
ALUMINUM CONTENT IN NORTH AMERICAN LIGHT VEHICLES 2016 TO 2028

Summary Report

July 2017

This Report Has Been Prepared Solely For :



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Ducker & Aluminum Association Project

- The Aluminum Association Auto & Light Truck Group (ATG) commissioned Ducker in October 2016 to determine the latest aluminum content in terms of net pounds per vehicle by vehicle and in aggregate for light vehicles produced in North America in CY 2016 through CY 2020 After 2020, Ducker agreed to provide a range of future aluminum scenarios based on TAR

Data and Information Sources

- Ducker determined that in addition to our methodology of gathering the latest information and opinions on the future from our extensive internal database and network of OEMs and their suppliers, we would use all the latest data available from NHTSA, EPA and other sources such as the Center for Automotive Research (CAR) to establish an independent view of what the technology paths in TAR imply about weight savings by OEM, vehicle type and even specific vehicles beyond 2020
- The theoretical or top down analysis relies primarily on reports and databases provided by the EPA, NHTSA and CAR with insights and input from industry respondents throughout the supply chain

Process, Goals, and Objectives

- The goal of the top down analysis was to determine the weight savings* and material mix solutions implied by the latest government reports and their supporting documents and databases. The top down analysis examined the effect of fuel prices, vehicle mix, secondary weight savings, electrification, vehicle design and vehicle launch cadence on the amount of weight that is expected to be shed by vehicle type to reduce the MY 2015 average vehicle weight by 7% by MY 2025
- The top down analysis is not an attempt to predict what each OEM will do to meet the regulations. It provides a framework of what the regulators believe the OEMs could do to meet the regulations in the safest and most cost effective manner in the time period 2022 – 2025. Average weight savings and material forecasts are only valuable to create a frame work. Vehicle segment analysis and where possible, specific vehicle weight savings are the key to the success for both the top down and bottom up analyses. NHTSA and the EPA have established slightly different weight reduction goals for 2025 and beyond. The average of the targets amounts to a reduction of 270 net pounds per vehicle or 7% compared to the average vehicle weight of MY 2015. The NHTSA technology path to achieve 7% is highly vehicle specific, and was critical to the Ducker analysis of material substitution options after 2020
- The regulation driven weight reduction goals vary by type of vehicle and by OEM. Less than 25% of the vehicles have to contribute 50% of the total savings. Pickup trucks, large cars and SUVs, minivans and electric vehicles will bear most of the burden. Nearly 20% of the vehicles are likely to reduce mass by 20% while an equal number of vehicles are likely to reduce mass by less than 7.5% according to NHTSA Technology Path in Chapter 13 of the Technical Assessment Report (TAR)

**All weight savings references in the report are the direct savings from material substitution. Under the assumption that weight creep increases and secondary weight savings and engine resize weight decreases offset each other, the material sum after substitution is the equivalent of curb weight*

EXECUTIVE SUMMARY



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This study is organized in two segments, 2015 to 2020 and Scenarios beyond 2020

- Mass reduction initiatives are influenced by CAFE regulations, consumer preferences, fuel prices, and OEM objectives. The CAFE regulation through 2021 is firm and the other influencing factors are recognized by OEM and in near-term reflected vehicle programs. Most vehicle programs through 2020 have been finalized, or are nearing final production commitments. The 2015 to 2020 section is the result of a detailed “Bottom up” model and component analysis of production vehicle materials content
- CAFE regulations have a major impact on mass reduction initiatives. Regulations after 2021 are currently the subject of the “Mid-Term Review” process and will have a draft regulation expected in April 2018. Content and timing of different Fuel Economy, CO2 levels and timing of future levels are being considered by OEMS and Regulators. To address that uncertainty, Ducker evaluated potential automotive materials utilization under three different mass reduction and timing assumptions:

Current Proposed Regulation	7% *Mass Reduction by 2025
Most Likely OEM Compromise	7% *Mass Reduction by 2028
Market Driven Solution (no CAFE regulation)	4.5% *Mass Reduction by 2028

**-based on 2015 average curb mass of 3834 Lbs.*

- Ducker believes that future CAFE regulations will be within the range defined by these bounds

Major Findings – 2020

- Aluminum content forecast for 2015 to 2020:

	2015	2020
Average Aluminum Pounds per Vehicle	397	466
% Share of Curb Mass per Vehicle	10%	13%
Average Curb Mass Pounds per Vehicle	3835	3735

- Fifty percent of total aluminum content growth over the next five years will be driven by aluminum for closures, crash management, steering knuckles and structural vacuum die cast parts
- Aluminum content by vehicle segment in 2020 will range from 262 pounds per vehicle in the A/B segment passenger cars to over 550 pounds per vehicle for the average pickup truck. The average passenger car will contain 362 pounds of aluminum and the average light truck will contain 523 pounds of aluminum by 2020
- The average aluminum content for five OEMs in 2020 will be over 600 pounds per vehicle

Sheet Growth Trends - 2020

- Aluminum sheet for closures is expected to increase from 23 pounds per vehicle in 2015 to 61 pounds per vehicle in 2020, or over 2.5 times in five years which is more growth for closures than expected
- Aluminum hood penetration will increase from 50% in 2015 to 71% in 2020. Penetration for doors will increase from less than 5% in 2015 to slightly over 25% 2020. Hoods will account for 25% of the of the total 2020 closure weight, and doors will be 43%. Other than the Tesla Model S, there were essentially no aluminum doors in North American produced vehicles prior to 2014
- At current production levels that equates to 1.06 million tons (or 2.1B lb.'s) of gross sheet consumption including process scrap (blanking scrap, stamping scrap, etc.). Aluminum sheet for Body-in-White (BIW) components is expected to increase from 14 pounds per vehicle in 2015 to 26 pounds per vehicle, an increase of 83% from 2015 to 2020. Closure and BIW sheet combined will reach 87 pounds per vehicle by 2020

Extrusion Growth Trends - 2020

- Total extruded product content including shapes, tube, rod and bar increases from 36 pounds per vehicle in 2015 to 49 pounds per vehicle in 2020. Aluminum extrusions for crash management parts are expected to increase by nearly six pounds per vehicle, up 65%. Extruded BIW components are expected to increase by 4.4 pounds or 100% by 2020. Bumper beam penetration will increase from 33% in 2015 to 54% in 2020

Casting / Forging Growth Trends - 2020

- Aluminum vacuum die castings (structural HPDC) for body components and sub-frames are expected to increase from 2.6 pounds per vehicle in 2015 to 14.4 pounds per vehicle in 2020, significantly more than expected
- Aluminum castings and forgings for steering knuckles will increase from 12.1 pounds per vehicle in 2015 to 16.4 pounds per vehicle in 2020 or 35% over the period
- Overall aluminum forgings grow from 7.9 pounds per vehicle in 2015 to 9.3 pounds per vehicle in 2020, while all casting content (HPDC, PM, Sand, others) will decline from 285.8 pounds per vehicle to 153.8 pounds per vehicle. Most of the declines come from content losses from powertrain and drivetrain castings

Mass Reduction Scenarios: 2021 - 2028

- Based on EPA and NHTSA technology implementation pathways, mass reductions from zero percent for some passenger cars and small SUVs to 20% for large trucks and SUVs is technically feasible and required to achieve an overall industry average mass reduction of 7% (270 pounds) from 2015 to 2025 and beyond
- Vehicle launch cadence is a critical factor influencing the pace of new technology adoption. The next launch of a high volume vehicle with significant aluminum BIW content is 2024. A plethora of vehicles with significant aluminum body content are expected to launch within the 2024 – 2028 timeframe further indicating the need to examine attainment of mass savings goal beyond 2025
- A total mass savings of 270 pounds is the goal for 2025; however, the weight savings achieved from 2015 to 2020 will only be 100 pounds leaving 170 pounds to be removed from 2021 to 2025. Empirical evidence from Ducker’s research with OEMs and their suppliers suggests achieving the 7% curb mass reductions is likely to be delayed to 2028 due in part to practical new model launch timing constraints
- Under all the scenarios, aluminum contributed to more than 50% of the total mass reduction ranging from 270 pounds (7% MR) to as little as 170 pounds (4.5% MR) by 2028
- Closures are the most consistent high growth application for aluminum under all scenarios. Crash management, steering and chassis aluminum parts don’t vary a great deal under the three mass reduction scenarios. Like closures, these components are very compatible with vehicle utilizing steel within its BIW
- Net increase in aluminum content in all scenarios includes a decline of 12 pounds per vehicle in aluminum powertrain content after 2020

