Fuel Economy with Aluminum

The road to fuel efficiency is enabled by Aluminum. Aluminum technology will support an additional 1.5 – 2.0 mpg save.

Todd Summe
Chief Research & Development Officer, Novels Inc

May 2019
The Aluminum Transportation Group

120+ Association Member Companies

Nearly 700,000 jobs supported

$3B invested since 2013
50 Years of Automotive Aluminum Growth

- Heat Exchangers: 100%
- Wheels: 76%
- Heads: 97%
- Blocks: 88%
- Bumpers: 51%
- Hoods: 71%

2020 Aluminum Share:
- Doors: 25%
- BIW: 6%

Aluminum Content in North American Light Vehicles 2016 to 2028, Ducker Worldwide, 2017
Increase in Total Aluminum Content for Light Vehicles


THEN 2012

High volume sheet applications mainly hang-on parts.

PRIMARY APPLICATIONS:

Heat Exchangers, Wheels, Engine Blocks and Heads, Hoods and Decklids

NICHE APPLICATIONS:

Aluminum body, doors, bumpers and crash systems.

NOW 2020

Demonstrated in high volume for BIW applications.

APPLICATIONS:

Status Quo: Heat Exchangers, Wheels, Engine Blocks and Heads, Hoods, Decklids, Bodyside

Conversion Underway: Doors (25% of Market by 2020)

Demonstrated Next Step: High Volume Aluminum body (6% of Market by 2020)
The 2015 Ford F-150 Changed the Game

Market Share
Market Leadership Expanded\(^1\)

Consumer Price
Reported New Model Price Increase\(^2\)

Curb Weight
Aluminum intensive body with steel frame.\(^1\)

Fuel Economy
Up to 19% better fuel economy\(^1\) (3-5 mpg\(^3\))

Jaguar I-PACE

- Lb: 802 lb Body with doors
- Al: 91.5% Aluminum Body Content by Wt.
- Mi: 234 mile range on a single charge.
- EV: Battery box is primarily 6xxx aluminum construction

I-Pace – Vehicle Overview, Attributes, & Sustainability, Stuart Rawlings, Euro Car Body, 2018
<table>
<thead>
<tr>
<th>Production Vehicle</th>
<th>Closures</th>
<th>BIW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Al Application</td>
<td>Component Weight Reduction</td>
</tr>
<tr>
<td>2012 Range Rover¹,²</td>
<td>Doors, Hood, Fender, Bodyside</td>
<td>est. 40%</td>
</tr>
<tr>
<td>2014 Cadillac CTS³</td>
<td>Hood, Doors</td>
<td>est. 30%</td>
</tr>
<tr>
<td>2015 Ford F150⁴</td>
<td>Hood, Fenders, Bodyside, Doors</td>
<td>39%</td>
</tr>
<tr>
<td>2015 Cadillac CT6⁵</td>
<td>Hood, Bodyside, Doors, Decklid, Roof</td>
<td>39%</td>
</tr>
<tr>
<td>2019 Chevrolet Silverado⁶</td>
<td>Hood, Doors, Tailgate</td>
<td>36%</td>
</tr>
</tbody>
</table>

Automakers continue to refine aluminum designs.

1. Bad Nauheim – The all new Range Rover – L405
3. A2MAC1 comparing ATS steel doors to CTS aluminum doors
5. EuroCarBody 2015 – Cadillac CT6 – Car body benchmarking data summary
6. A2MAC1 comparing 2014 to 2019
The road ahead is enabled by Aluminum

- Global Vehicle Platforms with Regional Regulations supported by the aluminum industry
- Ridesharing and Autonomy supported by the aluminum advantages
- Mixed Powertrain challenges supported by the aluminum advantages
Lightweighting is a key enabler for mixed powertrain platforms

Batteries add weight and will remain heavy:

Even as cost and energy density improves – batteries will continue to weigh 880-1,300 lb in the near to midterm.\(^1\) Lightweighting of structure can help to offset battery weight and cost.

Platform Sharing Adds Weight:

ICE, Hybrid and BEV platform sharing will drive weight addition through due to design trade offs ... structure lightweighting can help to offset weight penalty.

