Lightweight Vehicle and Powertrain Structures Roadmap

Updated by the Advanced Propulsion Centre in collaboration with and on behalf of the Automotive Council
Executive summary: Lightweight Vehicle and Powertrain Structures

- The 2013 roadmap focussed on materials, with the natural progression of more advanced materials trickling down from larger and premium vehicles into medium and small car segments.

- 2017 roadmap has built upon the targets created in 2013 and has been reinforced by a wide range of industry and academic experts. The targets reflect the different challenges in conventional and xEV (short term) and how the greater levels of autonomy impact design over the longer term.

- The 2017 roadmap reflects an acceleration to lower emissions and zero emission solutions, requiring lighter weight to offset additionality in conventional powertrain systems and to increase the range or reduce mass of battery required in xEVs.

- The 2017 roadmap focusses on design, materials and manufacturing weight saving themes, acknowledging all three have an equally important role to play in supporting weight optimised vehicle systems.

- The roadmap and research challenges acknowledge sustainability and the life cycle impact of different materials and manufacturing processes.
Update process: The 2017 Lightweight Vehicle and Powertrain Roadmap was updated via a structured consensus-building process involving experts.

- A public workshop was held at the Advanced Propulsion Centre’s hub on the 13th April 2017.
- The process was coordinated by the Advanced Propulsion Centre on behalf of Automotive Council.
- The Advanced Propulsion Centre was supported by an expert Steering Group, which shaped the roadmap before and after the workshop.
Technical targets: Mass market adoption of ultra low emission vehicles drives challenging performance targets for lightweight solutions

Drivers of change

- CO₂ targets and requirements for improved air quality have pushed OEMs towards increased energy efficiency. Reducing energy demand through weight reduction is a logical means to lower CO₂ in conventional ICE vehicles, offering secondary benefits since elements such as engines and brakes can also be made smaller as vehicle mass reduces.

- Vehicle weight has been increasing for a number of years due to greater inclusion of vehicle safety, comfort and entertainment content. In the past decade lightweighting has been applied to compensate this, resulting in broadly stable weight in most vehicle classes.

- In the short term, electrification poses additional challenges for vehicle weight. In PHEVs and BEVs, the larger batteries and electrified propulsion components make these vehicles heavier than conventional ICE vehicles. However in the long term, the introduction of connected and autonomous vehicles and geo-fenced zones will radically influence vehicle designs irrespective of powertrain.

- Life cycle considerations pose challenges for new materials and manufacturing choices, often narrowing options.

- Meeting the need for steep CO₂ reductions will require further weight reductions, many of which cannot be achieved through incremental changes. Targets have been set to drive innovation in vehicle materials, design and manufacturing, in support of overall CO₂ goals and emission reduction.

- A further challenge for weight reduction is that it should not be achieved at the detriment of unreasonable cost, safety or emissions reduction.

<table>
<thead>
<tr>
<th>Passenger Car</th>
<th>2015</th>
<th>2025</th>
<th>2035</th>
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</thead>
<tbody>
<tr>
<td>Conventional vehicle weight decrease (%)¹</td>
<td>Baseline</td>
<td>10 -&gt; 15%²</td>
<td>25 -&gt; 30%²</td>
</tr>
<tr>
<td>xEV vehicle weight decrease³</td>
<td>Baseline</td>
<td>5 -&gt; 7.5%</td>
<td>25 -&gt; 30%</td>
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<tr>
<td>Recyclability of material (%)</td>
<td>85%</td>
<td>85%⁴</td>
<td>95%</td>
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1. Some components will be untouched during this period, so those which are redesigned must have a higher % saving than the vehicle % saving required
2. Future vehicle weight reductions will need to counter weight gains from e.g. ADAS, infotainment, NVH, safety systems, refinement solutions (weight gain estimated to be around 5% in 2025 and up to 10% by 2035)
3. The target for 2025 is lower than conventional ICE because larger batteries will increase the weight of next generation xEVs. However the improved energy density of batteries, as well lighter motor and power electronics solutions, are keeping weight increases as small as possible.
4. Number remains the same to reflect the inclusion of battery packs in end of life regulations.
Technology categories: Parallel innovation is needed in design, materials and manufacturing in order to meet targets

<table>
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<tr>
<th>DRIVERS</th>
<th>TECHNOLOGY CATEGORY</th>
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<td>Smaller vehicle designs, tailpipe CO2 emissions, recycling</td>
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**TARGETS**