7% Mass Reduction Scenarios

- Ducker believes the 7% average mass reduction (270 pounds) by 2028, with nearly five million vehicle with 850 pounds of total aluminum content or greater is the most likely scenario.
- The 7% Mass Reduction Scenario uses the TAR as a guideline and requires a multi-material substitution strategy with significant quantities of aluminum, AHSS/UHSS, magnesium and some CFRP applied after 2020. Achieving the 7% goal requires nearly 5 million vehicles with a weight reduction of over 10% and a high content of aluminum BIW parts and all the pickup trucks and large SUVs with 15% to 20% mass savings
- Material content for mass reduction of 7% by 2025, or 7% mass reduction by 2028 are the same. The major difference is the technology implementation rates and the available vehicles for mass reduction based on vehicle model cadence
- In the 7% Mass Reduction scenarios, multi material / multi product BIW structures were assumed to be much more prevalent than all-aluminum body structures, and less prevalent than all-steel body structures in 2025 and 2028
- There were several parts identified as High Growth Aluminum parts and include: closures, BIW structures, crash management, sub-frame,/cradle, cross members and steering parts
- The 7% Mass Reduction (2025 or 2028) scenarios will result in:
 - Total aluminum content growing to 565 pounds per vehicle (16% of curb mass)
 - Aluminum share of curb mass growing from 10% in 2015 to 16% by 2028
 - Nearly 25% of 2028 vehicles having partial aluminum BIW and in some cases complete BIW. 2.1 million of those vehicle will be pickup trucks and 400,000 will have PHEV/ZEV powertrains

7% Mass Reduction Scenarios Continued

- Aluminum closures will grow to over 100 pounds per vehicle and 85 pounds per vehicle under 4.5% MR scenario)
- Thirty five critical vehicle programs will account for 25% of total vehicle production. These vehicles will provide over 50% of all weight savings from material substitution
- Aluminum stamped BIW parts will grow to 61 pounds per vehicle, but will drop to only 34 pounds per vehicle under the 4.5% MR scenario. Stamped aluminum BIW parts only grow under the need for significant mass reduction. Body extrusions display a similar pattern to body stampings
- Vacuum Die Castings are the most secure aluminum parts for BIW structures due to the parts consolidation available with VDC
- Steel, magnesium, CFRP and polycarbonate additions are critical, however, aluminum BIW and closure parts are the key to success for reaching the 7% MR goal sometime in the next decade

4.5% Mass Reduction Scenario

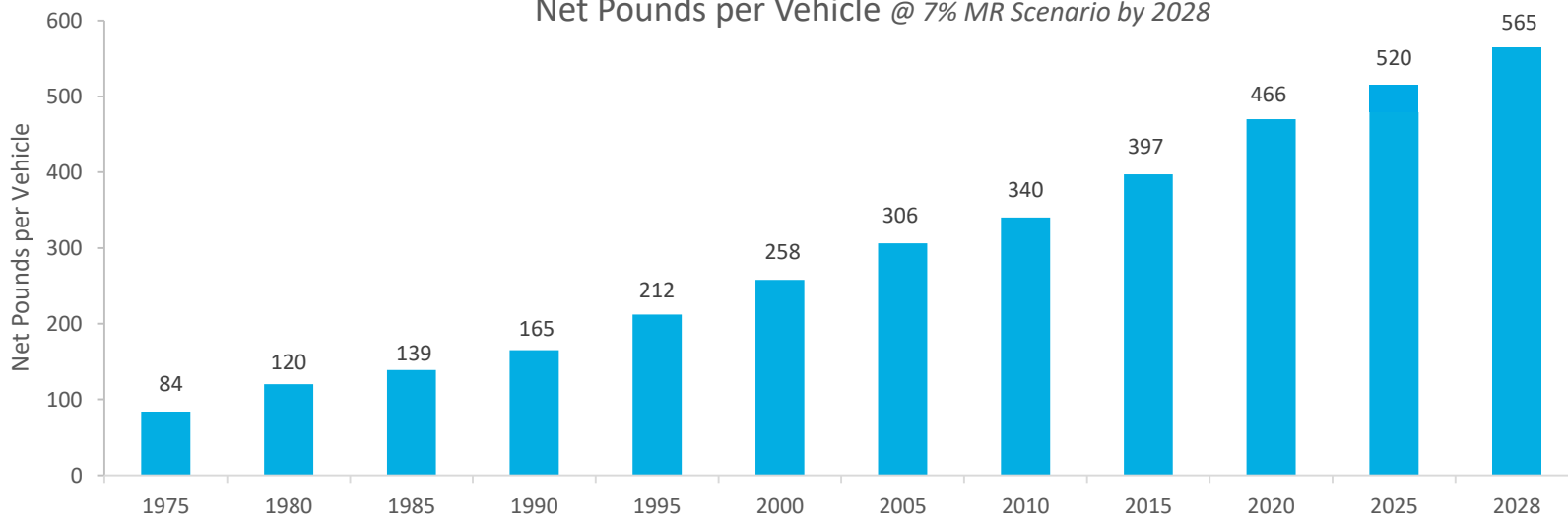
- A 4.5% Mass Reduction scenario reflects a more “market driven” scenario with less aluminum and polymer composites in the BIW. This scenario adds less than one million vehicles with a 10% weight savings after 2020
- The 4.5% MR scenario by 2028 results in total aluminum content of 494 pounds per vehicle, or only 28 pounds per vehicle over 2020
- Aluminum closures will grow to over 85 pounds per vehicle from 62 pounds per vehicle in 2020

Under all mass reduction scenarios, aluminum content in North American light vehicles will continue to show uninterrupted growth well into the next decade. The 7% mass reduction scenario by 2028 achieves an average addition of 15 pounds of aluminum content annually from 2015 onward.

