Accelerating the decarbonisation of transport
Roadmap on the future of European lightweighting

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Marcos Ierides; Bax & Company
Methodology
How do we address the challenges while taking the influence of the drivers into consideration?
The bigger picture
Background
The bigger picture

GHG emissions shares in the EU (2017)

Share of total emissions by activity
- Fuel combustion
- Transport
- Industrial processes
- Agriculture
- Waste Management

Transport: 25%

Share of transport emissions by transport mode
- Road transport
- Maritime
- Aviation
- Railways
- Other transportation

Road Transport: 72%
Background
From UN Sustainable Development Goals to Automotive Lightweighting

UN Sustainable Development Goals
The 2030 Agenda for Sustainable Development highlights transport as an 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

<table>
<thead>
<tr>
<th>Year</th>
<th>National Emission Ceilings Directive (gCO₂/km)</th>
<th>Provisional agreement: 15% less CO₂ emissions compared to 2021</th>
<th>Provisional agreement: 37.5% less CO₂ emissions compared to 2021</th>
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</thead>
<tbody>
<tr>
<td>2015</td>
<td>130 gCO₂/km</td>
<td></td>
<td></td>
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<tr>
<td>2020</td>
<td>95 gCO₂/km</td>
<td></td>
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<tr>
<td>2025</td>
<td>85 gCO₂/km</td>
<td></td>
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<tr>
<td>2030</td>
<td>75 gCO₂/km</td>
<td></td>
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<tr>
<td>2050</td>
<td></td>
<td></td>
<td>2050 Long-term strategy net-zero emissions</td>
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</tbody>
</table>

- National Emission Ceilings Directive
- Provisional agreement: 15% less CO₂ emissions compared to 2021
- Provisional agreement: 37.5% less CO₂ emissions compared to 2021

Beyond the National Emission Ceilings Directive:
- Agendas of European member states vary significantly
- Increasingly stricter implementation at city level (e.g. vehicle bans)

EU emission regulations
U.S. fuel economy regulations
China’s fuel consumption regulations
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:

- **Reuse & recovery**: 95%
- **Reuse & recycling**: 85%
- 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-material 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

- **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

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 Lightweighting 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)

Source: MIT 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

Although the multi-material approach is highly discussed, promoted and invested in, metals and here mostly steels are today still the predominant material choice!
Is Lightweighting still relevant?
The impact of future mobility trends
A shared, electrified and autonomous future

Shared mobility
- How will we move people and goods in the future?
- Who will own the car in the future?

Alternative power trains/ Electrification
- Are lightweight efficient cars still necessary in a 100% RES energy scenario?
- Will the car of the future have a (much) higher lifetime mileage?

Autonomous Driving/ Connectivity
- What will the architecture of tomorrow’s vehicles look like?
- Will we see less cars on our roads?
- 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 CO₂ 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

The challenges... ...can be addressed with...

Addressing the challenges while taking the influence of the drivers into consideration.
Scoping Lightweighting
From Challenges to Innovation

The challenges... ...can be addressed with...

- Technological Innovation
- Market Innovation
- Ecosystem Innovation

Addressing the challenges while taking the influence of the drivers into consideration.
Challenge
Affordability remains an issue for many lightweight 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 (?)
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 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 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 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
KPIs - Measuring lightweighting
# Moving forward

## KPIs 2019 to 2030

<table>
<thead>
<tr>
<th>KPI</th>
<th>Unit</th>
<th>2018/2019</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Energy consumption</td>
<td>kWh/pkm</td>
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<td>0.4</td>
<td>0.3-0.35</td>
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<tr>
<td>Recycled content</td>
<td>% per mass</td>
<td>15-20</td>
<td>25</td>
<td>&gt;35</td>
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<tr>
<td>Cost of lightweighting</td>
<td>€/kg saved</td>
<td>3</td>
<td>2.5</td>
<td>1.5</td>
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<tr>
<td><strong>Vehicle Module</strong></td>
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</tr>
<tr>
<td>Lifecycle performance*</td>
<td>gr of CO₂eq/pkm</td>
<td>?</td>
<td>?</td>
<td>?</td>
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<tr>
<td>Recycling</td>
<td>% per mass</td>
<td>80-85</td>
<td>90</td>
<td>&gt;95</td>
</tr>
</tbody>
</table>

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

KPIs 2019 to 2030

<table>
<thead>
<tr>
<th>KPI</th>
<th>2019</th>
<th>2030</th>
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</thead>
<tbody>
<tr>
<td><strong>Mono-material Part</strong></td>
<td></td>
<td></td>
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<tr>
<td>Cost compared to steel part</td>
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<td></td>
</tr>
<tr>
<td>Steel</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Aluminium</td>
<td>1.5-2.3</td>
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<tr>
<td>Magnesium</td>
<td>N/A</td>
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<tr>
<td>FRP</td>
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<tr>
<td>Ceramics</td>
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<tr>
<td>Polymers</td>
<td>1-10</td>
<td>1-7</td>
</tr>
<tr>
<td>Glass</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>**Degree of downcycling ***</td>
<td></td>
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<tr>
<td>Steel</td>
<td>4-5</td>
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<tr>
<td>Aluminium</td>
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</tr>
<tr>
<td>Magnesium</td>
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<tr>
<td>FRP</td>
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<td>Ceramics</td>
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<td>Polymers</td>
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<td>4-5</td>
</tr>
<tr>
<td>Glass</td>
<td>4-5</td>
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</tr>
</tbody>
</table>
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

Laszlo Bax
l.bax@baxcompany.com

Marcos Ierides
m.ierides@baxcompany.com

Johanna Reiland
j.reiland@baxcompany.com