Lightweight Options and Forecast of Material Types

Global snapshot of lightweight solutions

Presented by Vishwas Shankar

April 19, 2016

FROST & SULLIVAN
OEMs Identify 350 Kg Weight Reduction (20%) Opportunity

Global OEMs have identified to lose up to 350 kg depending on the model, segment, brand of the vehicle—en route to achieve the desired 2020 CO₂ emission / 2025 CAFE targets.

Automotive OEMs Identify Up to 350 Kg Weight Reduction, Global, 2013–2020

Source: Frost & Sullivan
50 years of Weight Trends – Global Best Selling OEM Models

1 in 2 OEMs reduced weight of their best selling model in fleet globally in the last generation.

Automotive Best Seller Model Generations Vs. Weight Reduction, Global, 1966–2013

Note: Models that lost weight in the last generation

Source: Frost & Sullivan
Vehicle/System Weight Reduction Offers Cost Savings Opportunity Also

Potential opportunity to reduce costs along with saving weight (about $0.5 per kg weight reduction)

Key Automotive Components Weight Reduction Potential, Global, 2015

Weight reduction combined with vehicle cost reduction potential

Weight reduction combined with vehicle cost impact potential

Source: ICCT Working Paper 2013; Frost & Sullivan
Material Substitution Economics—Weight Savings versus Cost Impact

Leading up to 2020, Steel has a bigger role to play, Al continues to find more acceptance than before in the short term, CFRP seen as a more sustainable mass production solution in the long term.

Automotive Material Choices Based on Weight Savings and Cost Impact, Global, 2016

Steel still has market potential as it can offer further 10-45% weight reduction given the current cost structure.

Growing interest in Al as a lightweight replacement in the mid term.

CFRP’s real potential could be seen in the long term.

Note: *Includes both materials and manufacturing.

Source: William F. Powers; Advanced Materials and Processes 2012); Frost & Sullivan
Availability of and Demand for Steel Force OEMs to Rethink Strategy

Iron and steel automotive requirements expected to still remain 65% total demand for materials. Al, plastics expected to grow by 2020.

[Bar chart showing automotive material demand, global, 2016-2020]

Key: MTPA - Million Tons Per Annum
Note: *Others include rubber, seals, glass, Cu and zinc.

Source: Frost & Sullivan
Efficient, Sensitive, and Convenient Materials—Key to Lightweighting

Aluminum in a Multimaterial Strategy: Although steel remains the primary material choice for automotive applications, aluminum adoption is increasing.


- **Material Demand, 2010**
  - Steel/Iron: 70.7%
  - Aluminum: 9.2%
  - Plastic: 8.4%
  - Others: 11.6%

Steel has been the most popular and accepted material for more than a century.

Aluminum is closest to steel in price; use of aluminum alloys is becoming widely accepted.

**Key Raw Material Prices, 2012**

- **Price per Ton ($)**

  - Steel
  - Al
  - Mg
  - CFRP
  - Ti

- **Density (g/cc)**

  - CFRP
  - Mg
  - Al
  - Ti
  - Steel

CFRP is best for density but not yet price as mass-production applications are limited.

Recent evidence indicates strong interest in aluminum as the material choice in hybrid construction.

Which material is best for long-term sustainability?

Key: CFRP—Carbon Fiber-reinforced Plastic; Al—Aluminum; Mg—Magnesium; Ti—Titanium.

Source: Frost & Sullivan
### Key Focus Areas and Lightweight Replacements of Key Global OEMs

Advanced grades of steel comprise the preferred choice for key BIW structures; CFRP is the preference for BIW panels, Al for small BIW parts and Powertrain; Mg for Chassis; and CFRP for Interiors by 2020.

#### Key Focus Areas and Materials Choice by Automotive OEMs, Global, 2013–2020

<table>
<thead>
<tr>
<th>Region</th>
<th>North America</th>
<th>Europe</th>
<th>Asia-Pacific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus Area</td>
<td>NA OEM1</td>
<td>NA OEM2</td>
<td>NA OEM3</td>
</tr>
<tr>
<td>Body Key Structures</td>
<td>Steel/CFRP</td>
<td>Steel</td>
<td>Steel/CFRP</td>
</tr>
<tr>
<td>Body Key Panels</td>
<td>Steel/CFRP</td>
<td>CFRP</td>
<td>Steel</td>
</tr>
<tr>
<td>Body Key FEMs</td>
<td>Steel</td>
<td>Steel</td>
<td>Steel</td>
</tr>
<tr>
<td>Small Body Parts (other)</td>
<td>Mg</td>
<td>Al</td>
<td>Al</td>
</tr>
<tr>
<td>Powertrain</td>
<td>Al</td>
<td>Al</td>
<td>Al/Mg</td>
</tr>
<tr>
<td>Chassis</td>
<td>Steel/Al/Mg</td>
<td>Al</td>
<td>Steel/Al/Mg</td>
</tr>
<tr>
<td>Interiors</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Frost & Sullivan