55 Years of Uninterrupted Growth

North American Light Vehicle Aluminum Content

Net Pounds per Vehicle @ 7% MR Scenario by 2028



Source: Ducker Analysis 1Q2017

STUDY FINDINGS – ALUMINUM 2020



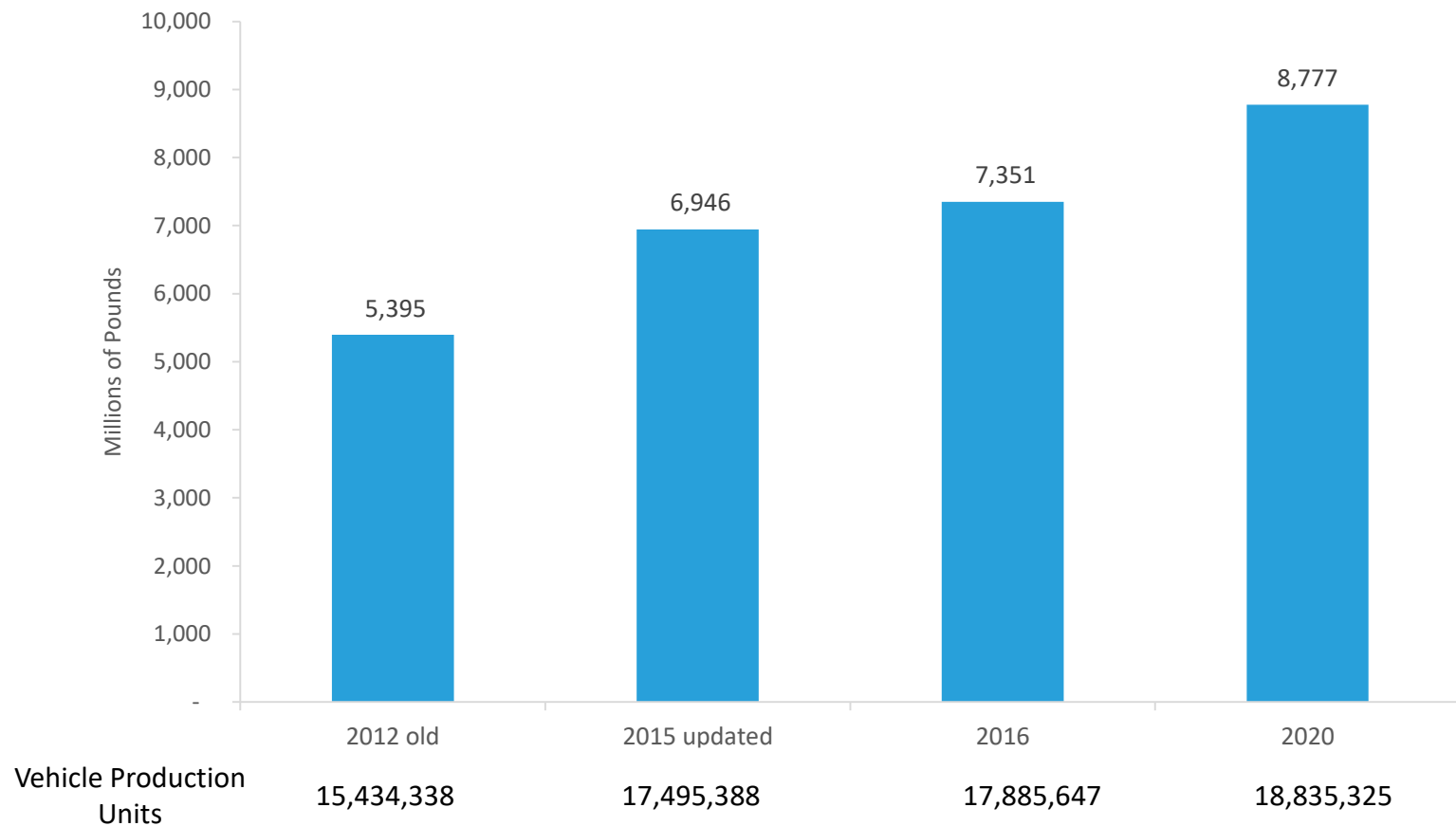
DUCKER WORLDWIDE

The growth for aluminum over the next five years has been analyzed and determined by a vehicle by vehicle, bottoms-up, additions and changes, based on primary research.

- The North American auto industry will achieve mass reduction of 100 pounds, (a reduction of 2.6%) compared to total vehicle weight of 3835 pounds in 2015. Aluminum will contribute 57 direct pounds
- Total aluminum content for 2020 will reach 466 pounds. This is an increase of 69 pounds from 2015
- Other aluminum parts will decline in weight by 9 pounds due to losses in engine size including the number of cylinders needed to maintain the current horsepower to weight ratio.
- The principal growth product for aluminum will be sheet for aluminum closures. For example, aluminum hoods will grow from 50% penetration today to over 71% penetration by 2020
- Total aluminum BIW & Closure sheet content for 2020 will be 1.63 billion pounds. The gross requirement could be as much as 2.42 billion pounds (1.1 million metric tons). Aluminum vacuum die castings will grow from less than 3 pounds per vehicle in 2015 to 14 pounds per vehicle by 2020. These thin-walled castings will be used on several new platforms as a replacement of steel stampings and in competition with aluminum stampings and some applications for extrusions
- After 2020, Ducker looked at different scenarios for aluminum auto growth in the next decade

Total North American light vehicle aluminum consumption will increase 29% in 2015 over 2012; this will increase another 6% in 2016 over 2015. Consumption in 2020 will surpass any records set before 2012 by nearly 3.5 billion pounds. This increase is an equal combination of more vehicles and aluminum content per vehicle.

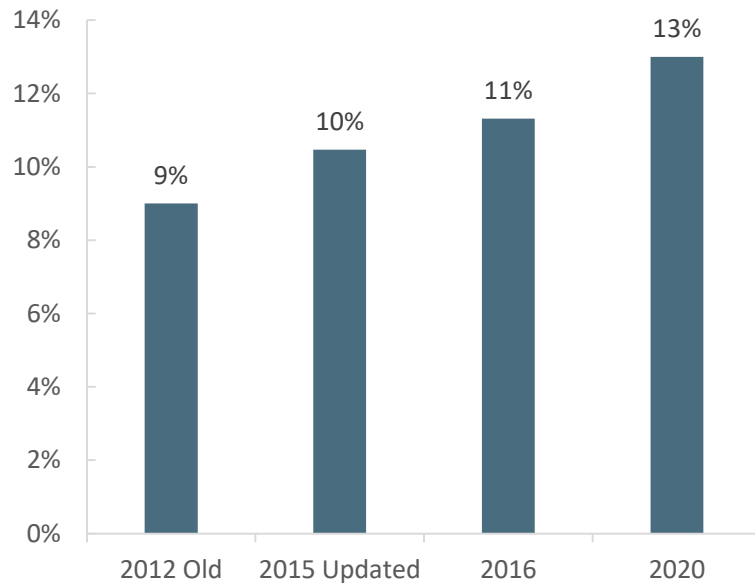
Total Aluminum Content for Light Vehicles



Source: Ducker Analysis 1Q2017

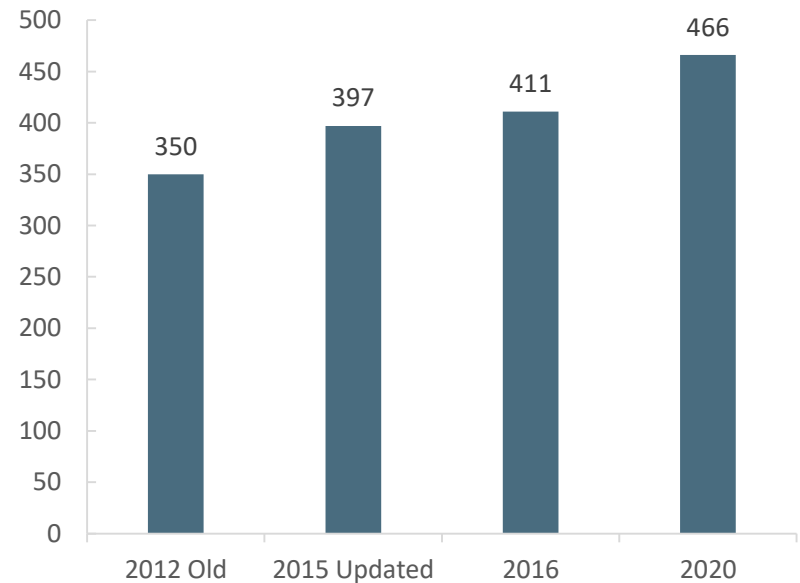
Aluminum's share of the curb weight in 2015 is 10%, compared to 9% in 2012. Aluminum's share of the curb weight in 2016 is 11%.

