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,
Novelis Inc

May 2019

The Aluminum Transportation Group

The Aluminum Association

KAISER ALUMINUM

Novelis

HYDRO

Aleris

RioTinto

Constellium

ARCONIC
Innovation, engineered.

TRI-ARROWS ALUMINUM INC.

- 120+ Association Member Companies
- Nearly 700,000 jobs supported
- $3B invested since 2013

50 Years of Automotive Aluminum Growth

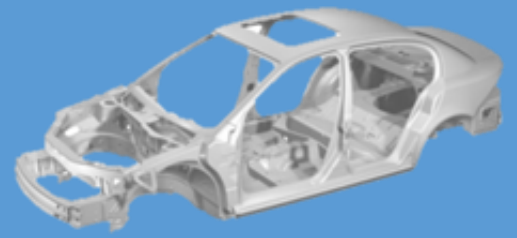
2020 Aluminum Share

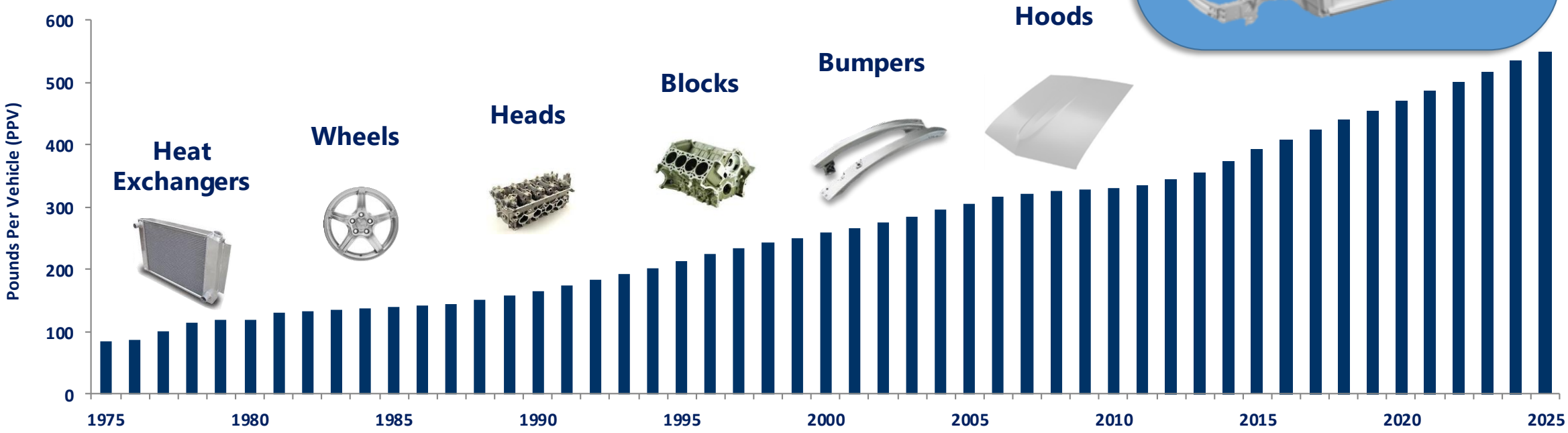
100% 76% 97% 88% 51% 71%

Opportunity

25% Doors

6% BIW





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

63%

Increase in Total Aluminum Content for Light Vehicles

Growth of North America Aluminum in Automotive from 2012 to 2020.

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*

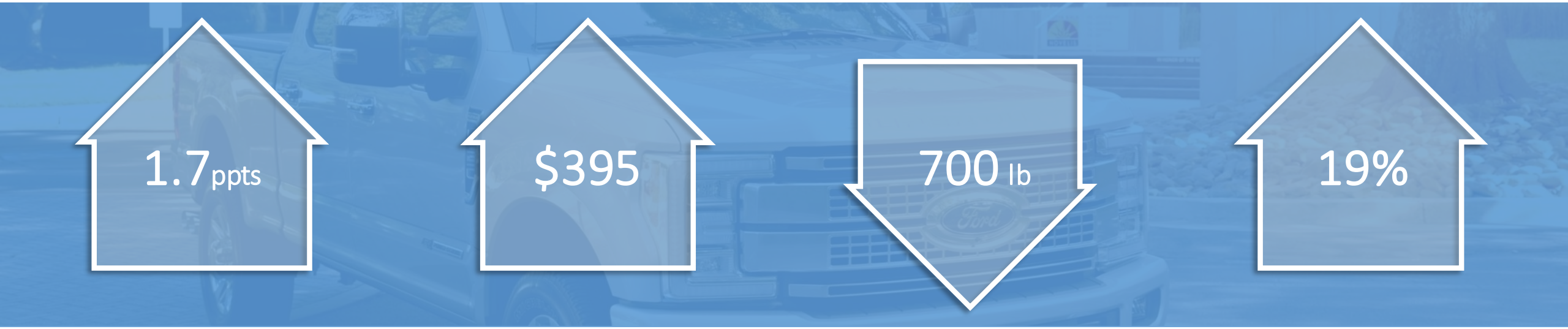
***Conversion Underway**: Doors (25% of Market by 2020)*

***Demonstrated Next Step**: High Volume Aluminum body (6% of Market by 2020)*

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

The 2015 Ford F-150 Changed the Game

2015 IIHS TOP SAFETY PICK



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])

1. *Ford's Use of Aluminum in the F-Series Truck Program By George Luckey, Ford Motor Company, Presented at the Aluminum USA Conference, Oct 25-26, 2017 Nashville TN*
2. *https://www.caranddriver.com/news/a15362316/all-new-2015-ford-f-150-pricing-goes-live-starts-at-26615/ [caranddriver.com] – F150 XL and XLT*
3. *EPA - fuel economy for 2014 and 2019.*

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

Automakers continue to refine aluminum designs.

