4] European Commission, Our Vision for a Clean Planet for All, 2018
[5] European Commission, Transport emissions - A European Strategy for low-emission mobility
[6] EEA, Greenhouse gas emissions from transport, 2018

BACKGROUND FOR POLICYMAKERS

Weight reduction in the automotive sector is an interface for multiple disciplines such as material science, metallurgy, mechanical engineering, systems engineering and design and is achieved with different approaches:

1 Material approach:

Traditional automotive materials with high specific weight are replaced by materials that have lower densities while retaining the rigidity and durability (and other performance aspects) of the components. Furthermore, several materials are combined to achieve better performance-weight-affordability balances. Ideally, a higher cost can be at least partially offset by a lower material usage and energy savings during the use-phase.

2 Design Approach:

The designs of components, assemblies and the entire vehicle (load carrying elements and non-load-carrying ones) are geometrically optimized while retaining their functionality. By 'lean' design approaches, any excess material can be eliminated, and by optimizing geometries further 'leanness' of structures can be achieved. Novel, more flexible or tailored manufacturing technologies allow for locally optimized wall thicknesses, cross sections and base material characteristics. Smarter designs squeeze out any superfluous material in components and can even re-define the way components can together deliver on a certain overall vehicle or assembly level performance requirement.

As successful examples show, the approaches cannot be separated from each other, since lightweighting is not simply replacing one material with another but requires in parallel also changes in the design serving the manufacturability according to the properties of the material and to improve material use.

The quest for lighter vehicles led to an extensive research in material sciences and process technologies. Entire categories of such advanced materials such as high-strength steels, aluminium and composite materials have been the results of research efforts. Significant improvements in properties compared to the originally used base level materials have been achieved by profound multi-level material optimisation (from atoms to part levels) or through advancements in manufacturing processes, which also have given rise to additional material solutions with significant light-weighting potential, such as polymers, ceramics, and hybrids.

Although there is common understanding that certain materials are more favourable in certain applications than others due to specific properties, there are no standardised material-application matches. Today's application of advanced light-weight materials is rather driven by related costs.

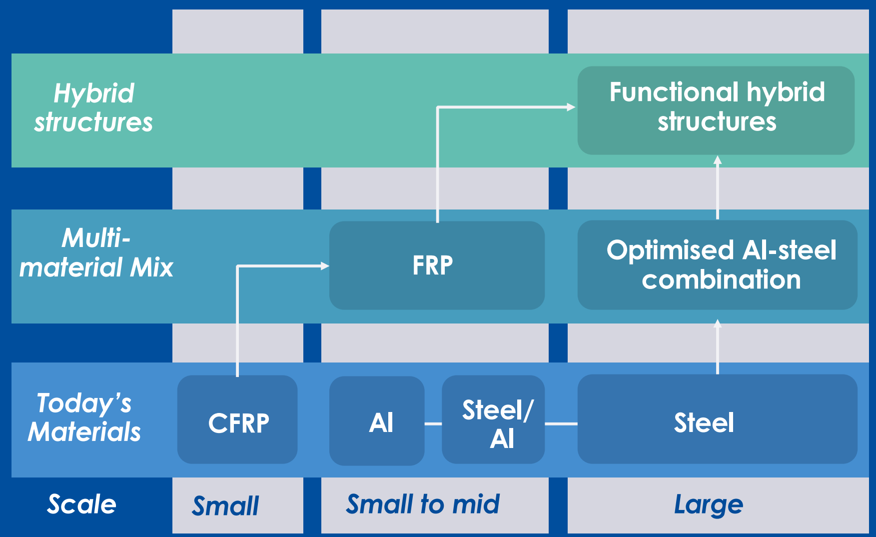


Figure 2: Lightweight materials in specific segments[7]

With individual materials reaching their performance limits, the combination of advantages of various mono-materials into one application has been gaining attention. These multi-material solutions are promising to not only increase the performance but also offer the opportunity to reduce the cost of lightweighting substantially. This approach is expected to be predominant in the future, although EoL recyclability and assembly line joining technology are challenging.

[7] Germany Trade & Invest, Industry Overview -The Lightweight Industry in Germany, 2018

FACTS & FIGURES

STEEL[8]

- ✓ Approx. 60% of the vehicle's weight
- ✓ >3,500 different grades of steel
- ✓ Roughly 1,000 times stronger than iron
- ✓ Two predominant manufacturing/ smelting processes: blast furnace and oxygen steel converter (2/3 of world's crude steel production), and electric arc furnace process (scrap)
- ✓ Can be recycled without loss of properties
- ✓ Specific properties are defined by alloying elements and process parameters

ALUMINIUM[9]

- ✓ Second-most-common metal in cars
- ✓ Endless recycling without loss of properties
- ✓ 75% of the aluminium produced in the last hundred years is still in use
- ✓ The energy consumption accounts for around 40% of manufacturing costs
- ✓ Bauxite the most important raw material is imported from e.g. Brazil & Australia
- ✓ Performance is mainly defined by alloying elements and process parameters

PLASTICS[10,11,12]

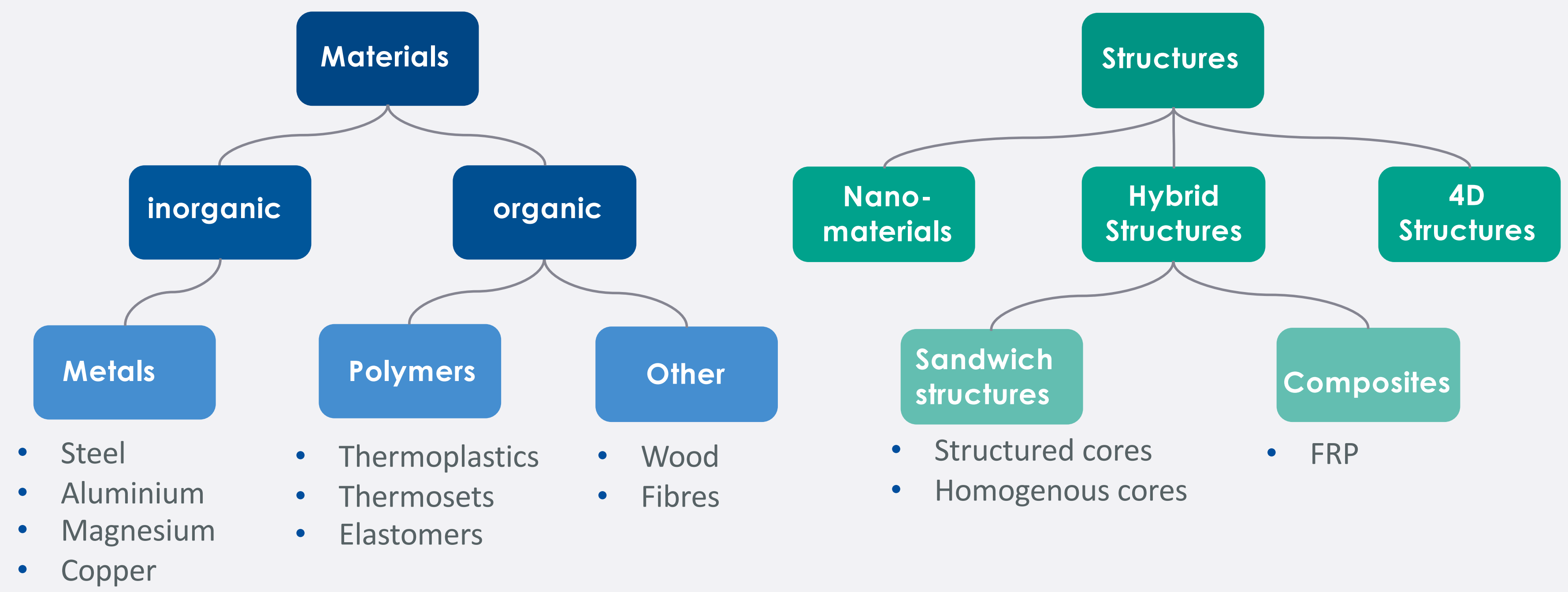
- ✓ About 50% of the vehicle's volume but only 10% of its weight
- ✓ Approx. 13 different high-performance plastics used in cars with PP, PU, PVC, ABS and PC accounting for ca. 70% of plastics
- ✓ Performance is defined by the material design (molecular structure) as well as process technologies and parameters
- ✓ Embodied energy for plastic production is slightly higher than that of steel but lower than that of aluminium (per mass)