Vehicle weight saving vs 2015 (%)

**DESIGN LED**

Innovative vehicle and component design is crucial to engineering structurally efficient vehicles that also meet sustainability targets

**MATERIALS LED**

There are a wide range of different materials OEMs can use to reduce weight across the vehicle. The applicability of these materials varies by vehicle area and materials innovation (supported by design and manufacturing) can expand the options for many materials

**MANUFACTURING AND PROCESS LED**

Improvements in manufacturing processes are required to support new lightweight materials and designs

Note that the roadmap does not list all design, material and manufacturing technologies that will be applied. For clarity the emphasis is upon those where significant innovation is anticipated.
Design led: Design innovation enables weight to be saved by avoiding unnecessary mass and applying the right materials

**Design of components and systems** to remove weight through application of advanced modelling tools and manufacturing. Material and component redundancy eliminated. Also supported by detailed understanding of materials properties.

Longer term the function of different components and systems is achieved through convergence, as part of a holistic design.

- **Component geometry optimisation**
- **System optimisation**
- **Accurate materials characterisation**
- **Predictive characterisation of structures based upon material properties**
- **Design for ease of disassembly, identification and recycling**

**Detailed materials data** is important to allow designs to be based upon best understanding of performance in real world. Calibration of designs then enables accurate prediction of the performance of structures based upon one or more materials.

**Vehicles that operate safely** (e.g. autonomously and/or in defined environments) do not require same levels of crash protection, implying different designs and materials choices.

**Structural health monitoring via sensors** to help inform next generation vehicle/component design.

**Data embedded into materials** (e.g. via Q-codes) to track component properties from design stage through to end of life.

**Vehicle designs already focus on end of life requirements** i.e. ease of recycling and recovery of materials by mass. As emphasis shifts towards total life cycle, material and process embedded impacts become significant consideration. Traceability of materials at end of life also important to be able to demonstrate responsible care.

**DRIVERS**
- Smaller vehicle designs, tailpipe CO₂ emissions, recycling
- Strong influence of LCA, autonomous vehicles

**TARGETS**
- Vehicle weight saving vs 2015 (%)
  - 2025 targets
    - Conventional = 10-15%
    - xEV = 5-7.5%
  - 2035 targets
    - Conventional = 25-30%
    - xEV = 25-30%

**MANUFACTURING AND PROCESS LED**
- Design innovation enables weight to be saved by avoiding unnecessary mass and applying the right materials
Advances in modelling tools enable more complex multi-material load-bearing structures, also combining non-metals.

Body panel and frame construction currently dominated by steel and aluminium. Expected to continue for high volume with improved specific strength, elongation, vibration damping and thermal performance also achieved by tailored addition of lighter metals/alloys.

Lightweight structural polymers (thermoplastics, composites) play an increasing role, especially in locations where primary crash energy can be absorbed by other structures. Roof panels a priority for lighter materials.

Composites applied where high tensile strength and lightness most valuable e.g. good potential for weight saving in unsprung mass and suspension components. Requires automation to decrease takt time.

Materials led: Lighter metals and non-traditional materials can reduce weight of body structures, leading to a more mixed material future.
**Materials led:** *Thermal propulsion systems and electrified powertrains offer strong potential for selective use of lighter materials*

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**Ferrous materials and aluminium currently dominate for engines. Selective lightweighting possible as manufacturing processes develop, allowing use of new types (e.g. foams, matrices) and materials (e.g. titanium springs, magnesium alloy castings and composite conrods). Driveline components also offer good potential e.g. thermoplastic differential and e-machine casings, CFRP propshafts.**

**TPS powertrain based on steels, Al**

- Major powertrain components also using lighter metals (inc. matrix, foam), polymers, composites
- High volume metal battery casings
- Polymer and composite casings
- Lightweight structural batteries

**Most battery casings and internal support structures are metal. Polymers and composites offer means to consolidate parts and integrate features, achieving insulation and strength with lower weight. Polymers require higher volumes to mitigate tooling costs. Composites require process development to achieve higher volume.**

**Longer term batteries are anticipated to be more readily integrated into vehicle e.g. as primary structural elements**
Materials led: Electrical systems and interiors can benefit from lighter and more sustainable approaches