Production Vehicle	Closures		BIW	
	Al Application	Component Weight Reduction	Al Application	Component Weight Reduction
2012 Range Rover[1,2]	Doors, Hood, Fender, Bodyside	est. 40%	Al intensive BIW	39%
2014 Cadillac CTS[3]	Hood, Doors	est. 30%	-	-
2015 Ford F150[4]	Hood, Fenders, Bodyside, Doors	39%	Aluminum BIW on Steel Frame	43%
2015 Cadillac CT6[5]	Hood, Bodyside, Doors, Decklid, Roof	39%	Aluminum/Steel Hybrid BIW	17%
2019 Chevrolet Silverado[6]	Hood, Doors, Tailgate	36%	-	-

1. Bad Nauheim – The all new Range Rover – L405
2. Mass Reduction for Light-Duty Vehicles for Model Years 2017-2025 – NHTSA, 2018
3. A2MAC1 comparing ATS steel doors to CTS aluminum doors
4. EuroCarBody 2015 – F150: The Future of Tough.
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

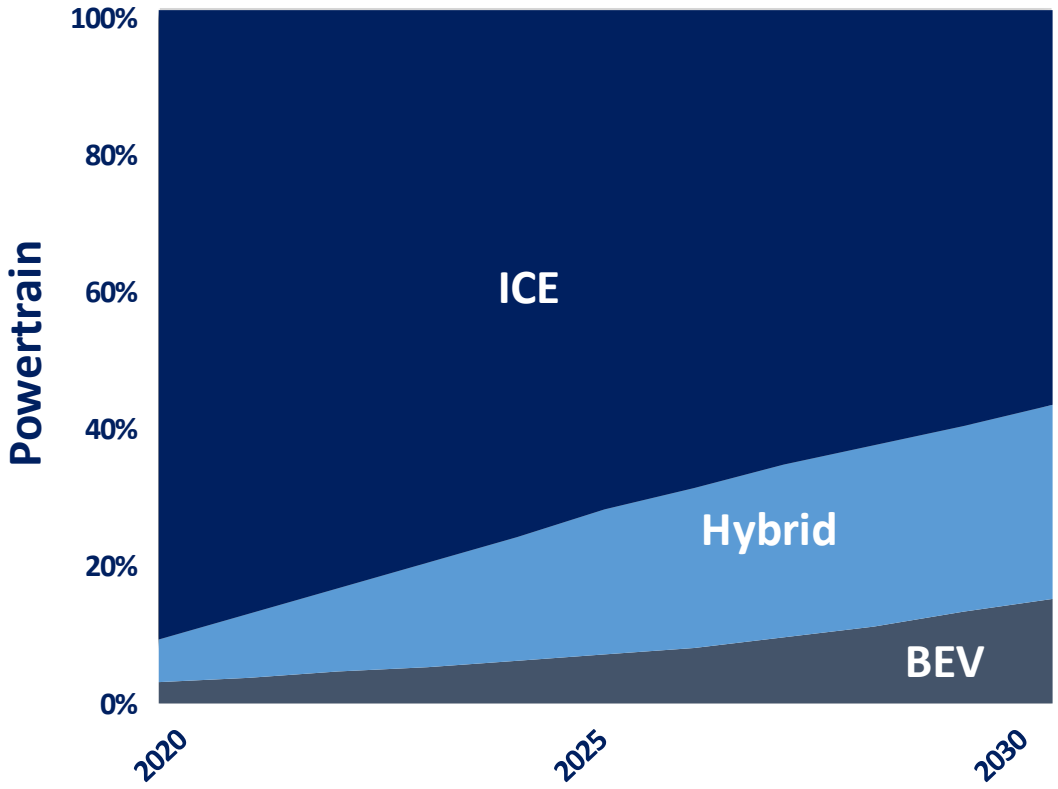
Batteries add weight and will remain heavy:

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:

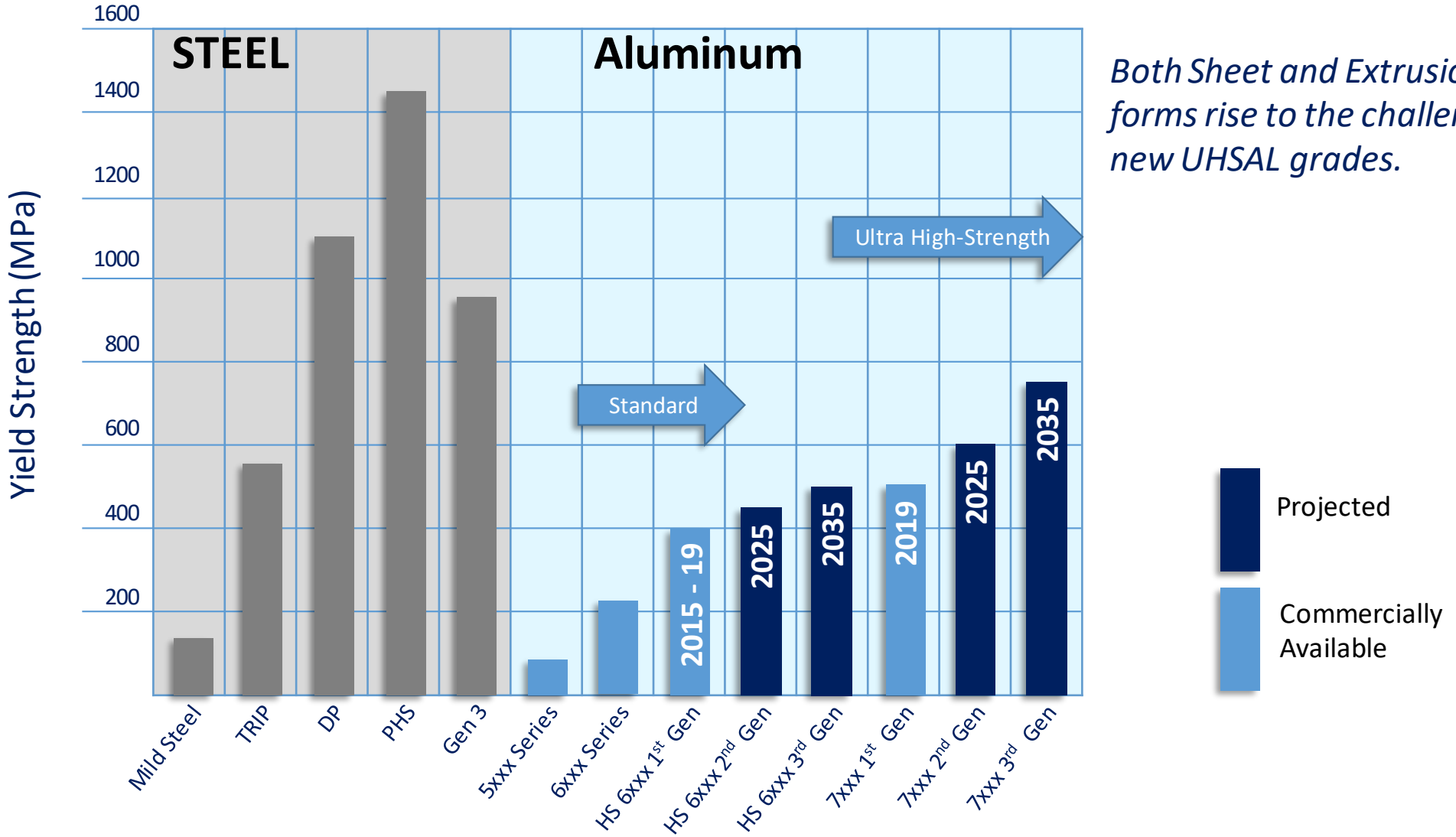
ICE, Hybrid and BEV platform sharing will drive weight addition through due to design trade offs … structure lightweighting can help to offset weight penalty.

ICE Remains Significant[2]



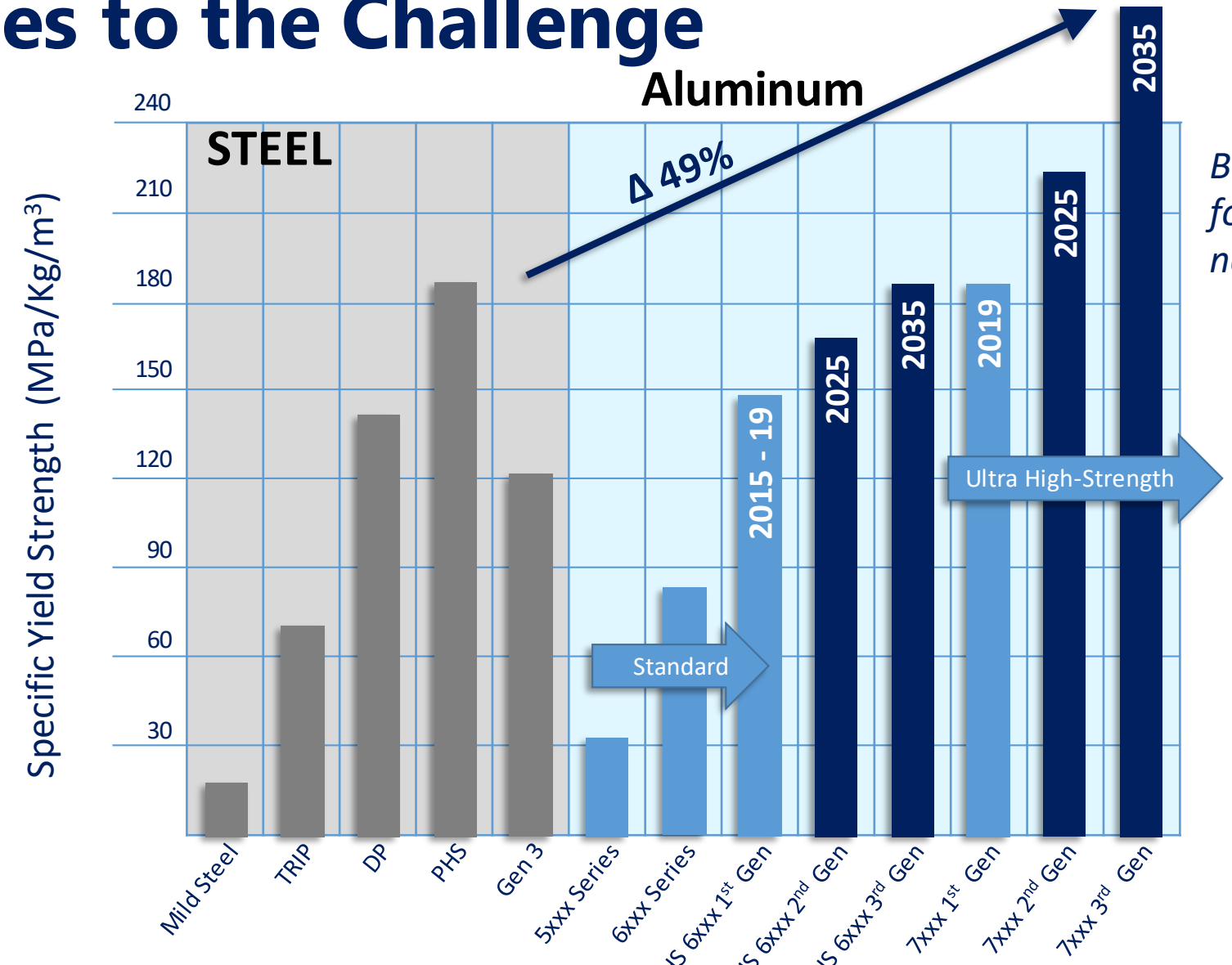
1. Boston Consulting Group (2019)
2. Average of projections from – Boston Consulting Group, US Market (2017), JP Morgan, NA Market (2018), LMC, US Market (2018), Bloomberg New Energy, US Market (2018) and others