COMPOSITES

- ✓ Combination of matrix and reinforcement
- ✓ Cost of components manufactured (CFRP) is up to 9 times higher compared to steel mainly due to material and energy costs.
- ✓ Performance is defined by type, content and orientation of the reinforcement
- ✓ More efficient structural design, as fibres can be placed in the direction(s) where the main load(s) occur
- ✓ Difficult to break down/ recycle: current practices include downcycling or incineration

[8] World Steel Association
[9] The Aluminium Association
[10] Jerin, M., Importance of Plastics in Automotive, Efficient Manufacturing (industr.com), 2018
[11] American Chemistry Council, Automotive Plastics
[12] Gutowski TG et al., The energy required to produce materials: constraints on energy-intensity improvements, parameters of demand, 2013

LIGHTWEIGHTING MATERIALS & STRUCTURES



LIGHTWEIGHTING – AN ONGOING SUCCESS STORY

Lightweighting efforts and (collaborative) research in Europe go way back. Legislation aimed at reducing vehicle emissions has driven research and development of new technologies to unprecedented intensity. Lightweighting profited from this urgency as several success cases highlight. EU research funding supported this rapid development substantially, helping stakeholders create real impact. Super Light Car for example, funded under FP6, demonstrated a reduction in the Body-in-White weight of up to 35% compared to the reference model back in 2009 and the ALLIANCE project (H2020 funded) achieved a reduction of the global warming potential by 24% on average across the various demonstrator modules.

Looking at the contribution of different approaches for lightweighting, in the last 30 years the weight reduction stemmed almost explicitly from the introduction of advanced materials in the vehicle.[13] Although efforts increased significantly the mass of the base car was almost unchanged since 1980.[14] At the same time the total vehicle weight even increased due to the integration of entertainment and safety features and measures to reduce exhaust emissions. The reason for this development are increasingly stricter safety regulations and consumer preferences for more spacious and comfort-table cars which led to increased vehicle sizes.

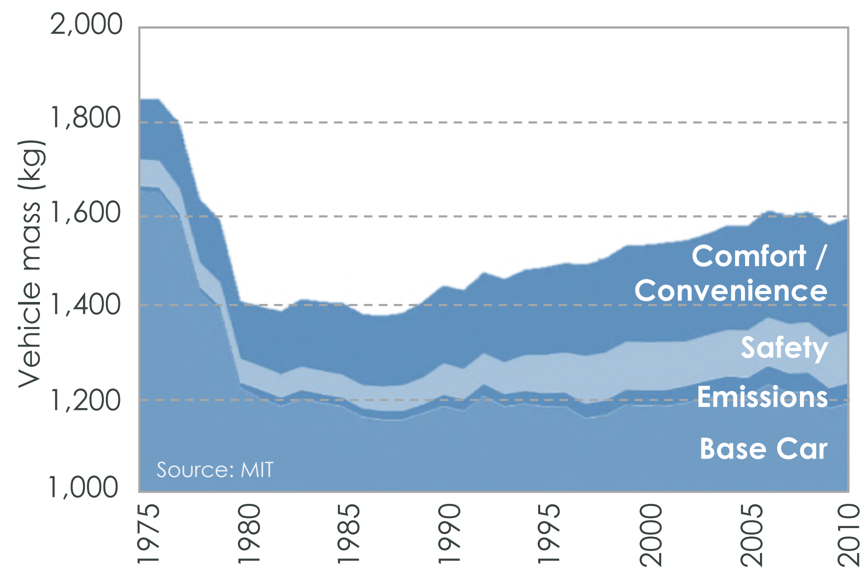


Figure 3: Evolution of vehicle mass between 1975 and 2010[14]

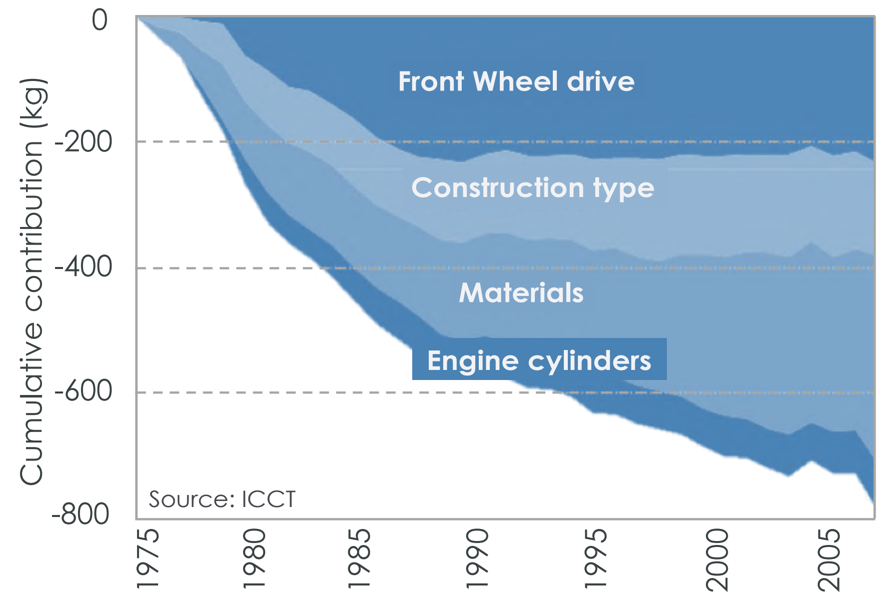


Figure 4: Cumulative contribution to weight reduction from 1975 [13]

The introduction of solutions in mass-produced mainstream cars is a very lengthy process but still many technologies have been successfully implemented. At present, the body-in-white material composition of an average car consists of a mix of various grades of steel, aluminium and plastics while composites have become more prevalent at the upper end of the market.

[13] ICCT, Lightweighting technology development and trends in U.S. passenger vehicles, 2016

[14] J. Baron (CAR), Identifying Real World Barriers to Implementing Lightweighting Technologies and Challenges in Estimating the Increase in Costs, 2016

Lightweighting initiatives in Europe go way back

2005 – SuperLightCar
19 M€, 37 partners
- -39% BiW Weight: Al (53%), Steel (36%), Mg (7%), Plastics (4%)

2010 – elva
5 M€, 7 partners
- Expand potential of vehicle architecture

2010 – HIVOCOMP
16 partners
- Cost effective use of PU & PP matrices
- High volume production

2012 – ALIVE
13 M€, 23 partners
- 4 years to mass production
- -35% Weight (BiW)

2012 – ENLIGHT
11 M€, 21 partners
- 8-12 horizon years
- - 45/50% vehicle weight

2013 – urban ev
3.6 M€, 10 partners
- Hybrid material architectures
- Off-the-shelf technology

2013 – epsilon
12.5 M€, 9 partners
- Novel architecture – focus on comfort, safety, efficiency

2013 – NewsPEC
13 partners
- Low cost production of CF from PE
- Pilot plant facility

2014 – FS (www.Fibralspec.net)
11 partners
- New CF precursors
- Industrialisation of composite

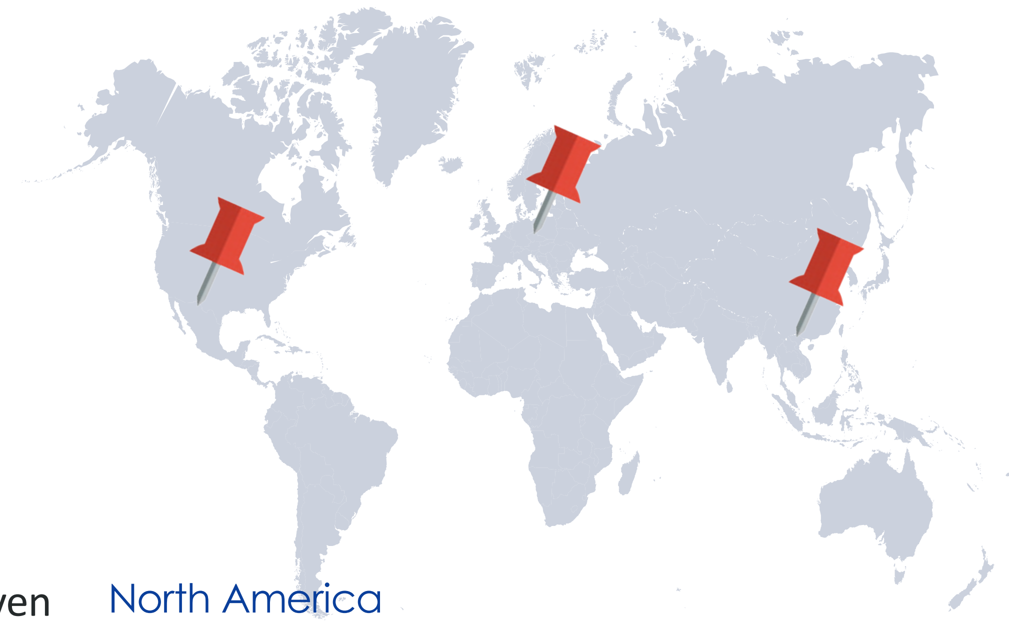
2014 – carboprec
14 partners
- Low CF precursors from lignin and cellulose
- New tech development