Aluminum Share of Curb Weight



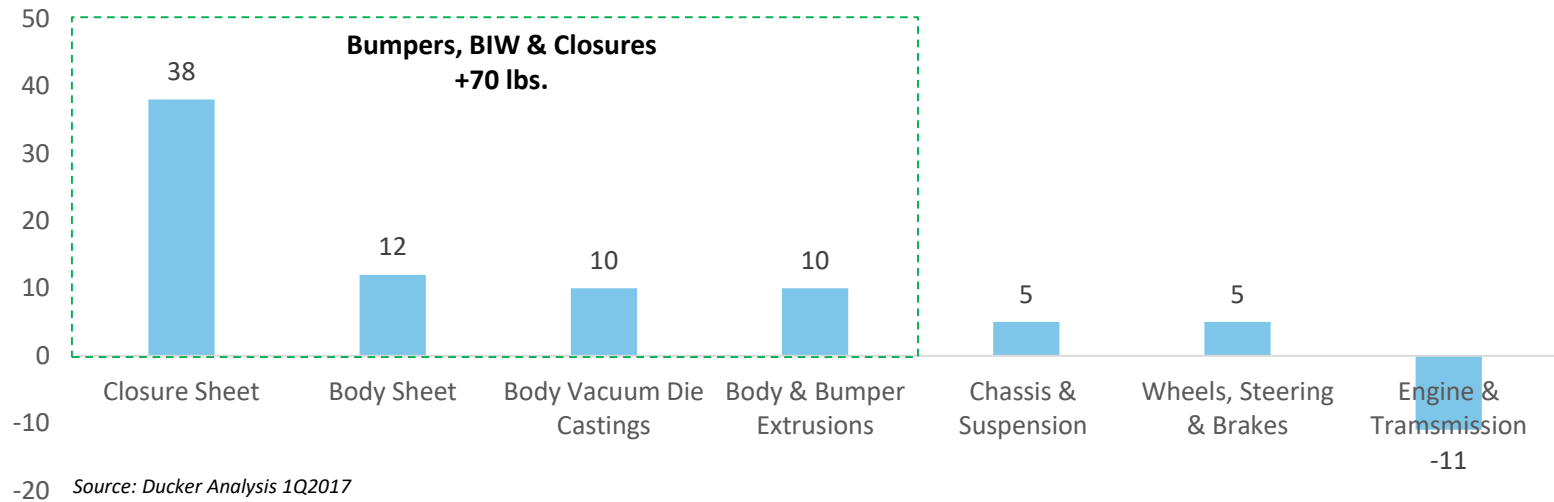
Source: Ducker Analysis 1Q2017

Avg. Aluminum Content in Pounds per Vehicle

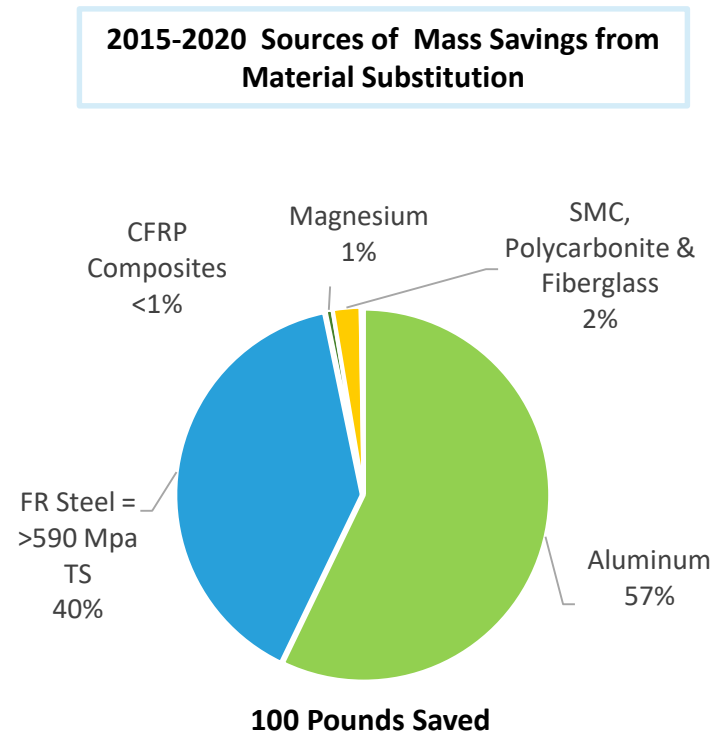


Large content increases for closures, body-in-white parts and crash management parts are driving nearly 69 pounds of net aluminum content growth from 2015 to 2020. However, even when combined with over 150 pounds of growth for AHSS/UHSS steels, the mass savings will only be 100 pounds or 2.6% from 2015 to 2020.

Component or System Changes for Aluminum Content in 2015 versus 2020



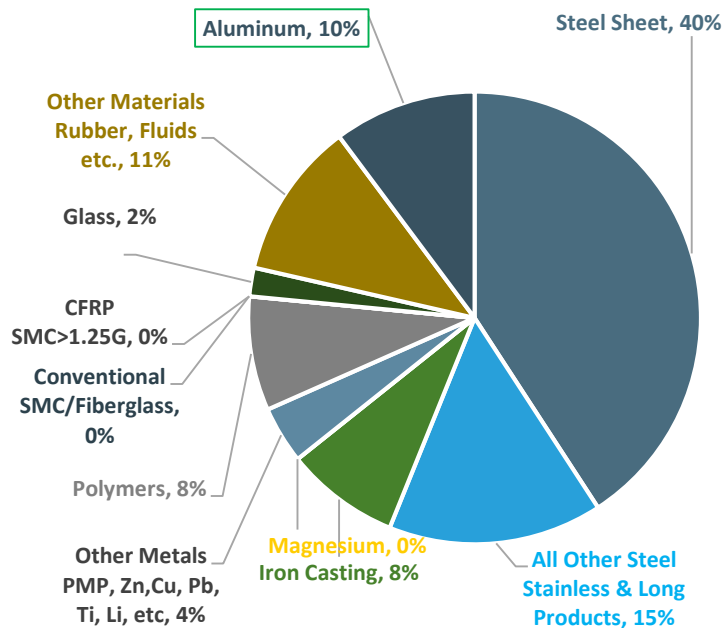
Most of the major material decisions have been made for vehicles to launch in the next four years. Those decisions reveal that advanced grades of high strength steels and aluminum will be added to achieve a mass savings from material substitution of approximately 100 pounds.



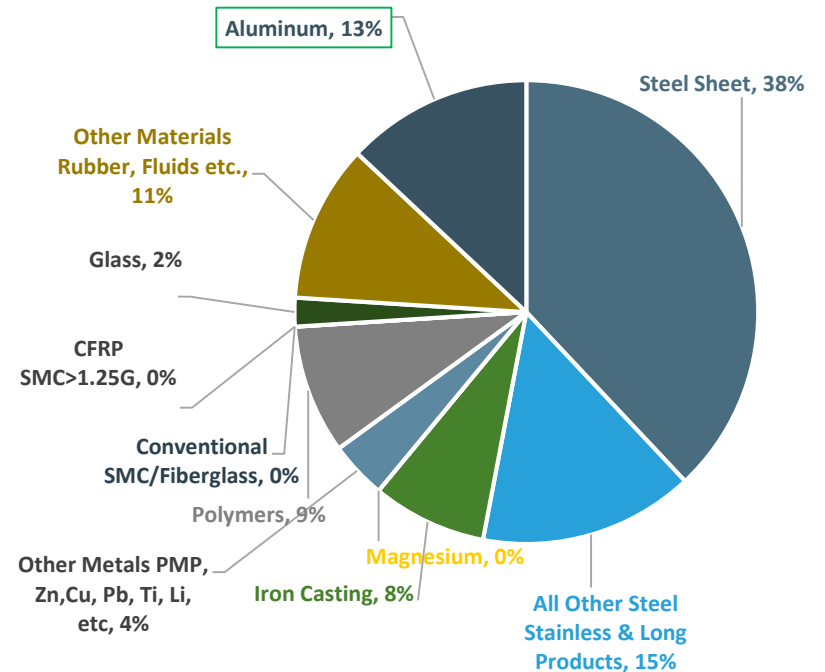
Source: Ducker Analysis 1Q2017

Light Vehicle Material Mix shows aluminum will grow to 13% of total weight by 2020, and the mass savings will be 100 pounds with over 50% attributable to aluminum substitution for steel.

2015 CURB WEIGHT 3835 LBS



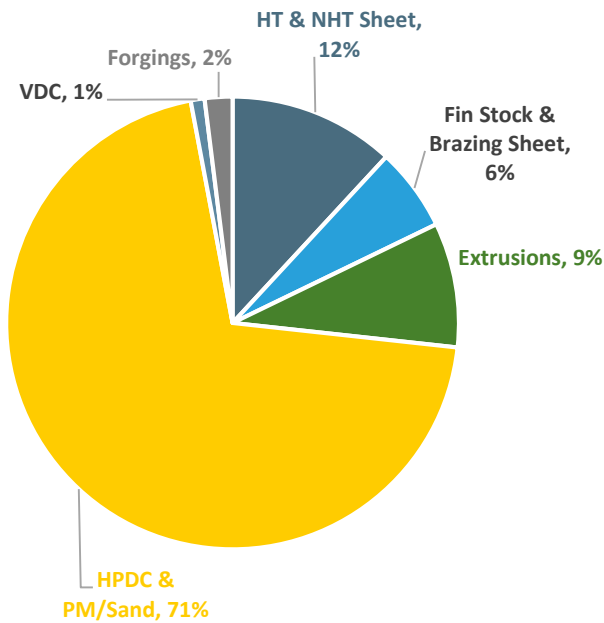
2020 CURB WEIGHT 3735 LBS



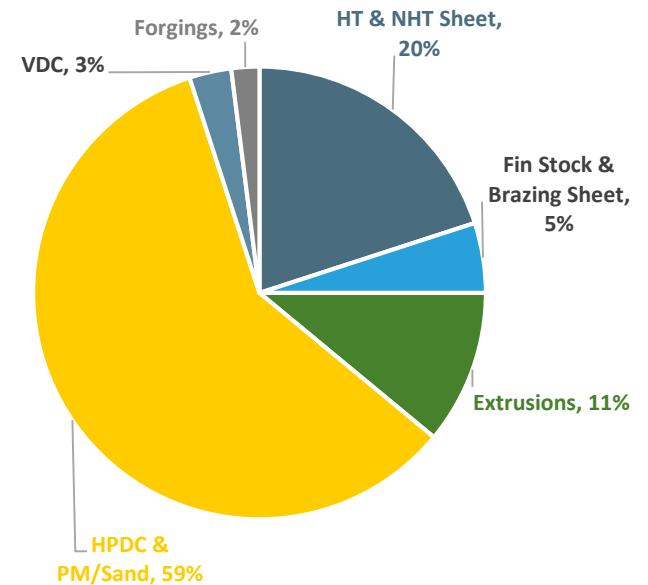
Source: Ducker Analysis 1Q2017

Mill products and vacuum die castings will increase their share of all aluminum products from 29% in 2015 to 41% in 2020, as conventional HPDC, permanent mold and sand castings lose share.