[Strong Existing Pattern]
Aluminum Usage Trends in Current-generation Vehicles

Wide spread Aluminium usage in more chassis components, small body parts and powertrain components, electrical distribution systems, bumper systems, and even seat frames.

Aluminum in Passenger Vehicles Usage Trends, Global, 2015

Key: Body, Powertrain, Chassis, Others

Source: Frost & Sullivan
Material Intensity Vehicle Matrix
The Audi A4 and Ford F-150 are expected to set benchmarks for aluminum usage in future.

### Aluminum in Passenger Vehicles: Material Intensity Vehicle Matrix, Global, 2015–2025

**OEMs**

<table>
<thead>
<tr>
<th>Best in Class</th>
<th>High</th>
<th>Moderate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>Aluminum</td>
<td>CFRP</td>
</tr>
<tr>
<td>BMW</td>
<td>Audi, Tesla</td>
<td>-</td>
</tr>
<tr>
<td>Honda</td>
<td>Ford</td>
<td>Honda</td>
</tr>
<tr>
<td>GM</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

**Segments**

<table>
<thead>
<tr>
<th>Steel</th>
<th>Aluminum</th>
<th>CFRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-Midsize</td>
<td>D-Midsize</td>
<td>-</td>
</tr>
<tr>
<td>C-Compact</td>
<td>Pickup</td>
<td>C-Compact</td>
</tr>
<tr>
<td>C-Compact</td>
<td>-</td>
<td>C-Compact</td>
</tr>
</tbody>
</table>

**Models**

<table>
<thead>
<tr>
<th>Steel</th>
<th>Aluminum</th>
<th>CFRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Series</td>
<td>A4, Model S, Model X, F-150</td>
<td>-</td>
</tr>
<tr>
<td>Insight</td>
<td>F-150</td>
<td>Golf</td>
</tr>
<tr>
<td>ATS</td>
<td>-</td>
<td>Insight</td>
</tr>
</tbody>
</table>

**Current (Beyond 2020)**

<table>
<thead>
<tr>
<th>Best in Class</th>
<th>High</th>
<th>Moderate</th>
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<tr>
<td>Steel</td>
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</tr>
<tr>
<td>GM</td>
<td>Honda</td>
<td>BMW</td>
</tr>
<tr>
<td>Audi, Tesla, Ford</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>GM</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Audi</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Ford</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>VW</td>
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</tbody>
</table>

Source: Frost & Sullivan
Lightweight Packages Creates Different Business Opportunities

Multiple packages within a particular brand could create a much-needed competitive advantage and attract a large number of end customers as well as those looking for a product differentiation.

**Automotive Lightweighting: Lightweight Packages, Global, 2025**

<table>
<thead>
<tr>
<th>Key Material</th>
<th>Conventional Steel</th>
<th>New Steel Grades</th>
<th>Al</th>
<th>Mg</th>
<th>Plastics</th>
<th>CFRP</th>
<th>Others*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evo Light Package</td>
<td>17-23%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inno Light Package</td>
<td></td>
<td>20-25%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revo Light Package</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>35-40%</td>
<td></td>
</tr>
</tbody>
</table>

Note: High Content | Low Content

*Others include rubber and glass.

Source: Frost & Sullivan
New Material/Joining Partnerships are Key to Material Substitution
Global mass market OEMs target vehicle body structures first, followed by panels; front/rear end modules and chassis parts are also on their radar.

- **Materials**
  - Next-generation Steel
  - Al
  - Mg
  - CFRP

**Automotive Lightweighting: Partnerships are Key to Substitution, Global, 2015**

**Focus Areas**

- **Low**
  - Next-generation Steel
  - Mg

- **High**
  - Al
  - CFRP

**Current Global Excitement Among OEMs**

- **All global mass market OEMs** target the vehicle body structures first, followed by panels, and front/rear end modules with next-generation steel.

- Since 2008, extensive new focus areas for Al are BIW and powertrain for **all premium market OEMs**, including some mass market OEMs.