2016 – alliance (AffordabLe LIghtweight Automobiles AlliaNCE)
9 M€, 10 partners
- 6 years to mass production
- -31-33% vehicle weight
- - 6% GWP
- ~ 3 €/kg saved

2019

Material/ Manufacturing
Vehicle Architecture

THE LIGHTWEIGHTING MARKET



The market for lightweight materials is driven primarily by the large volume of automotive applications. The automotive sector claims close to 90% of the total lightweight materials market, partly due to the moderate penetration of lightweight materials in this sector.[15]

Europe

As a big car manufacturing hub the region also became a hub for vehicle lightweighting. The European market for lightweight vehicles is led by developments and initiatives within the EU, driven by both technological advancements and the regulatory framework.

Although there was consensus among the industry that weight reduction was an important feature for the next generation of cars, since 2011 R&I in some areas of lightweighting was stagnating. This was right around the time when the electrification hype shifted the focus of European carmakers towards other features. Nonetheless, Europe is still the largest market for automotive lightweight materials and suppliers are investing in the development of advanced materials driving market growth.[16]

North America

In the US, lightweighting is mainly driven by the Corporate Average Fuel Economy standard, general fuel price instability and the industry push (steel and magnesium industries). This leads to an increasing demand for lightweight materials in the future. Primarily metals (HSS and aluminium) are used mostly in structural applications. Additive manufacturing is gaining attention for metals and engineering polymers with important global leaders being present.[17]

Asia-Pacific

The region is expected to witness the fastest growth driven by demand due to rise in income levels and also by production due to a rapidly growing manufacturing landscape. Increasing awareness about fuel efficiency and environmental concerns are strong drivers. Important material suppliers with competitive solutions are present putting players in other regions under pressure.[16,17]

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[15] Allied Market Research, Lightweight Materials Market, 2014-2022
[16] Markets&Markets, Automotive Lightweight Material Market - Global Forecast to 2027
[17] Freedonia, Lightweight Automotive Materials in North America, 2014

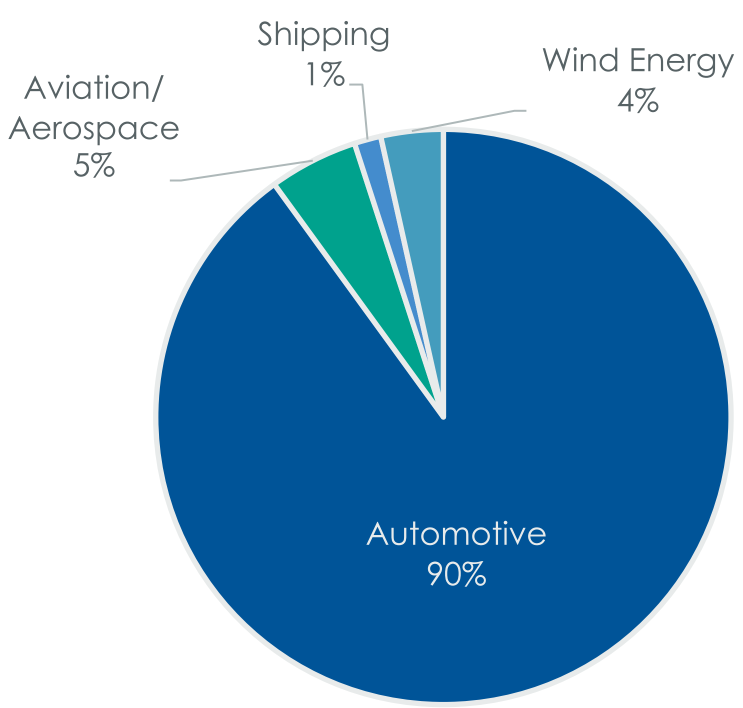


Figure 5: The lightweight materials market[15]

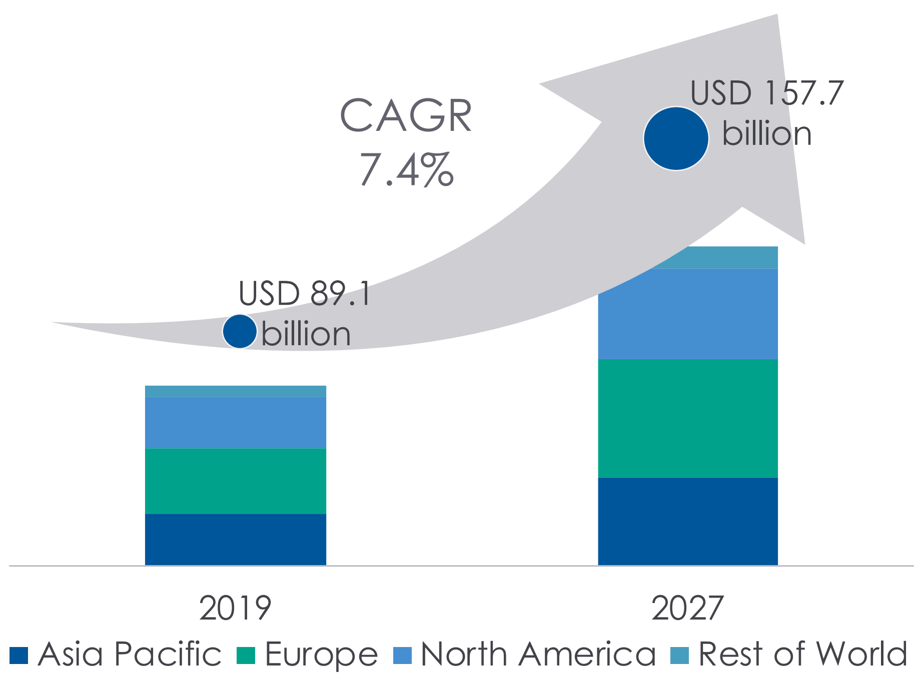


Figure 6: The automotive lightweight materials market[16]

POLICY DRIVERS FOR LIGHTWEIGHTING

Regulations that create the boundary conditions for lightweighting address all steps and stakeholders in the value chain from targets for material extraction and processing emissions, over emission standards and safety regulations in the use-phase to regulations on waste and circularity at EoL.

The combination of regulatory requirements and boundary conditions does not clearly favour any specific materials category, yet the present landscape also does not offer a holistic and fair framework to incentivise the choice for lifecycle impact optimising choices in car design.

Vehicle emission regulations (use-phase)

Over the last decade, national and European regulations on emissions during the use-phase have become stricter step by step. The trend, furthermore, goes towards tighter regulations at a local level (e.g. vehicle bans in cities). According to the European Commission, transport emissions should be reduced to a third of the current emissions by 2050.[18]

Around the globe, regulations are based on different strategies. While the EU bases their regulations on emission targets, the US and China focus on fuel economy and consumption - the differences, of course, increase the complexity for globally operating carmakers. Such regulations are translated into different OEM strategies. While some carmakers are shifting more towards alternative powertrains, others may primarily focus on developing highly energy-efficient ICEVs. Both approaches actually benefit from weight reduction, but the ability of carmakers to invest themselves heavily in this area is conditioned by the wide range of R&D investments that they need to make in order to maintain their future competitiveness.