2015 | 397 LBS



2020 | 466 LBS



Source: Ducker Analysis 1Q2017

COMPONENT ANALYSIS

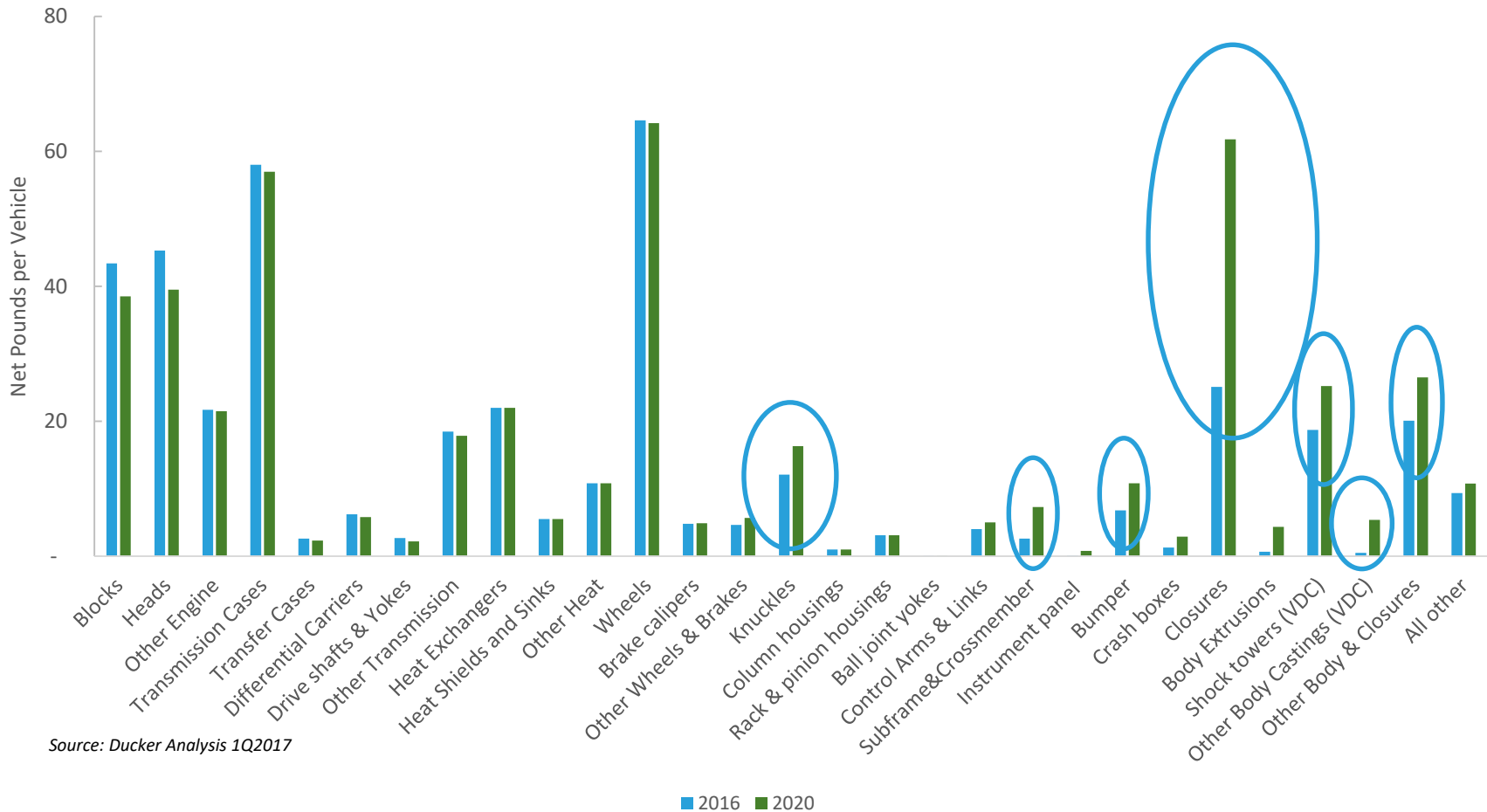


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2016 VS. 2020 COMPARISONS

We can summarize the nearly 100 individual components being tracked into approximately 30 key components or systems. The key components for growth are indicated.

Light Vehicle Aluminum Content by Key Components and Systems



Source: Ducker Analysis 1Q2017

■ 2016 ■ 2020

VEHICLE SEGMENT ANALYSIS



DUCKER WORLDWIDE

VEHICLE SEGMENT ANALYSIS: ALUMINUM 2020

In 2020 the A/B Segment and VANs have decline in aluminum content overall due to downsize in aluminum castings primarily from the engine and other powertrain applications.