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New Ultra High Strength Aluminum (UHSAL) Rises to the Challenge

Both Sheet and Extrusion product forms rise to the challenge with new UHSAL grades.
New Ultra High Strength Aluminum (UHSAL) Rises to the Challenge

<table>
<thead>
<tr>
<th>Specific Yield Strength (MPa/Kg/m³)</th>
<th>STEEL</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel</td>
<td>50</td>
<td>240</td>
</tr>
<tr>
<td>TRIP</td>
<td>80</td>
<td>190</td>
</tr>
<tr>
<td>DP</td>
<td>100</td>
<td>180</td>
</tr>
<tr>
<td>PHS</td>
<td>120</td>
<td>170</td>
</tr>
<tr>
<td>Gen3</td>
<td>140</td>
<td>160</td>
</tr>
<tr>
<td>5xx Series</td>
<td>160</td>
<td>150</td>
</tr>
<tr>
<td>6xx Series</td>
<td>180</td>
<td>140</td>
</tr>
<tr>
<td>HS 6xx 1st Gen</td>
<td>200</td>
<td>120</td>
</tr>
<tr>
<td>HS 6xx 2nd Gen</td>
<td>205</td>
<td>115</td>
</tr>
<tr>
<td>HS 6xx 3rd Gen</td>
<td>210</td>
<td>110</td>
</tr>
<tr>
<td>7xx 1st Gen</td>
<td>220</td>
<td>105</td>
</tr>
<tr>
<td>7xx 2nd Gen</td>
<td>225</td>
<td>100</td>
</tr>
<tr>
<td>7xx 3rd Gen</td>
<td>230</td>
<td>95</td>
</tr>
</tbody>
</table>

Both Sheet and Extrusion product forms rise to the challenge with new UHSAL grades.
Aluminum Intensive Architectures enabled by Ultra High Strength Aluminum (UHSAL)

ATG Silverado Lightweighting Study, EDAG, 2017
# New High Strength Aluminum (UHSAL) Application Map

<table>
<thead>
<tr>
<th>General Inners</th>
<th>General Outers</th>
<th>Safety Cage / BIW</th>
</tr>
</thead>
</table>

[Diagram showing application map with different sections highlighted]
Ultra High Strength Aluminum (UHSAL): Next steps with BIW

1. High Strength 7xxx Aluminum Alloys: Design and Business Case for Automotive Applications, Bad Nauheim, April 2019
2. Does not include possible cumulative secondary weight savings such as engine reduction
## Key Enablers to Increasing Aluminum Value-in-Use

### Joining
- Resistance Spot Welding
- Remote Laser Welding
- Multi-Material Joining

### Forming
- Hot Forming
- Roll Forming
- Textures & Lubes

### Recycling
- Closed Loop
- Open Loop
- End of Life

### Tailored Performance
- Continuous Casting
- Tailor Rolling & Welded Blanks
- Optimized Extrusion Design
- Multi-alloy Sheet

### Value Improvement
20–40%
Aluminum Continuous Casting will play an important role across the industry by 2035.

Continuous Casting opens new possibilities for transformational alloys, CO₂ footprint, and production efficiency for UHSAL alloys.

- **1.5X**
  - Strength increase new UHSAL 3rd Gen alloys enabled by continuous casting
  - Significant efficiency improvement for UHSAL alloys
Recycling Aluminum is a key enabler for the future

70-80%
Recycle content for new high recycle content grades

100%
of production scrap can be returned to the same material in a closed loop

>90%
of aluminum parts are recycled at vehicles’ end of life

1. Automotive Aluminum Recycling Rate Study, Sean Kelly, Diran Apelian, CR3 Center for Resources Recovery & Recycling
Putting it all together.

Less is more: “Lower” Value-In-Use enables broader use

Key Drivers of Value

- Design
- Advanced Alloys (UHSAL)
- Continuous Casting
- Recycling

Value-in-Use on component level ($/lb-saved)


2025-2035: value improvement of 20-40% from strength improvement and key enablers.
Aluminum technology will support an additional 1.5 – 2.0 mpg save … … economically and sustainably.