The ELV Directive and beyond

With the global material footprint rapidly growing and outpacing economic growth and population the UN sustainable development goal 12: “Ensure sustainable consumption and production patterns” is increasingly receiving attention. In Europe, the policy framework includes several regulations and strategies currently focusing mainly on the EoL.

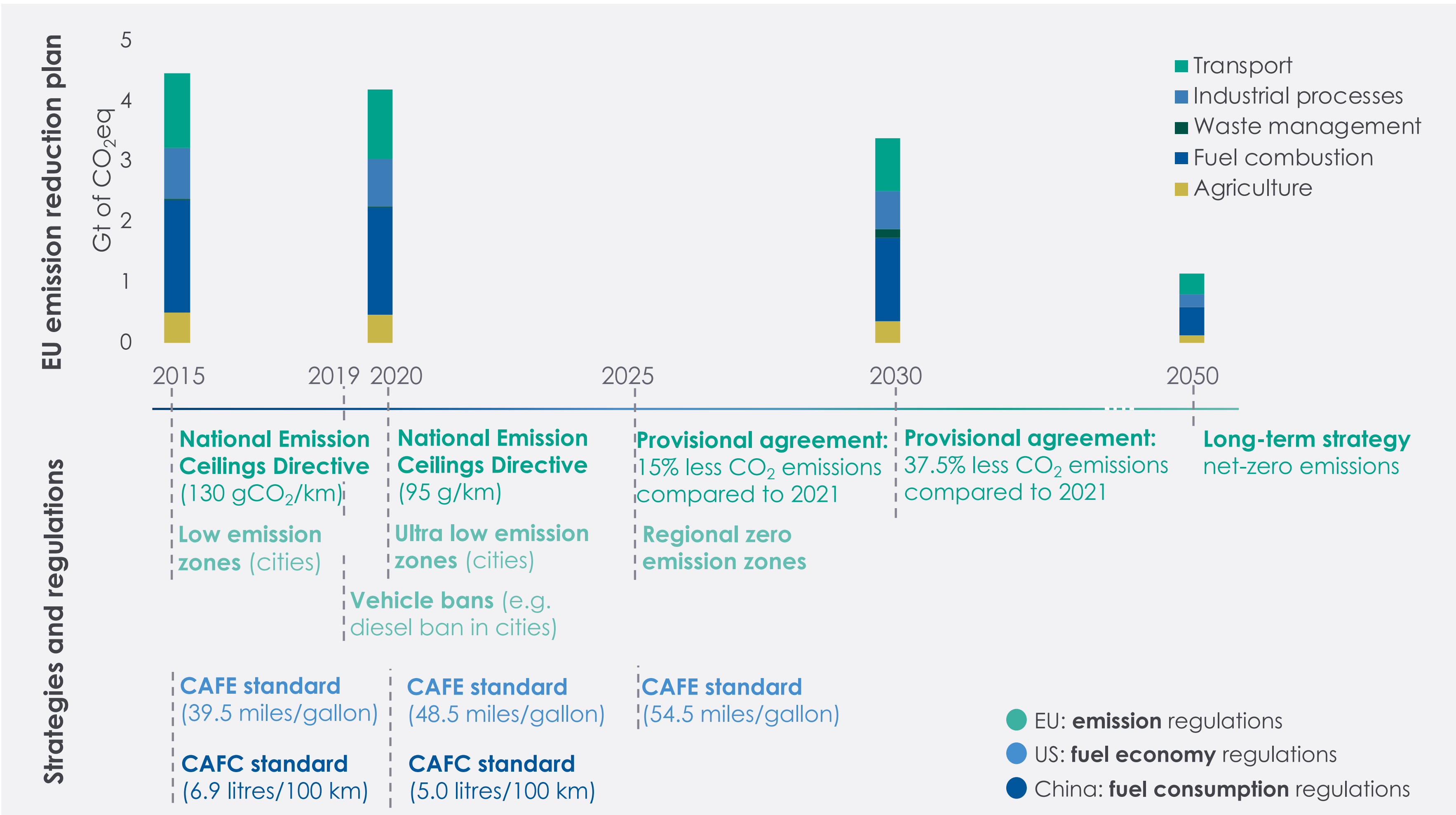
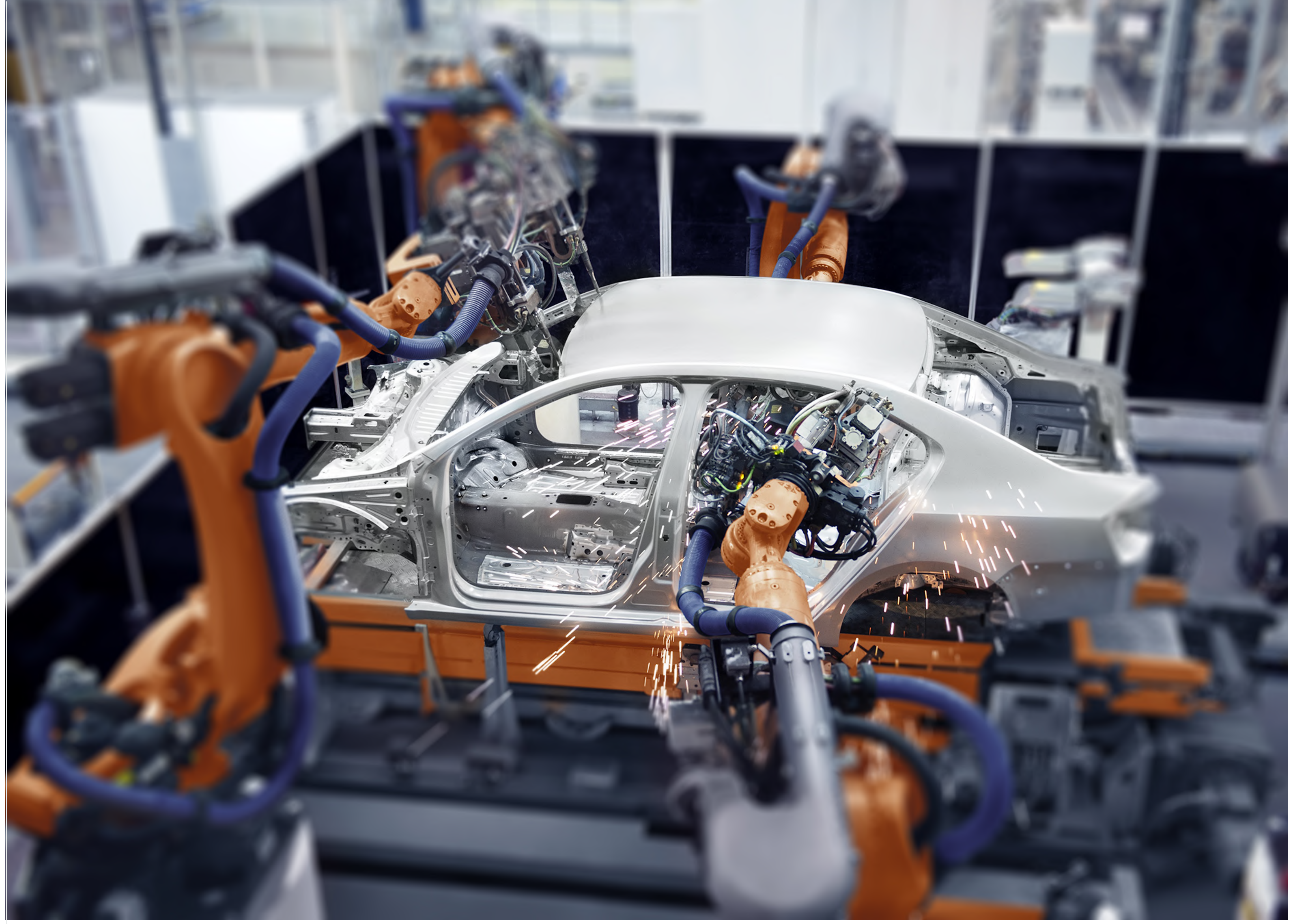


Figure 7: Evolution of EU emission regulations and the impact on the overall emissions plus regulations in the US and China[18]



The ELV Directive aims at making dismantling, recycling and reusing more environmentally friendly and minimizing the presence of hazardous substances with clearly set targets.

