AUTOMOTIVE ALUMINUM GROWTH SURGE

2016-2028: ALUMINUM CONTENT IN NORTH AMERICAN LIGHT VEHICLES

STUDY CONDUCTED BY DUCKER WORLDWIDE
PRESENTERS

Doug Richman
Technical Committee Chairman
ATG
Vice President-Engineering/Technology
Kaiser Aluminum

Abey Abraham
Project Lead & Director of Automotive and Materials
Ducker Worldwide
AGENDA

- Ducker Introduction
- Study Methodology
- Findings 2020
- Findings Beyond 2020
- Questions
DUCKER INTRODUCTION
DUCKER PROJECT OVERVIEW

2017 Project
- 8th tri-annual ATG study
- Team of researchers - multidisciplinary
- 6+ month market research

Three-Pronged Approach
- “Bottom up” forecasting process
- “Top Down” analysis of independent research
# RESEARCH METHODOLOGY (THREE-PRONGED APPROACH)

<table>
<thead>
<tr>
<th>Bottom-Up Analysis (2015-2020)</th>
<th>Top Down Analysis (Beyond 2020)</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ OEMs, Tier 1 supplier interviews</td>
<td>▪ EPA, NHTSA and CAR</td>
</tr>
<tr>
<td>▪ Future penetration:</td>
<td>▪ Impacts of:</td>
</tr>
<tr>
<td>- Metals</td>
<td>- Fuel prices, vehicle mix, secondary</td>
</tr>
<tr>
<td>- Alternate materials</td>
<td>- Weight savings, electrification, vehicle design, regulations, Vehicle launch cadence</td>
</tr>
<tr>
<td>▪ Material breakdown:</td>
<td>▪ Result:</td>
</tr>
<tr>
<td>- Product</td>
<td>- Three different mass reduction</td>
</tr>
<tr>
<td>- Product form</td>
<td>and timing assumptions</td>
</tr>
<tr>
<td>▪ Material content:</td>
<td>▪ Not an attempt to predict what</td>
</tr>
<tr>
<td>- Component</td>
<td>each OEM will do to meet</td>
</tr>
<tr>
<td>- Vehicle segment</td>
<td>regulations</td>
</tr>
<tr>
<td>- Product form</td>
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</tbody>
</table>
Mass Reduction (MR)* Scenarios

Current Proposed Regulation
7%** MR by 2025

Most Likely OEM Compromise
7%** MR by 2028

Market Driven Solution
4.5% MR by 2028
(no CAFE regulation)

* 2015 average curb mass 3,834 Lbs.
**2016 draft Technical Assessment Report (TAR)
MASS REDUCTION MEGATRENDS (2015:2028)

**Auto Industry**

- **MR:** 7% - 9% by 2028*
- **Multi-material Vehicle (MMV)**
- Materials Advancements
  - Steel, Aluminum, Plastics, Composites, Magnesium
- **Consumer benefits - Lightweighting**

**Automotive Aluminum**

- Materials advancements
  - strength, formability, energy absorption, ...
- Vacuum Die Castings (VDC)
- Micro Mill

*Based on 2015 Average Mass of 3835 Lbs.*
MASS REDUCTION SCENARIOS

Mass Reduction Scenarios

Pounds Saved

- 7% MR 2028
- 7% MR 2025
- 4.5% MR

2015 2020 2025
AUTOMOTIVE ALUMINUM: 2015
BY VEHICLE SYSTEM

- Engine: 30%
- Trans, Driveline: 21%
- Wheels: 11%
- Collision Mgt.: 7%
- Body & IP: 2%
- Closures: 7%
- Brakes: 2%
- Suspension: 3%
- Steering: 5%
- Heat Shields: 1%
- Heat Transfer: 9%
- Closures: 7%

Aluminum: 397 PPV
AUTOMOTIVE ALUMINUM: 2015
BY PRODUCT FORM

Castings/Forgings: 70%

- Castings 283 PPV 68%
- Sheet 78 PPV 20%
- Extrusions 41 PPV 10%
- Forgings 8 PPV 2%

Aluminum: 397 PPV
FINDINGS: 2015:2020
VEHICLE MASS REDUCTION (2015:2028)

Average Vehicle Mass

Vehicle Weight in Pounds

- 2015: 3835 pounds
- 2020: 3735 pounds
- 4.5% 2028: 3670 pounds
- 7% 2025/28: 3565 pounds
ALUMINUM CONTENT GROWTH (2015:2020)