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

A/B Segment
Fiat 500
Ford Fiesta



240.6 lb.'s

3% of Production

MPV Segment
Honda Odyssey
Chrysler Pacifica



399.7 lb.'s

3% of Production

C Segment
Ford Focus
Honda Civic



278.4 lb.'s

15% of Production

SUV Segment
Chevy Suburban
Jeep Grand Cherokee



475.1 lb.'s

41% of Production

D Segment
Chevy Malibu
Dodge Charger
MUSTANG



447.6 lb.'s

17% of Production

VAN Segment
Dodge Sprinter
Ford Transit



338.9 lb.'s

2% of Production

E Segment
Daimler E Class
Cadillac CT6



490.0 lb.'s

2% of Production

PUP Segment
Ford F150
Toyota Tundra

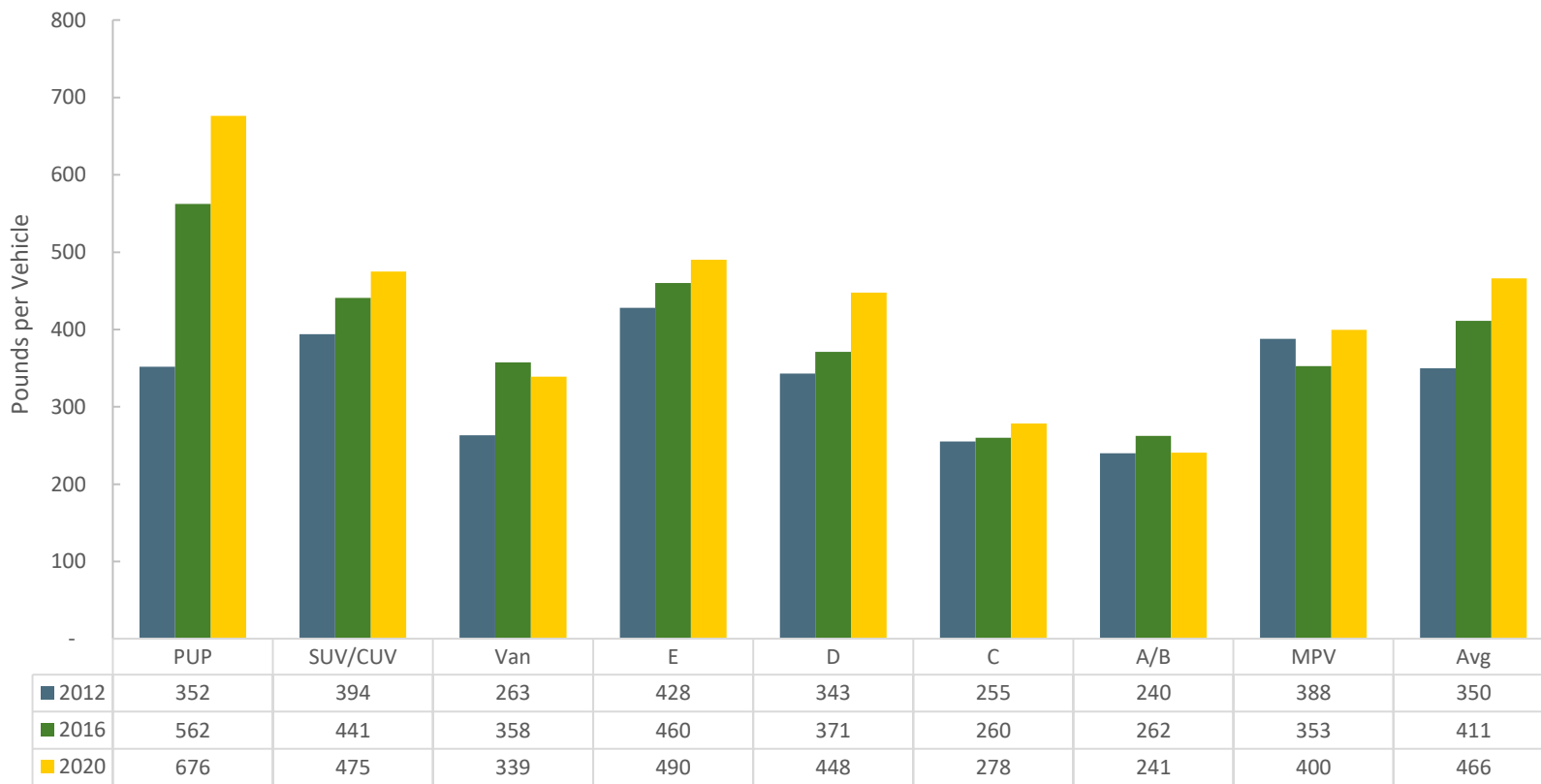


676.3 lb.'s

17% of Production

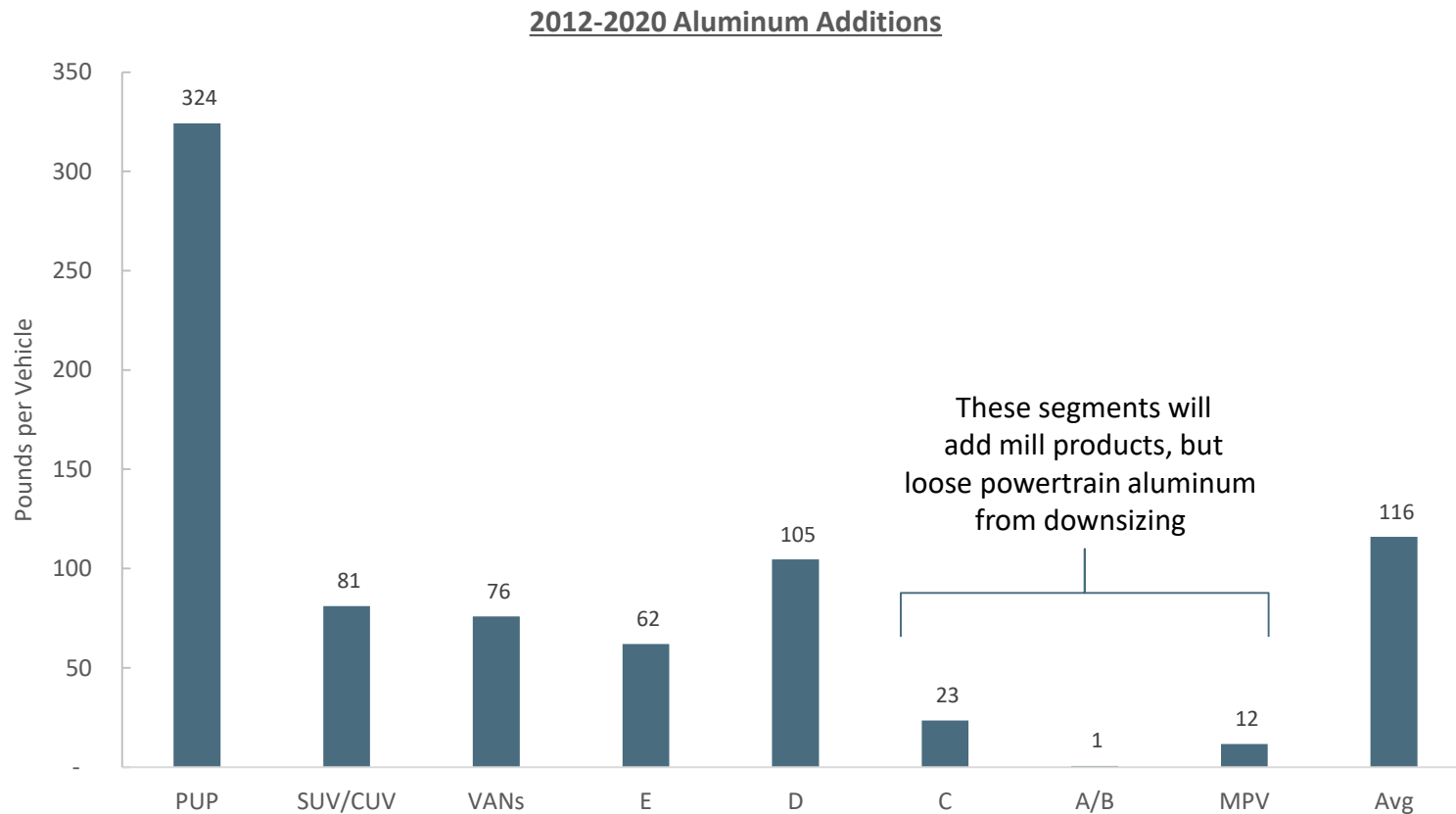
The average vehicle will add nearly 55 pounds of aluminum content between 2016 and 2020; PUP Segment will add the most aluminum with 114 pounds expected.

Aluminum Content by Segment

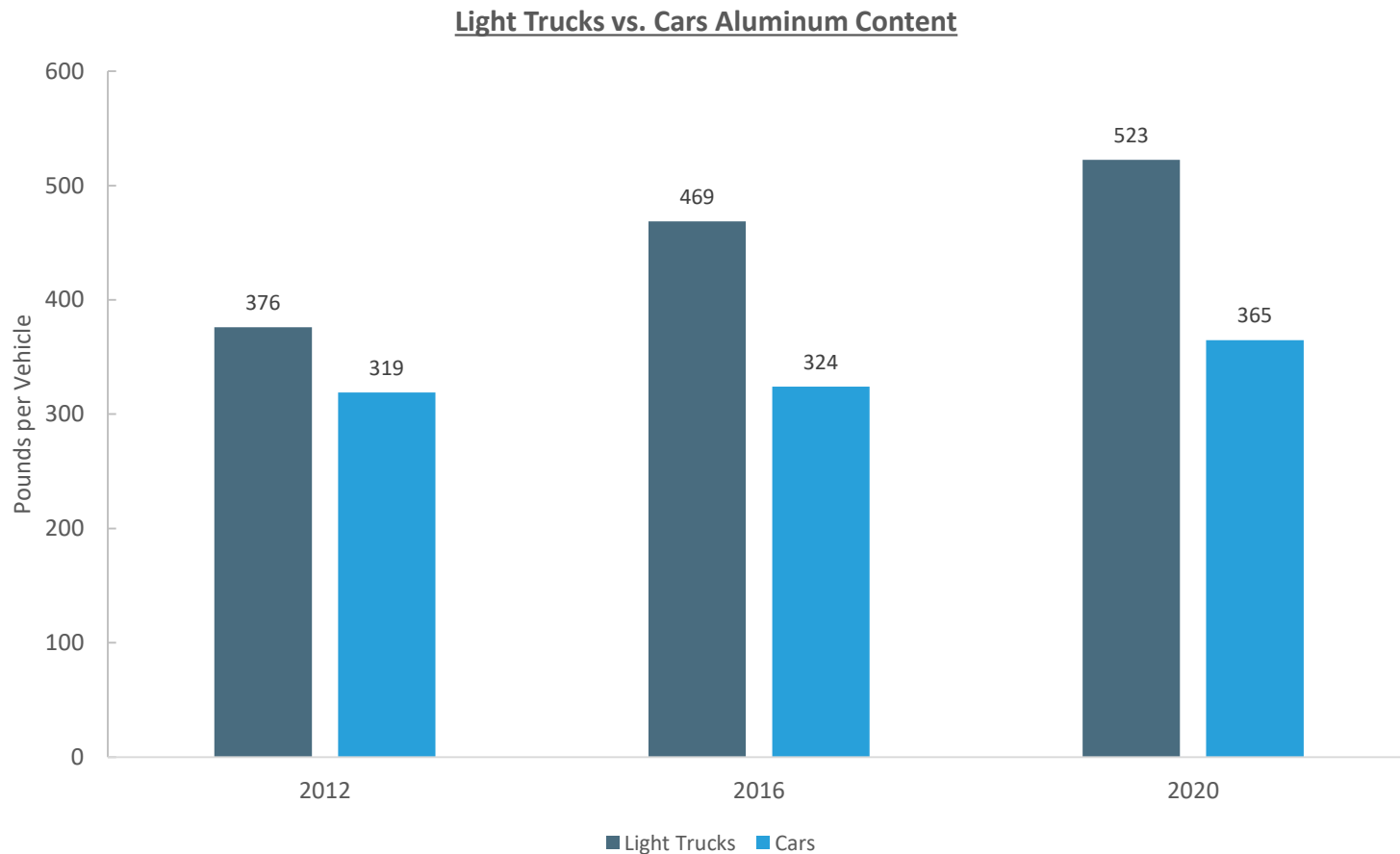


VEHICLE SEGMENT ANALYSIS: ALUMINUM 2020

Between 2012 and 2020, North American light vehicles add as much as 300 pounds for pickup trucks to less than 50 pounds for small cars and full size vans.