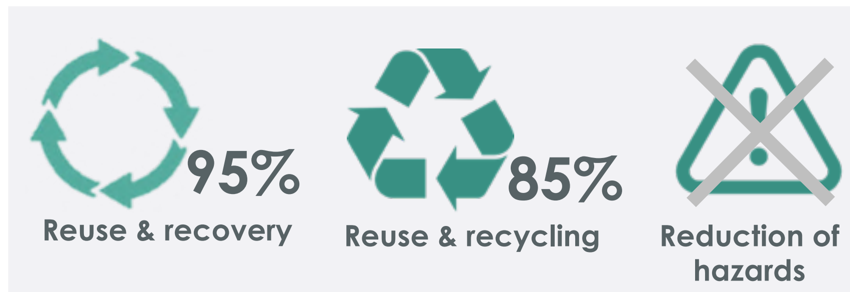


Figure 8: Set targets of the EoL Vehicle Directive[19]

Currently, the implementation and success of the Directive are reviewed with a stricter and more ambitious version expected to be introduced by 2021. Separability and ease of dismantling are expected to be key aspects affecting lightweighting options. Since multi-material options are more challenging to comply with such regulations (dismantling and material-specific recycling becomes more difficult), few-material approaches could be favoured (probably metals). This, in turn, eases manufacturing and assembly processes for OEMs significantly but limits the light-weighting potential and, therefore, the decreased energy/ fuel consumption.

As for the future, it is expected that extraction and processing of materials will be in the focus. This might cause shifts in material choices. Although restrictions for certain materials are at the moment not expected, there might be higher tolls for certain materials imported to the EU though (as seen before with steel from China). Material-specific regulations especially related to circularity will be on a more sophisticated level in the future which requires specific data on environmental performance throughout the lifecycle. Zero-emission targets are expected to be broken down to the material-level increasing requirements for materials.

[18] EEA, Greenhouse gas emissions from transport, 2018

[19] European Commission, Directive 2000/53/EC

TRENDS SHAPING FUTURE MOBILITY

As new technological, societal and political developments are in motion, the automotive market is in the midst of a historic change. Trends that start shaping mobility are an increasing use of alternative powertrains and shared mobility coupled with driving autonomy.

SHARED MOBILITY

On average private cars are used only 4% of their lifetime leading to a substantial cost per km.[20] Together with changing consumer preferences and advancing urbanisation, this resulted in users questioning car ownership. The trend is fuelled by affordable "use and pay as per requirement" services by aggregators.

Ultimately this leads to a shift in the loyalty from brands to car-sharing providers. Hence, carmakers are exploring ways to become fleet operators (e.g. Daimler's car2go or VW's WeShare) or establish partnerships. Deloitte expects that by 2025, globally up to 36% of all citizens will be using shared mobility offers.[21]

Which type of vehicle and lightweighting concept is required, can be locally very specific since regulations for such shared mobility concepts are starting to be crafted. Car-sharing is individually regulated e.g. at city level which leads to growth at different speeds and forms.

ALTERNATIVE POWERTRAINS

Electromobility has become the prevalent solution for the reduction of transport-related emissions. This led several OEMs to base their strategy partly or entirely on electrification. Since 2016, Europe is the second biggest .

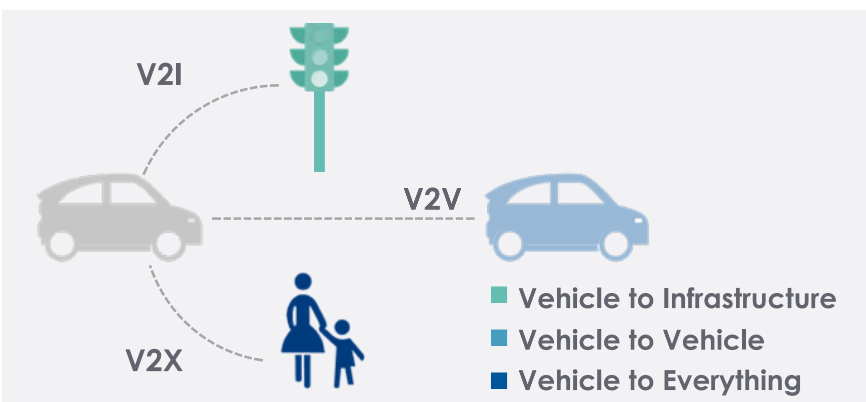


Figure 9: Connectivity as enabler for autonomous driving

market for electric cars, only outpaced by China. By 2030, 55% of cars globally sold will be electric according to PwC.[22]

The boom for electromobility is driven by the promise to eliminate emissions during the use-phase entirely. In fact, although direct emissions are prevented due to the elimination of the combustion process, emissions related to energy production exist. Those represent, at the current EU energy mix, still a big share of around 43% of the total CO_2 emissions of EVs.[23]

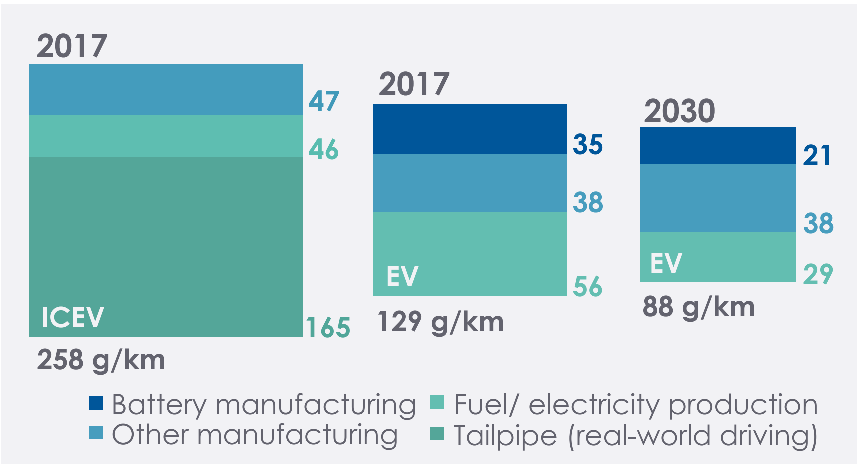


Figure 10: Emissions of electric cars with EU energy mix[23]

Although mixed opinions on the relevance of lightweighting exist, lighter vehicles will be necessary to increase the range per charge.

AUTONOMOUS DRIVING

In the EU more than 95% of all traffic collisions are caused by human error.[24] Among the drivers for autonomous driving (e.g. access to personal transport, environmental protection or comfortable driverless experience) the drastic decrease of traffic accidents is the most important one.

In modern cars increasing driving assistance and features such as adaptive cruise control, lane departure warnings or predictive ride tech are (becoming) already the standard. By 2030 McKinsey projects that 15% of all vehicles sold will be fully autonomous if all points such as building the infrastructure, dealing with cyber security issues and developing the supporting regulatory framework are addressed.[25]

Reliable high-speed data transmission to devices throughout the vehicle and to devices of other vehicles, infrastructure or road users is preconditional with the key enabling hardware adding weight of ca. 200kg.[26]

[20] J. Pöllänen, Mobility as a Service - The End of Car Ownership, 2019
[21] Deloitte Consulting, The Future of the Automotive Value
[22] PwC, Five trends transforming the automotive industry, 2017-2018
[23] ICCT, European vehicle market statistics – Pocketbook 2018/2019
[24] EP, Self-driving cars in the EU: from science fiction to reality, 2019
[25] McKinsey&Company, Automotive revolution - perspective towards 2030
[26] 3M, The promise of lightweighting, 2018

IMPACT OF TRENDS ON LIGHTWEIGHTING

SHARED MOBILITY

- ✓ A shift in material choices for lightweighting is expected as shared vehicles have a much higher utilization leading to a higher use-phase impact on the overall lifecycle carbon foot-print. Certain solutions would have a higher potential to lower the carbon footprint in a long lifecycle even though their production emissions are higher.
- ✓ Certain lightweight materials become more attractive and others economically less viable as production volumes change. Changing boundary conditions (e.g. urbanization) and consumer preferences, likely will change production volumes.
- ✓ The development of light-weight technologies might be accelerated since new vehicle concepts that meet the requirements of users and operators for shared mobility must be developed. This creates opportunities to rethink the design and integrate lightweighting at an early stage.
- ✓ Weight reduction will become more important with changing payload requirements (e.g. shuttles).