Aluminum Share of Curb Weight

<table>
<thead>
<tr>
<th>Year</th>
<th>2012</th>
<th>2015</th>
<th>2016</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share</td>
<td>9%</td>
<td>10%</td>
<td>11%</td>
<td>13%</td>
</tr>
</tbody>
</table>

Avg. Aluminum Content in Pounds per Vehicle

<table>
<thead>
<tr>
<th>Year</th>
<th>2012</th>
<th>2015</th>
<th>2016</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pounds</td>
<td>350</td>
<td>397</td>
<td>411</td>
<td>466</td>
</tr>
</tbody>
</table>
HIGH GROWTH ALUMINUM APPLICATIONS

High Growth

1) Closures  
2) Body-in-White  
3) Shock Towers  
4) Sub-frames / cradles  
5) Bumpers  
6) Suspension Knuckles
2020 ALUMINUM GROWTH TRENDS

Sheet – Body

- Closures – 165% increase:
  2015 - 23 PPV
  2020 – 61 PPV

  - Hoods:
    2015 – 50%
    2020 – 71%

  - Doors:
    2015 – 5%
    2020 – 25%

- BIW components:
  83% increase 2015 to 2020

- Body-in-White (BIW) & closure sheet:
  1.6 billion pounds

Extrusions/Castings/Forgings

- Extruded products – 35% increase:
  2015 - 36 PPV
  2020 – 49 PPV

  - Crash management: + 65%
  - BIW: + 100%

- Castings and Forgings:
  - Steering knuckle - + 35%

- Vacuum Die Castings: +360% increase:
  2015 - 3 PPV
  2020 – 14 PPV
ALUMINUM CONTENT BY VEHICLE SEGMENT

Vehicle Segment: PUP, SUV/CUV, Van, E, D, C, A/B, MPV, Avg

Pounds per Vehicle: 2012, 2016, 2020

Bar chart showing aluminum content by vehicle segment for years 2012, 2016, and 2020.
AUTOMOTIVE ALUMINUM CONTENT (2020)

2020 466 LBS.

- Engines: 24%
- Transmissions & Driveline: 18%
- Closures: 13%
- Body and IP Structures: 10%
- Bumper Beams & Crash Boxes: 3%
- Brakes: 2%
- Steering Components: 5%
- Suspensions/Cradles/Subframes: 2%
- Heat Shields: 1%
- Heat Exchangers: 7%
- Wheels: 14%
- All Other Components: 1%

2020 466 LBS.

2020 466 LBS.
AUTOMOTIVE MATERIALS MIX SHIFT (2015:2020)

2015 CURB WEIGHT 3835 LBS

- Steel Sheet: 40%
- Steel: 56%
- Other Metals: 4%
- Magnesium: 0%
- Iron Casting: 8%
- Polymers: 8%
- Glass: 2%
- CFRP: 0%
- SMC/Fiber: 0%
- Other Materials: 11%

2020 CURB WEIGHT 3735 LBS

- Steel Sheet: 38%
- Steel: 53%
- Other Metals: 4%
- Magnesium: 8%
- Iron Casting: 15%
- Polymers: 9%
- Glass: 2%
- CFRP: 0%
- SMC/Fiber: 0%
- Other Materials: 11%
ALUMINUM COMPONENT WEIGHT CHANGES (2015:2020)

Aluminum Net Increase: 69 Lbs.
SOURCES OF MASS SAVINGS
MATERIAL SELECTION (2015:2020)

2015:2020 — 100 Pounds Saved

- Aluminum: 57%
- Advanced Steels: 40%
- Magnesium: 1%
- SMC, Polycarbonate, Fiberglass: 2%
- CFRP: <1%

DRIVE ALUMINUM

DUCKER WORLDWIDE
55 YEARS UNINTERRUPTED ALUMINUM GROWTH

N.A. Light Vehicle Aluminum Content
Net Pounds per Vehicle (PPV) @ 7% MR Scenario by 2028