Light trucks (pick ups, SUVs, vans and multipurpose vehicles) will add 150 pounds of new aluminum content from 2012 to 2020. These vehicles need to rely on weight savings for fuel economy improvement than cars. Passenger cars will only add approximately 50 pounds of new aluminum over the same period.



MASS REDUCTION SCENARIOS AFTER 2020



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Duckers study and model is based on OEM and supplier tendencies and outlook and is further unconstrained by material bias.

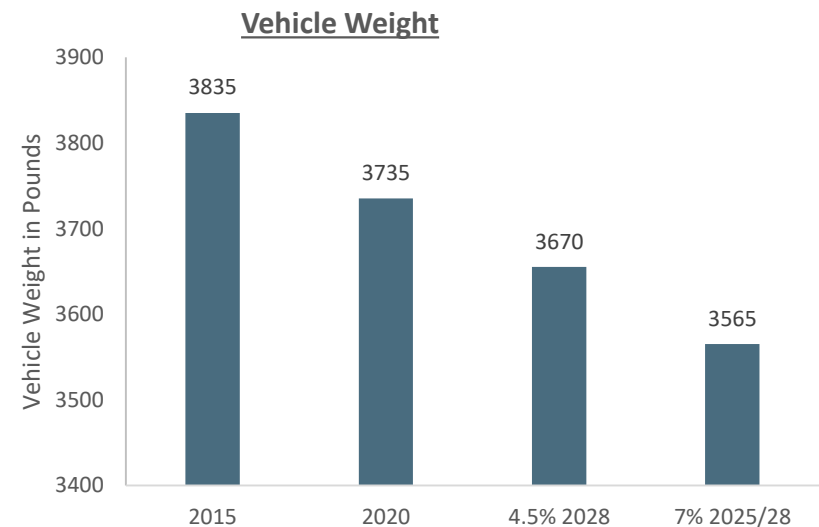
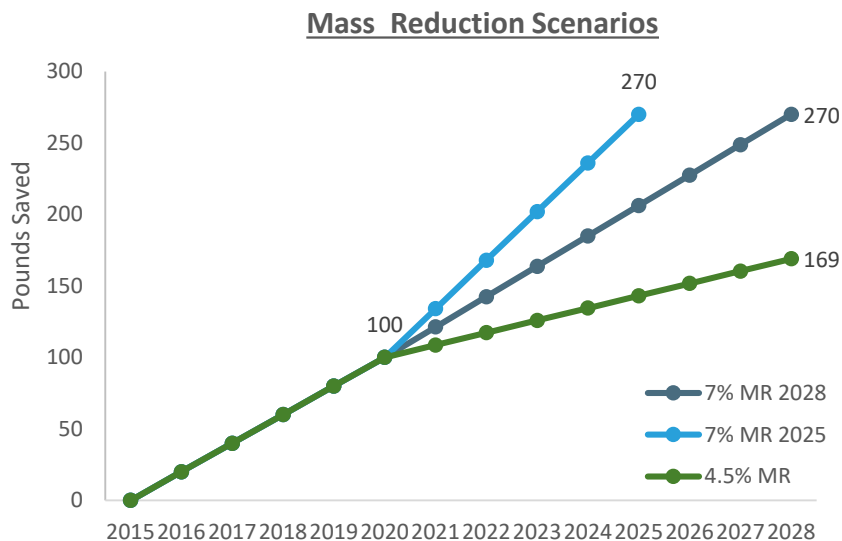
Modeling Constraints:

- Overall weight savings from aluminum was constrained to 50% of the overall weight savings. Some vehicles used aluminum for over 75% of their weight savings, but overall 50% was still maintained for the fleet
- Significant weight savings was concentrated on full frame vehicles, large unibody SUVs, minivans, luxury sedans and PHEV/ZEVs
- Significant weight savings requires new vehicle designs in most cases. The model replacement cadence from 2023 to 2026 is conducive to some dramatic changes in materials and powertrains
- Ducker recognizes that many vehicles will save less than 100 pounds over the next fifteen years due to safety concerns, cost and competitive conditions
- OEM tendencies for spot welded body structures, aluminum structural castings, UHSS/AHSS (advanced steel) for occupant compartments and steel/polymer for pickup cargo boxes were taken into account. Multi material (MMV) body structures were assumed to be much more prevalent than 'all aluminum' body structures, but less prevalent than 'all steel' body structures
- Finally, the emphasis on proven technologies for mass production can not be overstated. Most of the alloy technology for 2025 has already been invented. It may not be well known, but the patents have been filed. It is unlikely that there is a material magic bullet for weight savings awaiting discovery

MASS REDUCTION SCENARIOS

The 7% Mass Reduction Scenario is consistent with the TAR, and maintains the current trend to save approximately 20 pounds per vehicle per year over the next ten years.

- The 7% Mass Reduction Scenario uses the TAR as a guideline, ultimately requires a multi-material substitution strategy with significant quantities of aluminum, AHSS/UHSS, magnesium and CFRP applied after 2020 to get to a 7% mass reduction by 2025 or by 2028.
 - To achieve a 7% MR by 2028 requires nearly 5 million vehicles with a weight reduction of over 10% and a high content of aluminum BIW parts with all the pickup trucks and large SUVs showing a 15% to 20% weight savings
 - Achieving a 7% MR by 2025 will require an accelerated adoption (than the 2028 scenario) by the OEMs in converting to greater levels of aluminum, AHSS, magnesium and CFRP. Based on calculations, discussions and analysis, Ducker believes the 7% MR by 2028 is a more achievable
- The 4.5% Mass Reduction by 2028 Scenario reflects a more market driven and performance requirement scenario with less aluminum and polymer composites in the BIW
- Ducker believes the 7% weight savings by 2028 is the most likely scenario for the next decade

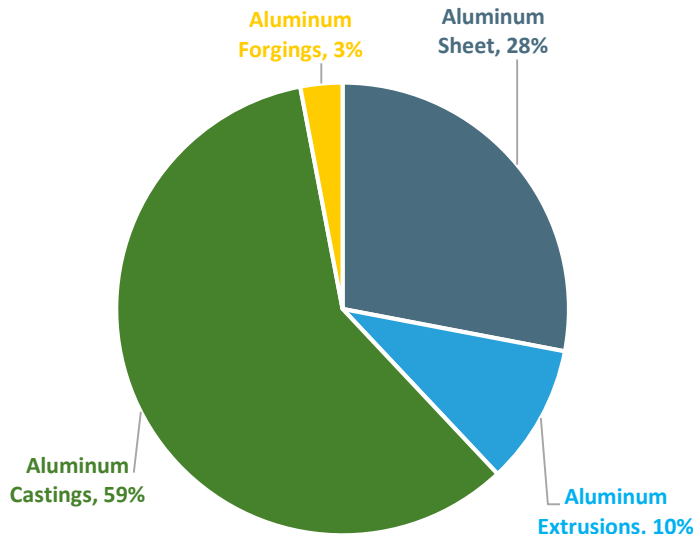


MASS REDUCTION SCENARIOS

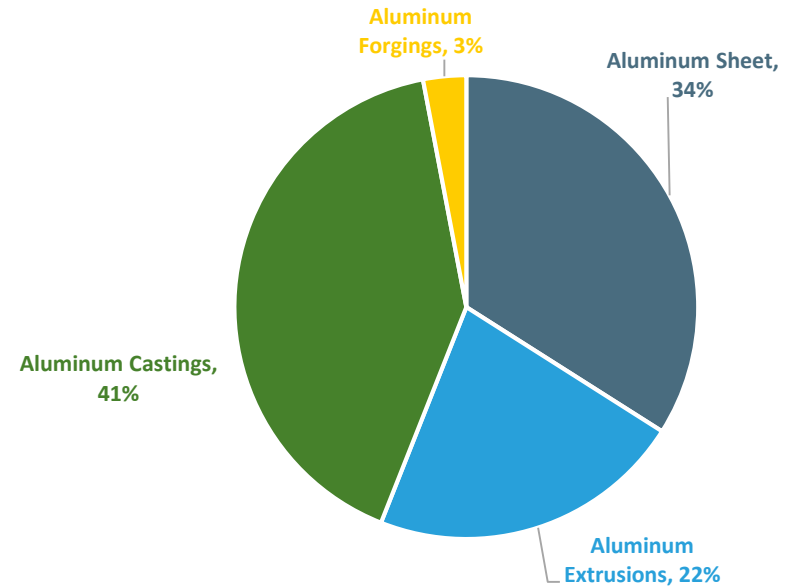
Depending on the level of mass reduction, aluminum content will range from 494 pounds per vehicle to 565 pounds per vehicle, flat rolled sheet will range from 28% to 34% of the total, extrusions will range from 10% to 22% and castings will range from 59% to 41%.