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



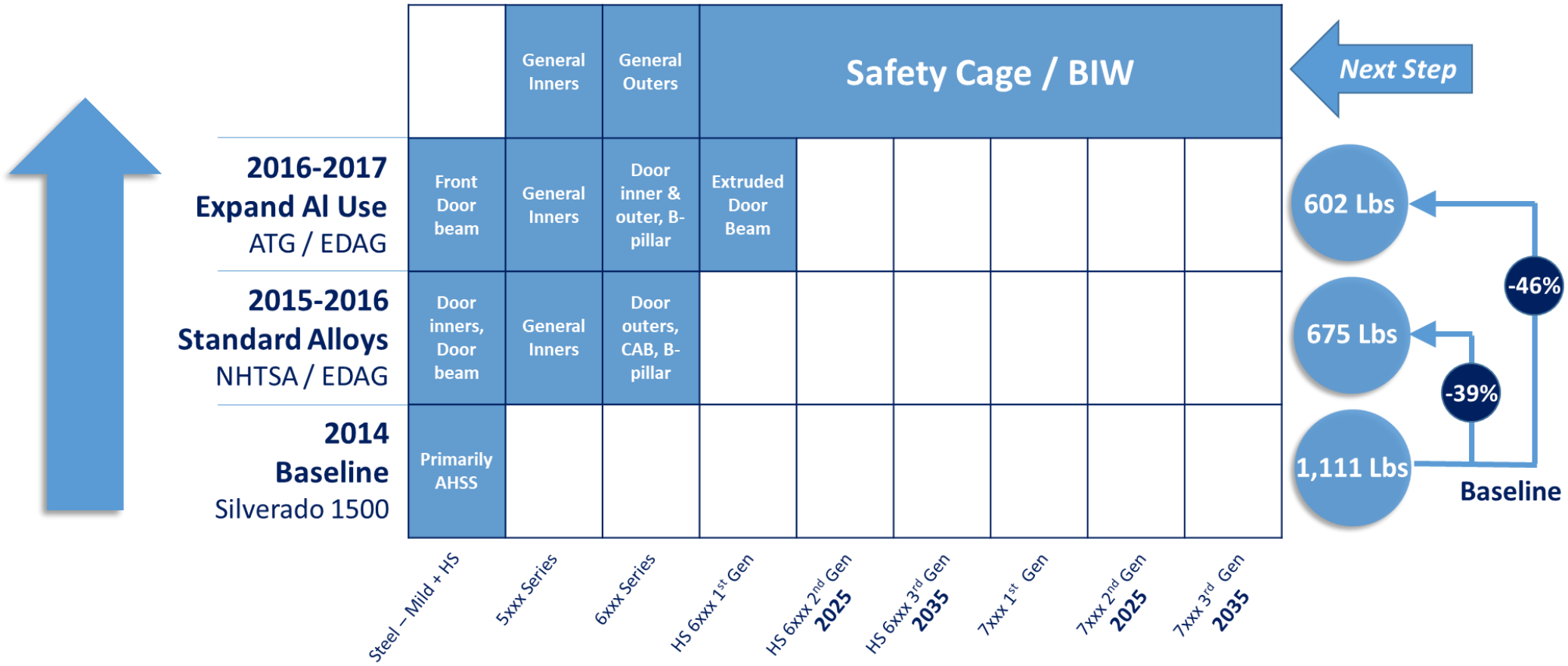
Both Sheet and Extrusion product forms rise to the challenge with new UHSAL grades.