ALTERNATIVE POWERTRAINS

- ✓ Lightweighting in EVs may be accelerated since battery manufacturing for EVs has a high CO_2 impact increasing the urgency to balance these emissions out in other phases.
- ✓ The need for lighter cars could be accelerated due to EVs ad-ding more requirements to safety which increases weight, e.g. the battery (EVs) or the H2 storage tanks (FCEVs) need protection during a crash. It will be important to maintain the mass of the vehicle under a limit so users can drive it without requiring a different type of license.
- ✓ Lighter cars will reduce the energy consumption and, there-fore, increase the driving range which ultimately leads to reduced operating costs in the use phase.
- ✓ The "urgency" to make vehicles more efficient, may be reduced due to energy regeneration from braking in EVs (temporary effect and will just apply for short-distances).
- ✓ Lightweighting will be less important for the purpose of reducing emissions in the use-phase with an increase in renewable energy sources (far-future and territory-specific).

AUTONOMOUS DRIVING

- ✓ R&D in advanced materials will be fuelled by the urgency to develop multifunctional components for information and entertainment systems.
- ✓ An increase in materials with lower structural properties is expected due to a decreasing need for structural parts in vehicles in a scenario where autonomous vehicles are the majority.
- ✓ Lightweighting might be affected by changes in the vehicle architecture due to changing crash-test require-ments as autonomous driving promises absolute compliance with speed limits. This might lead to predominantly shorter cars due to a reduced crumpling zone.
- ✓ Low-emission lightweight materials will be important to compensate for high emissions in the use-phase. The operation of cameras, guidance systems and sensors in every vehicle is required. Thus, the amount of server capacity and activity globally will drastically increase. With diesel generators typically backing up the server main-frames, the emission output is expected to be immense.

DILEMMAS AND CONTROVERSIES AROUND LIGHTWEIGHTING

Multi-materials versus ease of recycling

Lightweighting often suggests a multi-material approach to decrease weight and consequently to offer optimum GWP emission reductions during the use-phase. Yet, multi-materials solutions may not be optimal in terms of circularity, since mixed material- streams create challenges at EoL. Vehicle configurations with only a few materials on the other hand offer favourable end-of-life options/ circularity performance, yet might be limited in reducing the weight. A certain trade-off related to the ELV Directive and National Emissions Ceiling Directive seems with current technologies unavoidable.

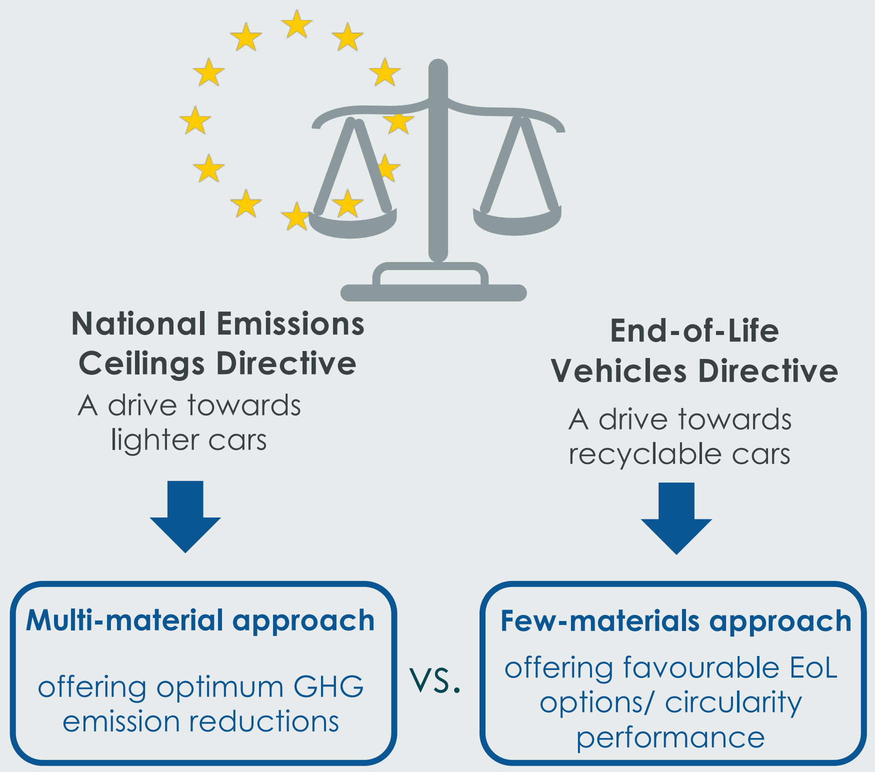


Figure 11: The controversy between the EU emission and circularity targets

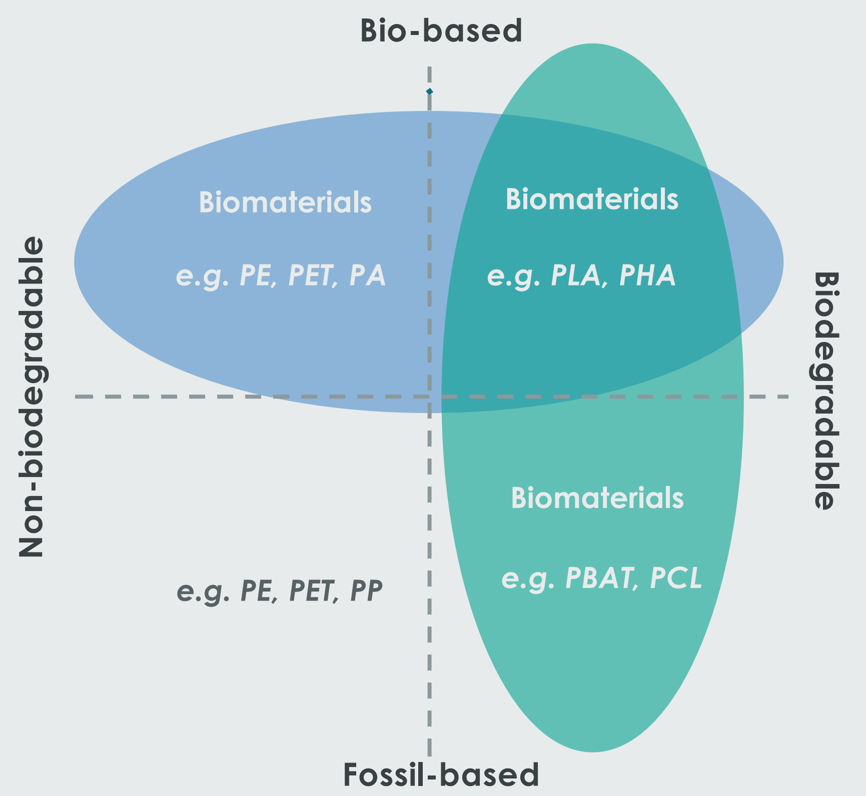


Figure 12: Classification of biomaterials[27]

New material groups add complexity

There is confusion on biomaterials among the industry. The term is often associated with bio-based materials although it is much broader combining all materials based on biomass or biodegradable - or both.

The lifecycle performance of bio-materials is still under considerable debate due to lack of experimental data. Bio-based materials have lower non-renewable energy use and GHG emissions, yet increased land-use (translates also in emissions). Another consideration is whether biodegradation at EoL is more favourable than keeping materials in the technical cycle. A holistic evaluation of all materials is required to allow for sustainable material choices.