Higher electrical and electronic content tends to increase wiring mass. First step is rationalisation of circuits and use of lighter wires especially Al (where oxidation must be overcome). Next step expected to see conductive body structures (e.g. embedded strips) to reduce need for wiring. Beyond this functional integration and wireless control further reduces wiring mass.
Current focus area is seat lightweighting mainly through use of alloys for seat frames. Composites could make a strong contribution if takt time reduced. As LCA becomes stronger driver bio fabrics also relevant for seating, as well as biomaterials for trim and, potentially, biopolymers and composites in other interior (and exterior) applications.
Development of mono-material processes for multi-materials such as multi-point joining (e.g. remote laser welding, hot, cold and thermoplastic welding), bonding (e.g. quick cold cure resins), mechanical joining (e.g. self-piercing rivets, fasteners and friction bit joining).

Surface treatments enable enhanced component performance such as conductivity, thermal, hardness, low friction, aesthetics.

Metal processes to reduce need for machining to enable fast, low cost production of accurate parts e.g. additive layer, metal injection moulding. In time highly automated processes enable multi-material net shape manufacture to achieve optimal performance and low weight.

Reducing the takt time of composites manufacture unlocks new applications at mid and potentially high volume. Requires robotic automated fibre placement to increase speed, reduce waste and increase accuracy. Also full automation of pressing and curing steps.

Manufacturing and process led: Many of the new component designs and material applications can only be achieved through innovation in manufacturing processes.
TECHNOLOGY ROADMAP 2017: LIGHTWEIGHT VEHICLE AND POWERTRAIN STRUCTURES

**DRIVERS**

Smaller vehicle designs, tailpipe CO₂ emissions, recycling

Strong influence of LCA, autonomous vehicles

**TARGETS**

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**DESIGN LED**

Component geometry optimisation

System optimisation

Functional integration

Mission-suited lightweighting (e.g. CAVs)

Predictive characterisation of structures based upon material properties

In-vehicle condition monitoring to inform design

**MATERIALS LED**

Accurate materials characterisation

Design for ease of disassembly, identification and recycling

Metals for sheet and frame

Next generation ultra high strength steels, Al and Mg alloys for sheet and frame applications

High volume polymer panels, closures and glazing (e.g. panoramic roof)

High volume structural composites in key load-bearing areas (e.g. wheels)

TPS powertrain based on steels, Al

Major powertrain components also using lighter metals (inc. matrix, foam), polymers, composites

High volume metal battery casings

Polymer and composite casings

Lightweight structural batteries

High volume net shape manufacture of metals e.g. MIM, ALM

Joining processes for structural multi-materials e.g. hot/cold welding and bonding

Surface treatments that enhance material properties e.g. ceramic, diamond, conductive

High volume composites incl. robotic layup

**MANUFACTURING AND PROCESS LED**

1 chevron = some uncertainty around timing of mass market adoption or phase out

2 chevrons = considerable uncertainty around timing of mass market adoption or phase out

* Challenges for reducing weight differ between xEVs and conventional powertrains
Glossary: Explanation of acronyms and terms not described in the roadmap due to space constraints

- **CAVs (Connected and autonomous vehicles)** – Connected and autonomous vehicles is an umbrella term to capture the varying levels of autonomy and technologies relating to self-driving vehicles.

- **LCA (Life cycle analysis)** – Identifying the total environmental impact of a given product.

- **MIM (Metal injection moulding)** – Metal injection moulding (MIM) merges two established technologies, plastic injection moulding and powdered metallurgy. The process uses finely-powdered metal, which is mixed with binder material to create a feedstock, that is then shaped and solidified using injection moulding.

- **ALM (Additive layer manufacturing)** – Originally used for rapid prototyping, additive layer manufacturing creates three dimensional parts by assembling numerous two-dimensional layers. There are numerous forms of additive layer manufacturing that range from 3D printing to electron beam melting.

- **TPS (Thermal propulsion systems)** – A thermal propulsion system is a device that integrates an engine or fuel cell with thermal and / or electrical systems to manage power delivery to the wheels and recover waste energy to improved performance and efficiency. The key feature of a TPS is that the primary energy is stored chemically (rather than electrochemically like in a battery)

- **V2X (Vehicle-to-X)** – Vehicle-to-X refers to an intelligent transport system where all vehicles and infrastructure systems are interconnected with each other.