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



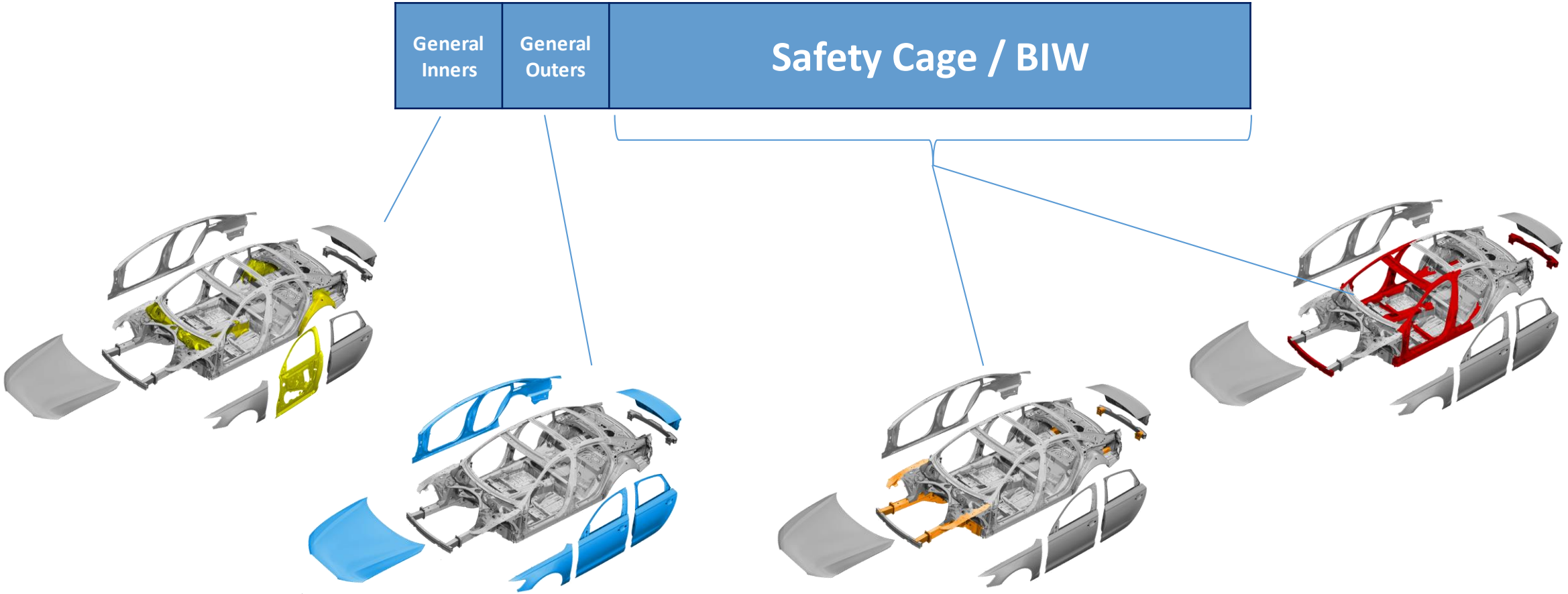
Both Sheet and Extrusion product forms rise to the challenge with new UHSAL grades.

Aluminum Intensive Architectures enabled by Ultra High Strength Aluminum (UHSAL)