Heavier cars are safer than lighter ones

Although advancements in safety measures made small cars safer than ever, physics gives heavier cars an inherent advantage in crash situations and in particular in frontal crashes since a heavier car would push the lighter car backwards reducing the force on the occupants in the vehicle. A study carried out by the Insurance Institute for Highway Safety (IIHS) found that very large SUVs had the lowest fatality rate in 2015 compared to all other vehicle types while the highest was found in mini cars.[28]

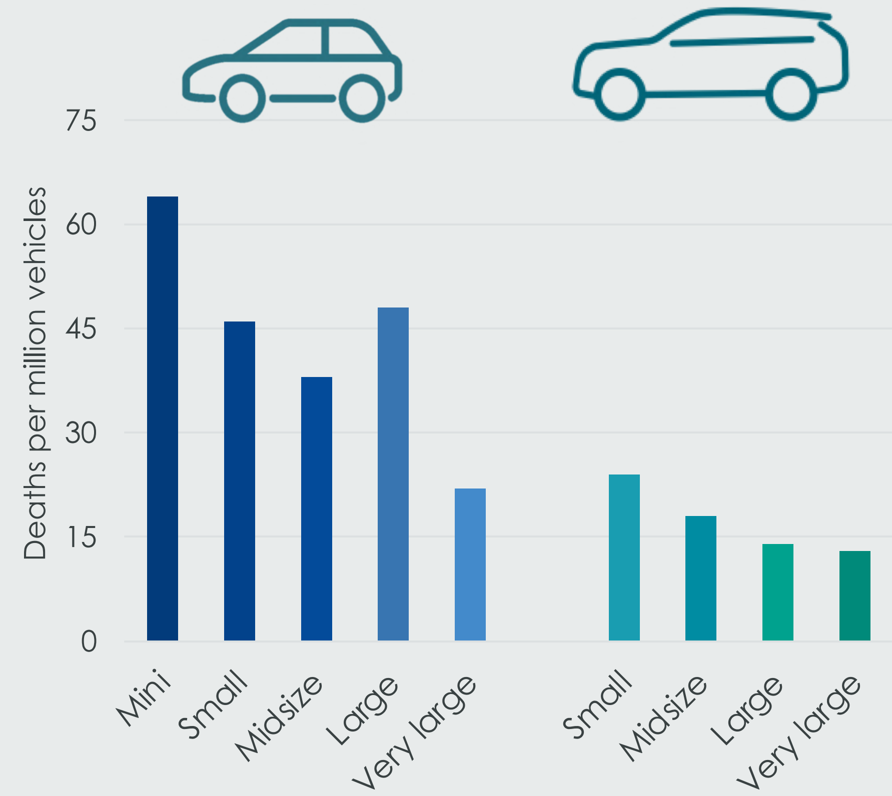


Figure 13: Driver deaths per million registered vehicles 1-3 years old[28]

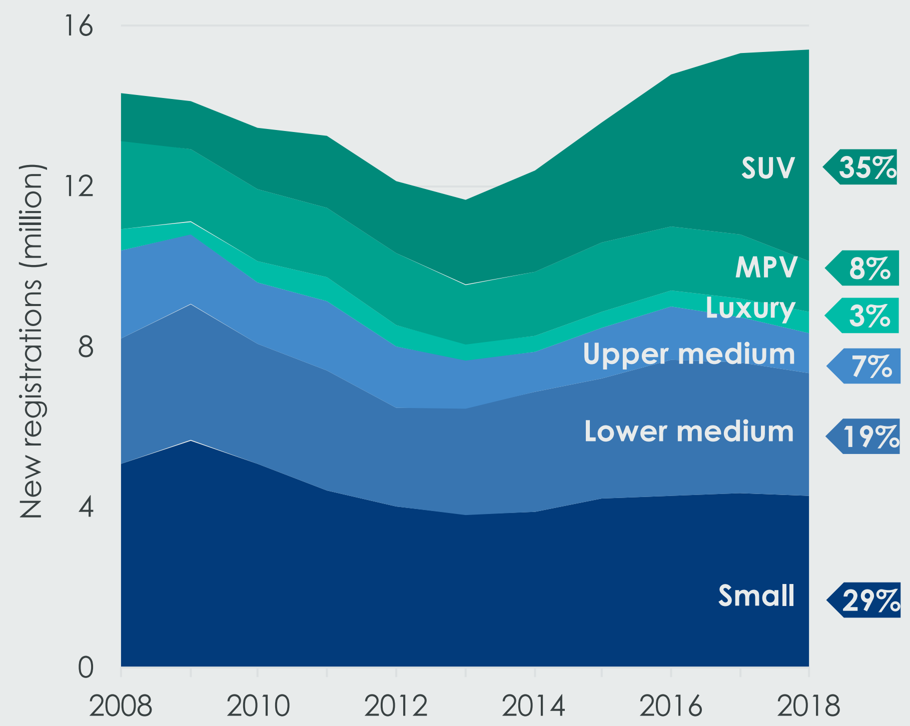


Figure 14: New registrations of passenger vehicles in the EU (million) 2008 - 2018[29]

Consumer preference for spacious cars

Although lightweighting efforts increased significantly, the average mass of cars did not de-crease. This is due to the increasing sizes of vehicles, driven by consumer preferences. Safety, fuel economy and the brand are often named as important criteria for buyers, yet vehicle size and comfort are especially in the US and in the European market a determining factor. In the EU, SUVs were the fastest-growing segment in the last 10 years accounting for about 35% of the vehicles on European roads. In comparison, the SUV penetration in the US market and in Asia-Pacific is 45% and 27% respectively. At the same time the share of mini and small cars continues to decrease.[29, 30]

[27] European Bioplastics, Fact Sheet: What are bioplastics?, 2016

[28] IIHS, Fatality Facts 2017 – Passenger vehicle occupants

[29] ACEA, The Automobile Industry Pocket Guide 2019-2020

[30] F. Munoz (Jato), Global SUV boom continues in 2018 but growth moderates, 2019

EUROPEAN LIGHTWEIGHTING

S	✓ High level of expertise on advanced materials/ structures and processing technologies ✓ Very deep understanding of the fundamentals ✓ European players are very good at modelling and simulation. ✓ Advanced recycling landscape	✓ EU landscape of highly specialized SMEs offering specialized solutions. ✓ Lightweighting technologies are available like nowhere around the globe. ✓ Players in Europe provide the majority of advanced steels.	✓ Regulations (e.g. emissions) are pushing for novel (material) technologies.
W	✓ The strict separation of fundamental and applied research and the lacking structure for research transfer slow the innovation process down. ✓ The EU lacks relevant multidisciplinary engineering education programs. ✓ Research focuses on hyped technologies (excluding potentially better solutions). ✓ Open Innovation stops usually at TRL 6/7 due to competitiveness reasons.	✓ Industrial point of view on IP hinders the fast uptake of promising solutions. ✓ Lacking investment: lightweighting requires new architectures and hence new production plants. Uncertainty about future mobility is freezing OEM investments. ✓ Lack of communication among stakeholders lead to unclarities about requirements. ✓ Complications for non-EU entities to do business with EU entities slows down R&I.	✓ Slow regulation and legislation processes within the EU ✓ Regulations on safety, emissions, sustainability and circularity create uncertainties. ✓ Environmental impacts outside the EU are not considered in regulations (e.g. material sourcing impacts).
O	✓ Increasing research in optimization of multi-parameter design systems ✓ The available infrastructure and open innovation offer opportunities to become global leader in affordable lightweight technologies, and circular economy. ✓ New vehicle configurations require new components creating the opportunity to design with lightweighting in mind.	✓ Emerging business models make more expensive lightweighting technologies viable. ✓ Shared mobility concepts create new business cases for lightweighting. ✓ The new era of mobility offers the opportunity for closer collaboration e.g. design approaches with common component interfaces (interchangeable parts increasing circularity).	✓ Creating competitive value through LCA-based regulations.
T	✓ The inability to develop acceptable sustainable end-of-life routes and related process technologies poses a threat for the application of (certain) lightweight technologies.	✓ Lightweighting is not a priority of European carmakers as the market is not asking for it. ✓ The EU relies on non-EU countries for raw materials especially for alloying elements. ✓ Local players in the export markets show growing technological expertise and suppliers are being acquired by non-EU players. ✓ The sector faces a shortage of skilled human resources due to a high employee turnover and increasing need for innovative solutions.	

CHALLENGES & INNOVATION ACTIONS

Among the many challenges faced within automotive lightweighting three main points have been highlighted in the discussions with value chain players. Defined innovation actions address the potential that is still unused and the developments and research still to be done related to the strengths and weaknesses of the European lightweighting scene focusing on these main challenges:

Affordability of lightweighting solutions (cost)

Affordability remains an issue for many lightweighting solutions. The highest performing lightweight solutions suffer from high raw material prices (alloying elements, carbon fibres), high manufacturing costs (tooling, equipment, machinery, labour-intensive processes) and long cycle times (process and delay times) leading to overall higher costs in comparison to traditional solutions preventing the introduction of materials in mass vehicle production.

Additionally, as the industry is challenged by new mobility trends the integration of additional functions is an important focus in R&D. Yet, currently apart from insufficient performance, multifunctionality is limited by too high additional costs for mass-market applications.