 Avg. + 5 PPV per year

 Avg. + 9 PPV per year

 Avg. + 12 PPV per year

<table>
<thead>
<tr>
<th>Year</th>
<th>Net Pounds per Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>84</td>
</tr>
<tr>
<td>1980</td>
<td>120</td>
</tr>
<tr>
<td>1985</td>
<td>139</td>
</tr>
<tr>
<td>1990</td>
<td>165</td>
</tr>
<tr>
<td>1995</td>
<td>212</td>
</tr>
<tr>
<td>2000</td>
<td>258</td>
</tr>
<tr>
<td>2005</td>
<td>306</td>
</tr>
<tr>
<td>2010</td>
<td>340</td>
</tr>
<tr>
<td>2015</td>
<td>397</td>
</tr>
<tr>
<td>2020</td>
<td>466</td>
</tr>
<tr>
<td>2025</td>
<td>520</td>
</tr>
<tr>
<td>2028</td>
<td>565</td>
</tr>
</tbody>
</table>
7% Mass Reduction Scenario (2025 or 2028):

- Total aluminum content: 565 PPV
- Aluminum share of curb mass: 16%
  - Nearly 25% of vehicles having partial aluminum BIW with some complete BIW

Multi-Material Body Design:

- Significant quantities: Aluminum, AHSS/UHSS, Magnesium and some CFRP
ALUMINUM TRENDS BEYOND 2020

7% Mass Reduction
- Closures grow to 100+ PPV
- Hood penetration of 90%
- Door penetration near 60%
- Aluminum BIW parts grow to 61 PPV
- Vacuum Die Castings are the most secure aluminum parts for BIW
- Aluminum, Advanced Steel, Magnesium, CFRP and Polycarbonate additions are critical

4.5% Mass Reduction
- Aluminum closures:
  2020: 62 PPV
  2025: 85 PPV
- Aluminum stamped BIW parts: 34 PPV
- Total aluminum content: 494 PPV
ALUMINUM EXTRUSION GROWTH (2015:2028)

**BIW and CMS Extruded Shapes and Tube**

<table>
<thead>
<tr>
<th>Year</th>
<th>Net Pounds per Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>7</td>
</tr>
<tr>
<td>2015</td>
<td>14</td>
</tr>
<tr>
<td>2016</td>
<td>15</td>
</tr>
<tr>
<td>2020</td>
<td>24</td>
</tr>
<tr>
<td>2025</td>
<td>33</td>
</tr>
<tr>
<td>2028</td>
<td>40</td>
</tr>
</tbody>
</table>
ALUMINUM VACUUM DIE CASTINGS
(2015:2028)

Aluminum Vacuum Die Casting Content

CT6: 198 Lbs.
AUTOMOTIVE MATERIALS CONTENT SHIFT (2015:2025[28])

2015 CURB WEIGHT
3835 Lbs.

Steel Sheet, 40%
GEN 3 Steel, 0%
Other Materials, 45%
Aluminum, 10%
Iron Casting, 8%
Magnesium, 0%
Other Metals, 4%
Polymers, 8%
SMC/Fiberglass, 0%
CFRP, 0%

2025 CURB WEIGHT
3554 lbs.

Steel Sheet, 15%
GEN 3 Steel, 4%
Other Materials, 15%
Aluminum, 16%
Iron Casting, 8%
Magnesium, 1%
Other Metals, 5%
Polymers, 10%
SMC/Fiberglass, 0%
CFRP SMC, 0%
CFRP Epoxy, 0%

Steel: 56%
Steel: 47%
SOURCES OF MATERIALS RELATED MASS REDUCTION

2020

- Aluminum: 57%
- Steel: 40%
- Other: 3%

Average Mass = 3735 Lbs. (-100 Lbs.)

2025/2028 7% MR

- Aluminum: 51%
- Steel: 31%
- Other: 18%

Average Mass = 3565 Lbs. (-270 Lbs.)

7% MASS REDUCTION SCENARIO BY 2028

North American Net Aluminum Content in Light Vehicles
(Net Pounds per Vehicle)
ALUMINUM: THE FASTEST GROWING AUTOMOTIVE MATERIAL

GROWTH SURGE 2015:2028+
DOWNLOAD FULL REPORT

www.DriveAluminum.org
THANK YOU

Please submit questions through the box that appears on your screen

Full Report available for download:
www.DriveAluminum.org
Weight savings from aluminum constrained to 50%.