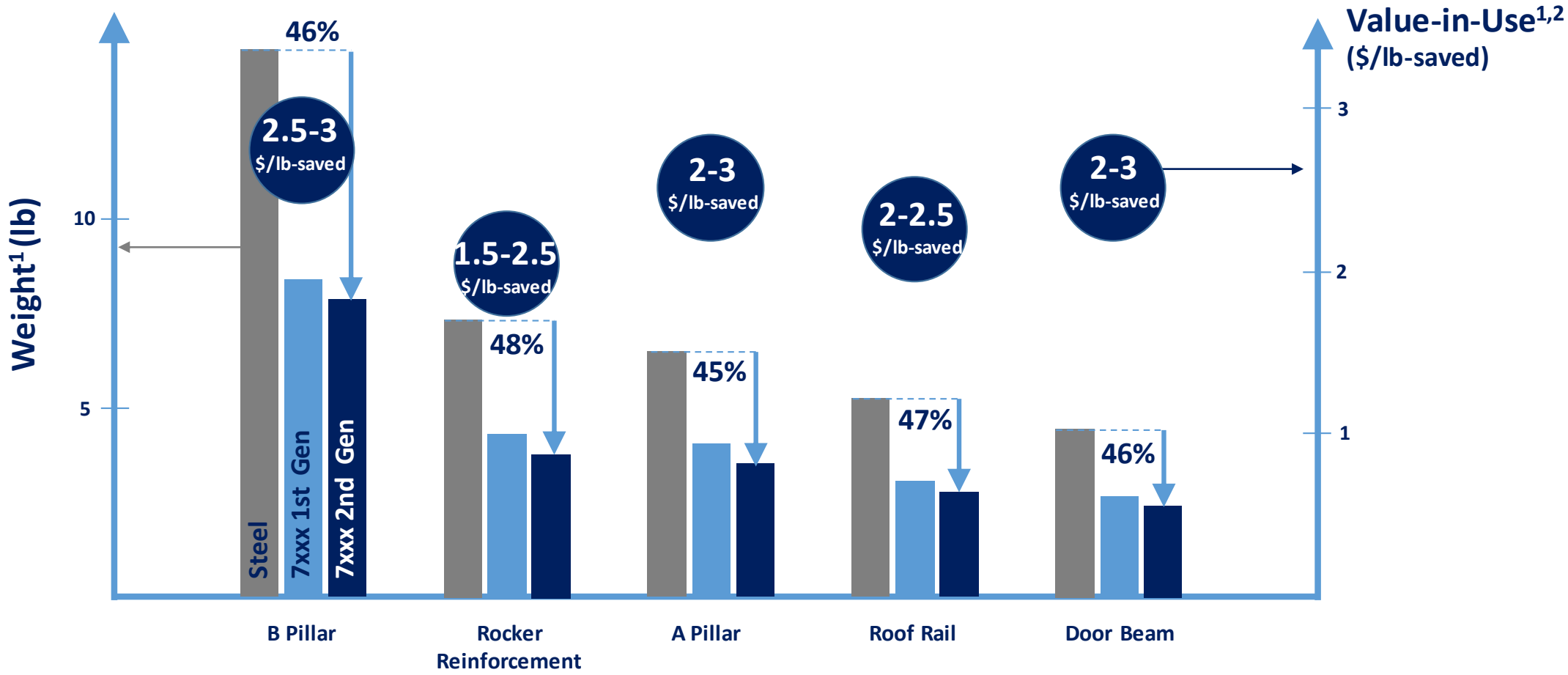


ATG Silverado Lightweighting Study, EDAG, 2017

New High Strength Aluminum (UHSAL) Application Map



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

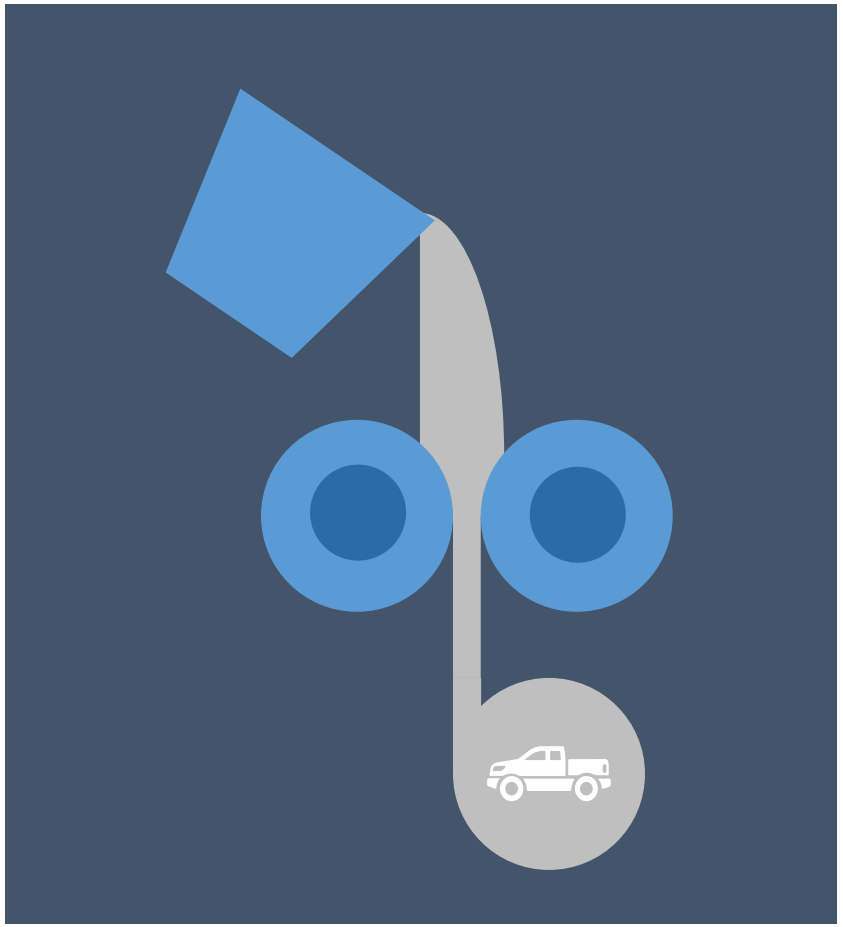
- Continuous Casting
- Tailor Rolling & Welded Blanks
- Optimized Extrusion Design
- Multi-alloy Sheet

20-40%

Value Improvement

Aluminum Continuous Casting will play an important role across the industry by 2035

Continuous Casting opens new possibilities for transformational alloys, CO_2 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%