The correlation between fuel or energy consumption and a vehicle's weight creates an economic benefit for the customer. At the same time, the lightweighting acceptance (what the customer is willing to pay for it) is not in line which leads to the fact that the costs are carried by OEMs and suppliers. This makes it increasingly difficult to make the business case for lightweighting.

Time for material qualification and innovation mainstreaming

Lightweighting grew into more mature phases due to many breakthrough advancements in material and process technologies as well as in design approaches as seen in the last decades. Yet, the question remains why many of such innovations are still nowhere to be found in mainstream cars.

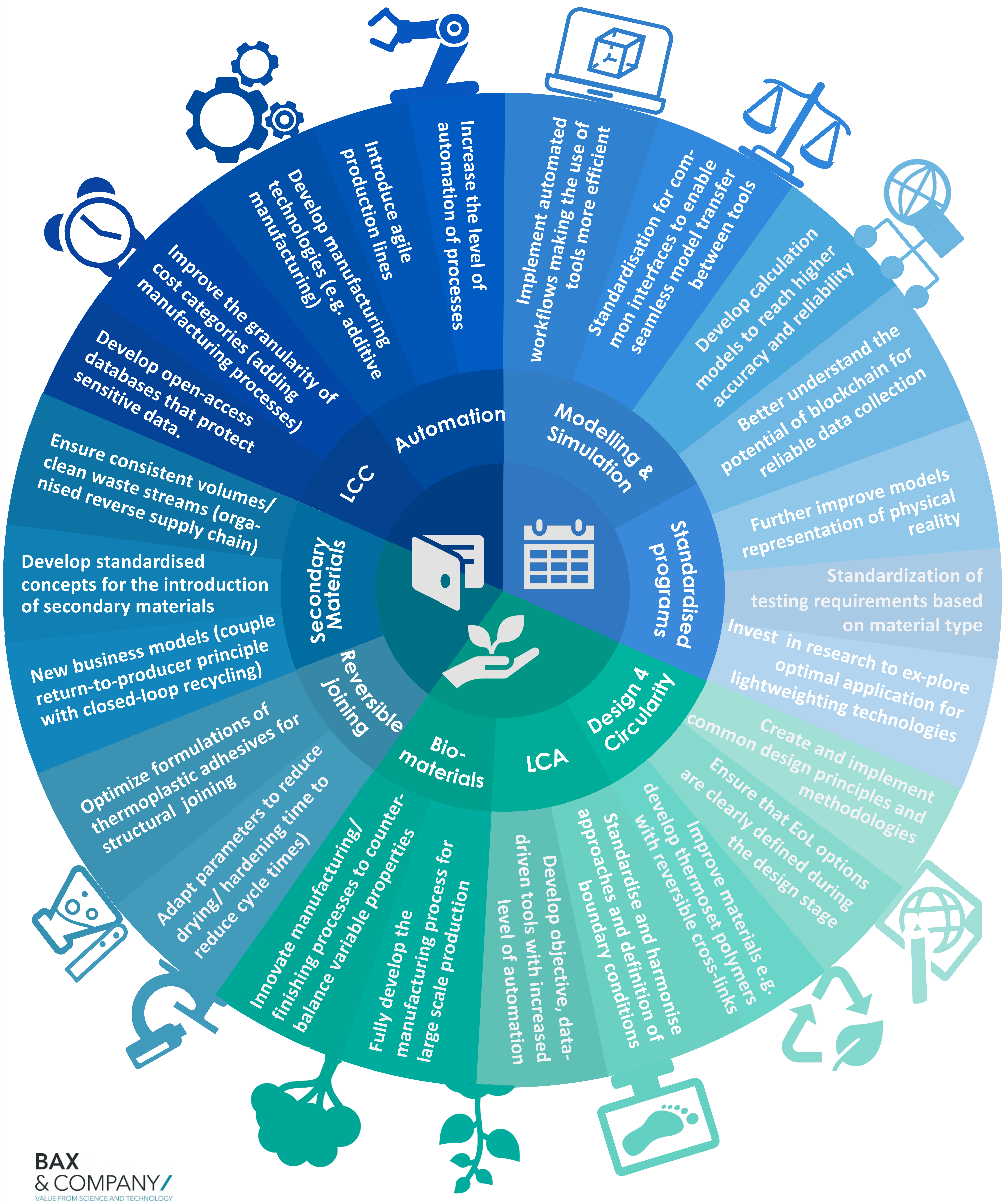
Currently, material qualification stretches over several years (up to 9 years). The long voyage from R&D results to mass-produced car designs is due to the need to manage risks (e.g. robustness of supply chain), ensure viability (compatibility with other materials, skill-set of workforce) and safety and maintain affordability, business viability and growth. This is also to the lack of understanding of systems as a whole.

The lack of understanding on how new mobility concepts, evolving legislation and societal changes will shape the requirements for future vehicle architectures and ultimately for the materials is fuelling the reluctance to invest in certain technologies due to increased complexity to understand risks fully. E.g. by the time a material is ready for introduction the requirements could have changed.

Sustainability and material circularity

The reduction of the overall environmental impact e.g. raw material extraction, energy use, process emissions or recyclability at EoL challenges several material technologies. As the industry leans more towards multi-material designs and multifunctionality (e.g. the integration of haptic, optic, acoustic or sensing functions), this challenge is even increasing as EoL options are either not satisfying or not well explored at this stage.

Looking at the overall regulatory framework, sustainability strategies and regulations are complex. While some favour certain materials/practices, others prioritize the opposite. This is also due to the lack of data on the lifecycle impact of technologies which can lead to erroneous conclusions or guestimates.



FIVE KEY FINDINGS

1 The future of lightweighting is moving from improving the performance of a single material, to gaining a better understanding of how multiple materials can be combined in a single component.

Furthermore, combining functionalities is another strategy to reduce the number of components and an enabler for automated and connected mobility. This will require further development and combination of processing technologies which, besides enabling multi-material and multifunctional structures, will also allow for reduced cost and cycle times, and higher resource efficiency.

2 Lightweighting efforts need to pursue a reduction of overall lifecycle emissions, not just to make cars lighter which only affects the use-phase in the lifecycle.

Materials that offer strong light weighting benefits may have an unfavourable emission footprint in their raw material extraction, material processing or EoL process. Only the combined holistic lifecycle impact assessment can offer balanced insights into the relative benefits of a specific materials combination or design solution. Full lifecycle assessments in early development stages will need to become the standard to support the decision-making process for the best lightweighting solution backed by real numbers. This requires a new level of data quantity and quality (e.g. break-even calculation for GHG emissions require reliable data from all phases of a vehicle). Databases should be open-access and the data collection process should follow standardised methodologies.

3 Lightweighting continues to offer many benefits but must be affordable to reach adoption in mass-produced cars especially as efforts expand beyond the BiW; focusing now on interiors and auxiliary systems.

Mainstreaming novel lightweighting solutions necessarily takes a long time, with associated risks and costs carried by carmakers/ suppliers over several years. Customers show a low willingness to pay for lightweighting due to the lack of awareness of the benefits beyond emission reduction (e.g. better driving performance and crash properties) which usually limits efforts. Therefore, substantial efforts that cover more than just technology are required to address affordability.

4 As the boundary conditions such as regulations, crash requirements and material availability/ scarcity constantly evolve, lightweighting itself will continue to evolve.

Dealing with the consequences that can be expected as a result of these ongoing changes requires collaboration and aligned approaches among OEMs and the entire value chain. The multidisciplinary character of lightweighting suggests also combination of technological, market and ecosystem innovation. A coherent regulatory framework among member states will be securing a strong automotive value chain that operates in a global context.

5 EU funding has improved the impact of very substantial value chain player R&D&I investments creating real impact.

Lightweighting breakthroughs have been achieved mainly through the collaboration of several stakeholders of the value chain – some even competing, as success cases from past EU research projects show. Such initiatives should be in the focus to address future challenges especially in higher TRL levels as cooperation usually stops due to competitiveness reasons. The collaboration among stakeholders will only become more important as lightweighting and the challenges become more complex. Supported by effective EU funding, light-weighting in Europe can continue to substantially contribute to a green and competitive automotive sector.

Today, Automotive lightweighting is in many ways not limited by technology, but by a lack of affordability, the necessity to avoid any safety and business risk and by the lack of consumer awareness of its benefits.

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