Model replacement cadence 2023 to 2026
  - conducive to some dramatic changes in materials and powertrains

OEM preferences recognized in study
  - spot welded body structures, aluminum structural castings
  - advanced steels for occupant compartments, steel/polymer for pickup cargo

Emphasis on proven mass production technologies

Advanced material technology
  - most 2025 technology already in OEM development (Al, Steel, Composites)
CONSUMERS ARE RECOGNIZING BENEFITS OF LIGHTWEIGHTING

- Safety
- Performance
- Fuel Economy
- Braking
- Handling
- Ride
AUTO INDUSTRY FAVORS ALUMINUM, MULTI-MATERIAL SOLUTIONS

Question: Which material family are you relying upon most heavily to help meet the 2025 CAFE fuel economy standards?

- **Aluminum**: 26% (2017), 25% (2016)
- **Multi-Material Solution**: 17% (2017), 21% (2016)
- **Engineering Plastics**: 16% (2017), 11% (2016)
- **Advanced High-Strength Steel**: 13% (2017), 17% (2016)
- **Advanced Composites**: 13% (2017), 11% (2016)

*Base: 678 Not Shown: Magnesium 2%: Other, 13%*  
*Base: 492 Not Shown: Magnesium 1%: Other, 14%*

**Source:** 2017 WARDSAUTO, DuPont Automotive Trends Benchmark Study, conducted by Penton Research
## ALUMINUM 2020 BY VEHICLE SEGMENT

### 2020 Vehicle Segment Average Aluminum Pounds and Share of 2020 Production

<table>
<thead>
<tr>
<th>Segment</th>
<th>Model(s)</th>
<th>Average Aluminum Pounds</th>
<th>Share of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/B Segment</td>
<td>Fiat 500, Ford Fiesta</td>
<td>240.6 lb.’s</td>
<td>3% of Production</td>
</tr>
<tr>
<td>C Segment</td>
<td>Ford Focus, Honda Civic</td>
<td>278.4 lb.’s</td>
<td>15% of Production</td>
</tr>
<tr>
<td>D Segment</td>
<td>Chevy Malibu, Dodge Charger, MUSTANG</td>
<td>447.6 lb.’s</td>
<td>17% of Production</td>
</tr>
<tr>
<td>E Segment</td>
<td>Daimler E Class, Cadillac CT6</td>
<td>490.0 lb.’s</td>
<td>2% of Production</td>
</tr>
<tr>
<td>MPV Segment</td>
<td>Honda Odyssey, Chrysler Pacifica</td>
<td>399.7 lb.’s</td>
<td>3% of Production</td>
</tr>
<tr>
<td>SUV Segment</td>
<td>Chevy Suburban, Jeep Grand Cherokee</td>
<td>475.1 lb.’s</td>
<td>41% of Production</td>
</tr>
<tr>
<td>VAN Segment</td>
<td>Dodge Sprinter, Ford Transit</td>
<td>338.9 lb.’s</td>
<td>2% of Production</td>
</tr>
<tr>
<td>PUP Segment</td>
<td>Ford F150, Toyota Tundra</td>
<td>676.3 lb.’s</td>
<td>17% of Production</td>
</tr>
</tbody>
</table>
STUDY FINDINGS: 2020

- Aluminum content 2015 to 2020:

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2020</th>
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<tbody>
<tr>
<td>Average Aluminum Pounds per Vehicle</td>
<td>397</td>
<td>466</td>
</tr>
<tr>
<td>% Share of Curb Mass per Vehicle</td>
<td>10%</td>
<td>13%</td>
</tr>
<tr>
<td>Average Curb Mass Pounds per Vehicle</td>
<td>3835</td>
<td>3735</td>
</tr>
</tbody>
</table>

- 50% of total aluminum growth driven by:
  closures, crash management, steering knuckles, structural vacuum die castings

- Aluminum content range by vehicle segment
  262 PPV in the A/B segment passenger cars
  550 PPV for the average pickup.
UNPRECEDENTED ALUMINUM GROWTH

**2015:2028**
- + 168 PPV (+ 12 PPV per year)
- + 3.2 B Lbs. p.a.

- Major growth:
  - closures, BIW, bumpers

- Maintain import role:
  - engine, wheels, heat exchanger, driveline

- Emerging AL technologies:
  - materials advancements, VDC, MicroMill

**By 2028**
- 565 PPV (2015 397 PPV)
- 16% of average vehicle mass (2015 10%)
- 10.8 B lbs. year - Total Auto Aluminum (2015 6.9 B)