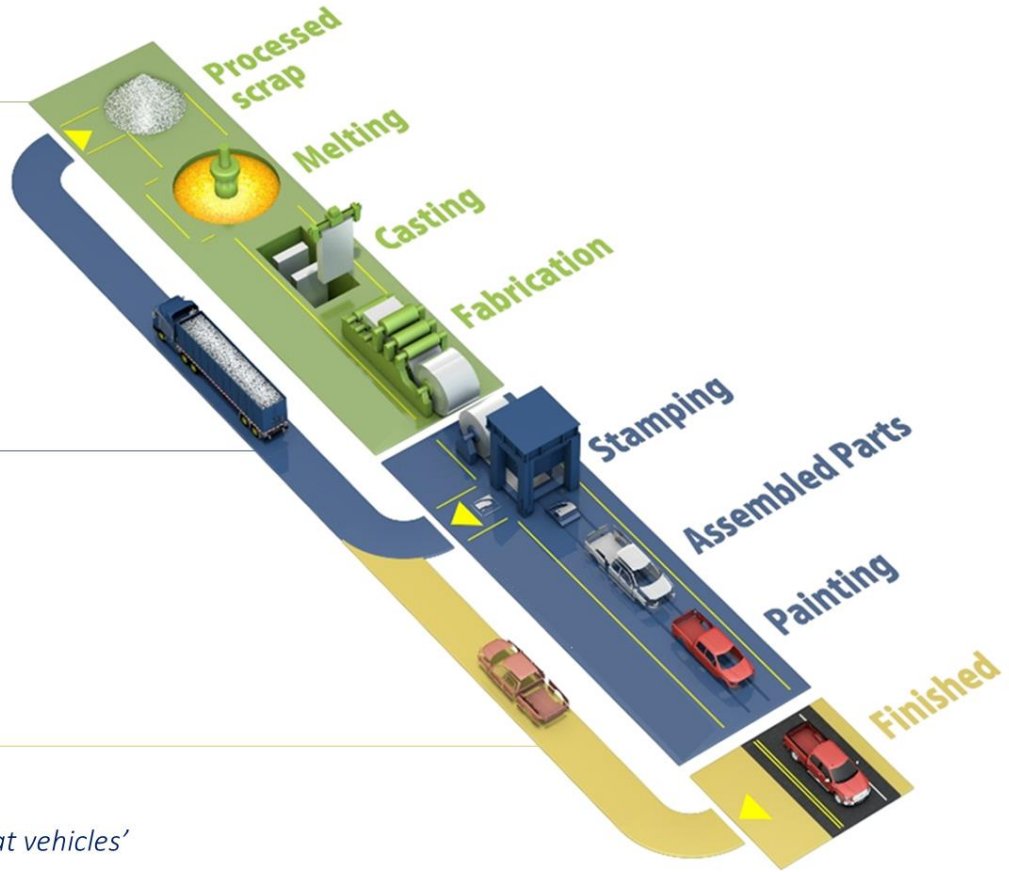
Recycle content for new ***high recycle content*** *grades*

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]



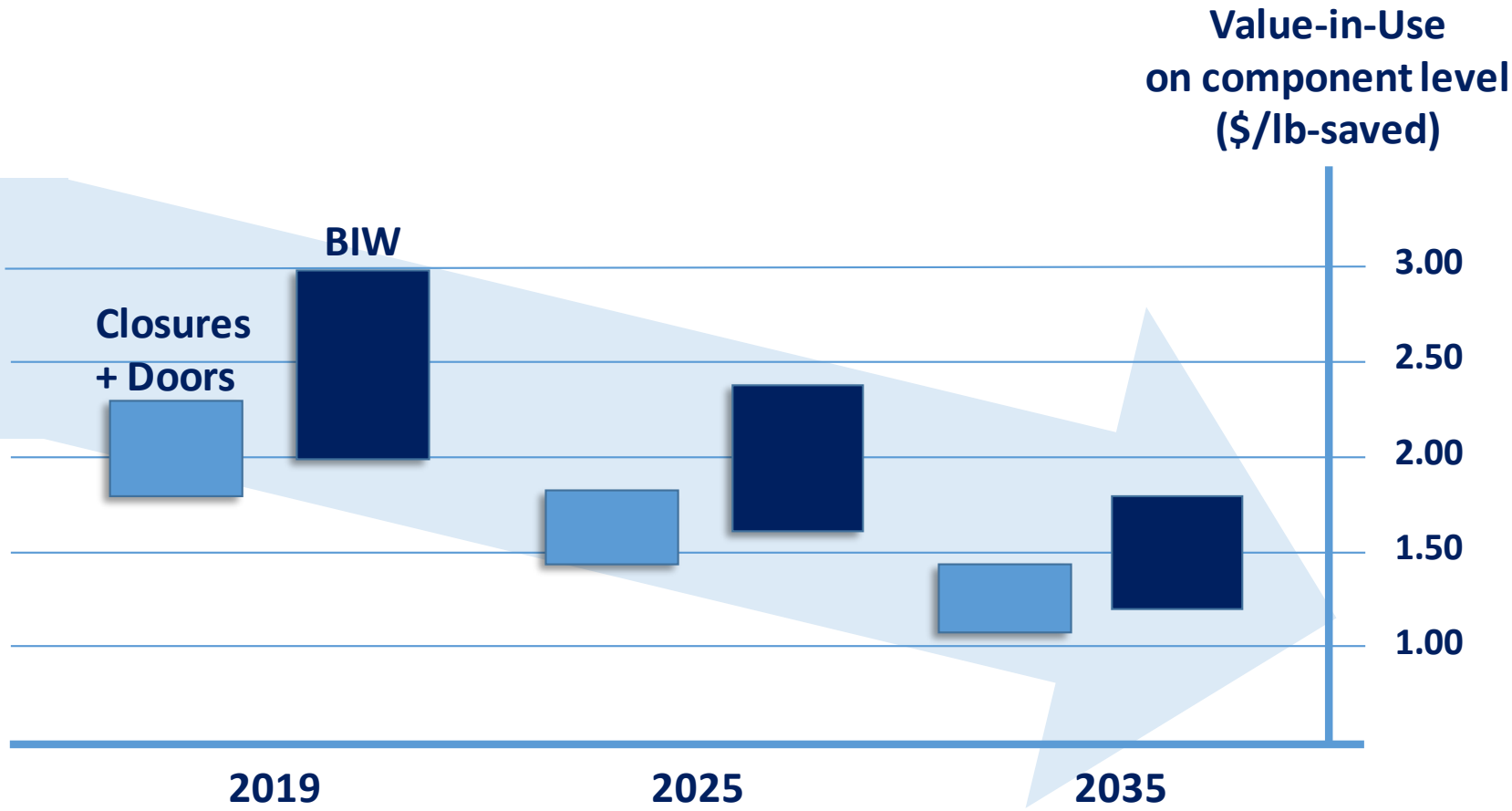
1. Automotive Aluminum Recycling Rate Study, Sean Kelly, Diran Apelian, CR3 Center for Resources Recovery & Recycling