- A few global mass market OEMs have made recent advancements in mass-produced Mg processing and joining/manufacturing technologies.

- **10 to 12 OEMs** have partnered with key global suppliers to introduce mass-production and use CFRP in next-generation cars.

Source: Frost & Sullivan
Automotive Materials Joining Technologies—Current and Future Focus
Steel or CFRP are the center of focus, and steel-CFRP joining is attracting research as is Al-Al, Al-CFRP and plastic-plastic joining.


Future Focus

Current Focus

Source: Frost & Sullivan

KEY
1 Welding
2 Fasteners
3 Adhesives
4 Heat Sealing
5 Tongue & Groove
6 Collar joining
7 Sandwich
T To be identified

S Steel
P Plastic
C CFRP
A Aluminum
M Magnesium
Revolutionary Effort in Lightweighting—Out-of-the-box Thinking
OEMs and suppliers are moving towards solutions including plastic wheels, Al instead of Cu in wiring harness, fabric body panels, and composites in tires are expected in future production models.

Automotive Lightweighting: Revolutionary Effort in Lightweighting, Global, 2012–2020

1. Use of shape memory alloy (SMA) trunk opening mechanism
2. “Evolution seats” (10 kg)
3. New plastics in seat recliner (Golf) (7 kg)
4. Airbag inflator (25%) lighter
5. Planar speaker technology (magnets); fabric covers (bowls)
6. Wiper blades with holes (2 kg)
7. Three layer dash insulation solution: lightweight foams as key (3-4 kg)
8. Ethernet-based communication solution; reduces wiring complexity
9. Fiber composites in tires
10. GFRP springs in brakes (6 kg)
11. CFRP body panels acts as battery (15%)
12. Fabric body panels (40-80 kg)
13. Al wires instead of Cu
14. Polycarbonate to replace glass (50%)
15. Use of plastic in wheels (12 kg)
16. Use folding bikes made of CFRP (instead of spare wheels)

*Replacing wires with light beams

* TBA – To be Announced

OEMs
1. GM
3. VW
10. BMW
11. Volvo
12. BMW, Lotus
13. BMW
14. Fiat, Ford
15. Daimler
16. VW

Tier I
2. Lear
4. TRW
5. JBL, Harman
6. Valeo
7. Faurecia
8. Broadcom
9. Michelin
15. BASF

Source: Frost & Sullivan
Advantages Offered by Key Materials Continue to be Re-evaluated

Commercial and technical advantages of aluminum versus next generation steel, CFRP continue to be re-evaluated with every new model(existing model) generation change.

### Aluminum in Passenger Vehicles: Material Advantages, Global, 2015

<table>
<thead>
<tr>
<th>Category</th>
<th>Mild Steel</th>
<th>HSS</th>
<th>Al</th>
<th>CFRP</th>
<th>Mg</th>
<th>Plastics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current Solutions</strong></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Alternative Solutions</strong></td>
<td></td>
<td></td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Raw Material Availability**
  - Mild Steel: Low
  - HSS: Low
  - Al: High
  - CFRP: Low
  - Mg: Low
  - Plastics: Low
  - **Source:** Aluminum availability among alternative solutions is better than CFRP and comparable to plastics and magnesium.

- **Raw Material Price (Comparative)**
  - Mild Steel: Low
  - HSS: Low
  - Al: Low
  - CFRP: High
  - Mg: High
  - Plastics: High
  - **Source:** Certain grades of aluminum are becoming less expensive.

- **Effort Required to Manufacture**
  - Mild Steel: Low
  - HSS: Low
  - Al: Low
  - CFRP: High
  - Mg: High
  - Plastics: High
  - **Source:** Similar to plastics, aluminum requires less manufacturing effort (comparable to steel).

- **Production Friendliness**
  - Mild Steel: Low
  - HSS: Low
  - Al: Low
  - CFRP: High
  - Mg: High
  - Plastics: High
  - **Source:** Aluminum is as production-friendly as mild steel and HSS.

- **Application in Different Functional Areas**
  - Mild Steel: Low
  - HSS: Low
  - Al: Low
  - CFRP: High
  - Mg: High
  - Plastics: High
  - **Source:** Aluminum is ahead of all other materials.

- **Ability to be Joined with Any Other Material**
  - Mild Steel: Low
  - HSS: Low
  - Al: Low
  - CFRP: High
  - Mg: High
  - Plastics: High
  - **Source:** Aluminum is seen as a strategic material choice because it is easy to join with another aluminum, steel, or plastic component.

Source: Frost & Sullivan
Thank You!

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