Putting it all together.

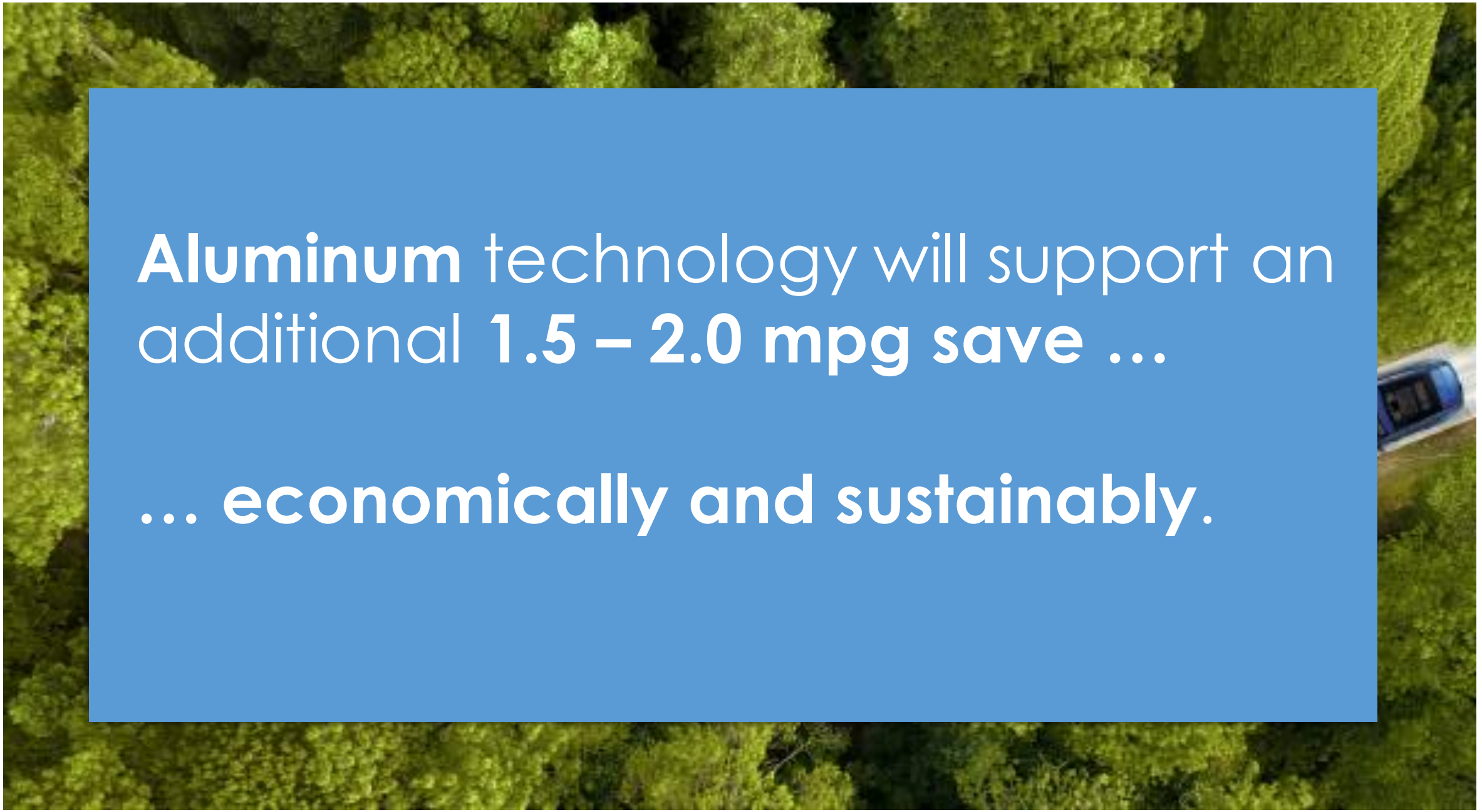
***Less is more**: "Lower" Value-In-Use enables broader use*

Key Drivers of Value

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



2019: Mass Reduction for Light-Duty Vehicles for Model Years 2017-2025, High Strength 7xxx Aluminum Alloys: Design and Business Case for Automotive Applications, Bad Nauheim, April 2019 and Ultralight Door Design, Magna, 2019 – DOE Award # DE-EE0007306
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**.