- Aluminum product mix will vary with the percent mass reduction

4.5% | 494 LBS

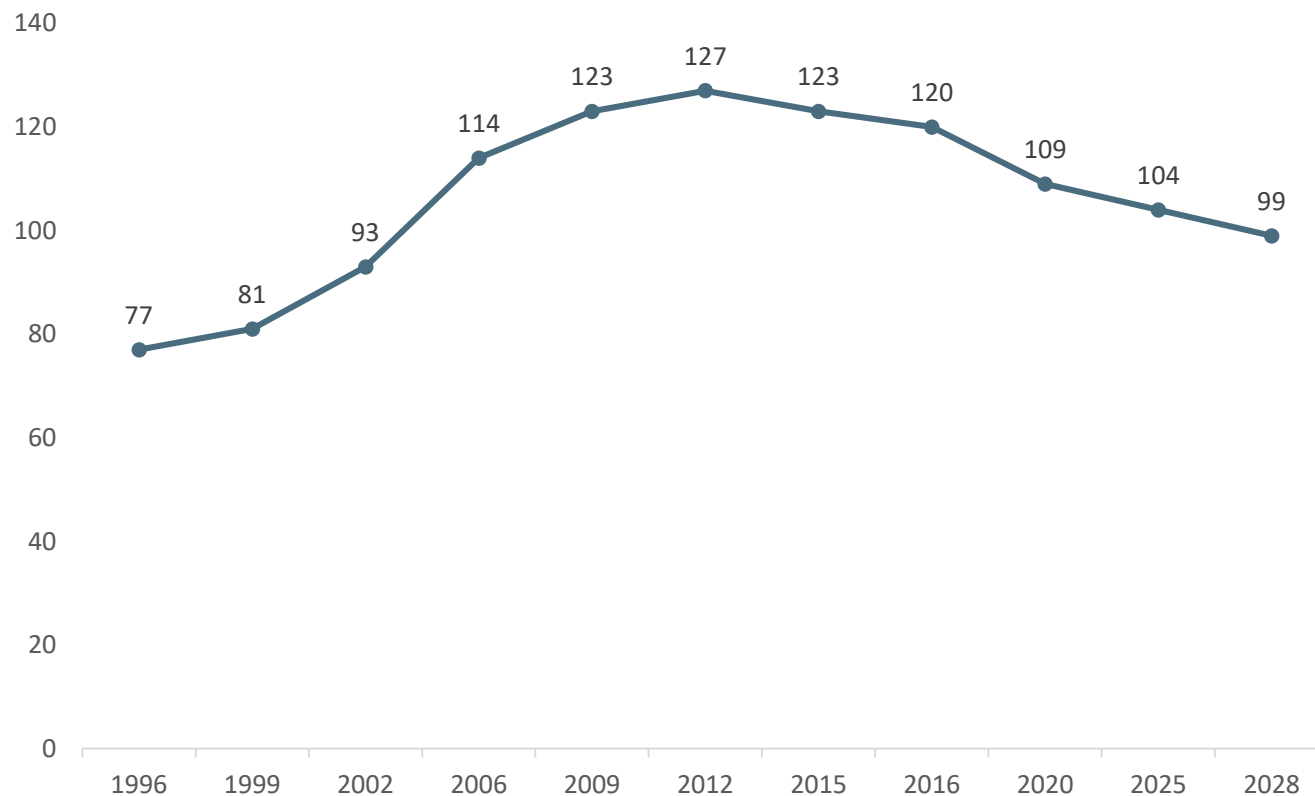


7% | 565 LBS



Aluminum content continues steady growth in spite of significant losses of aluminum engine weight due to downsizing. Alternative powertrains will also negatively impact aluminum engine weight, particularly later in the decade.

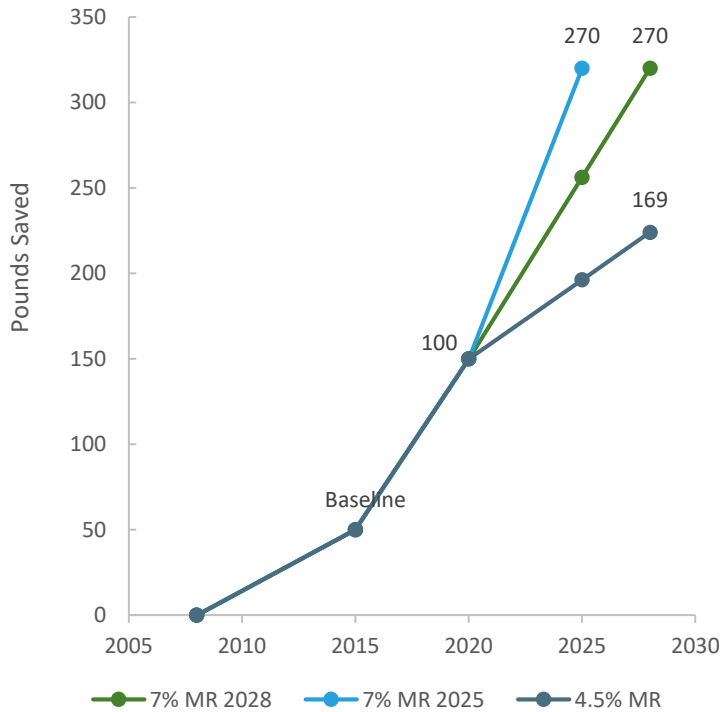
Aluminum Engine Components Pounds per Vehicle – 7% MR 2028



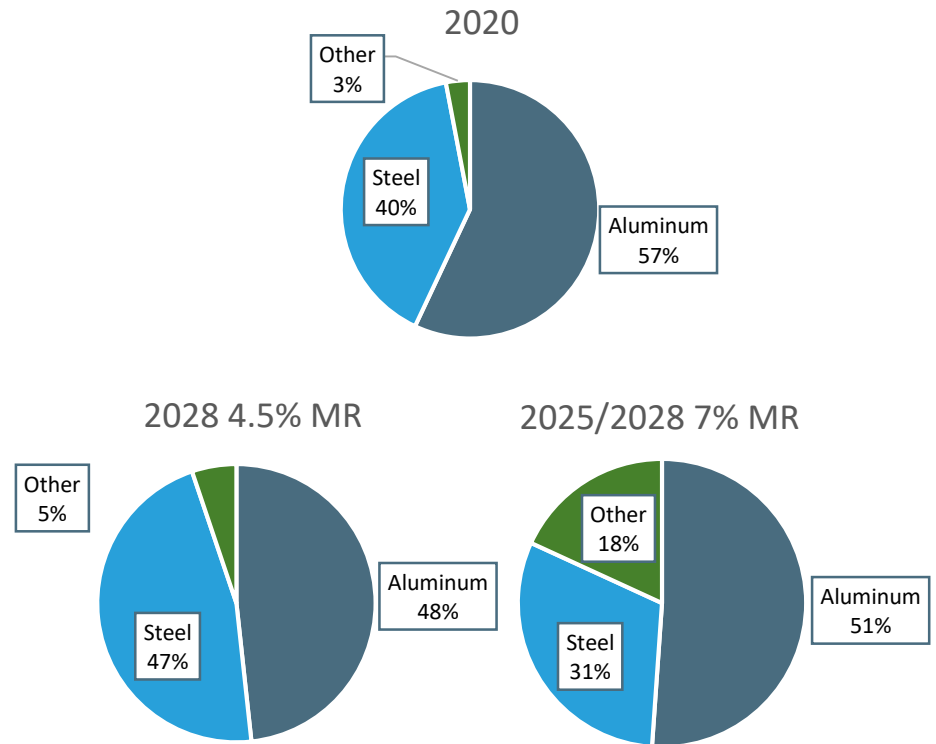
MASS REDUCTION SCENARIOS

In most cases aluminum will provide over 50% of the savings for the next fifteen years.

Weight Savings From Material Substitution



Sources of Weight Savings 2015 - 2028



7% MASS REDUCTION BY 2025 SCENARIO DETAIL



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A total mass savings of 270 pounds is the goal for 2025; however, the weight savings achieved from 2015 to 2020 will only be 100 pounds leaving 170 pounds to be removed from 2020 to 2025.

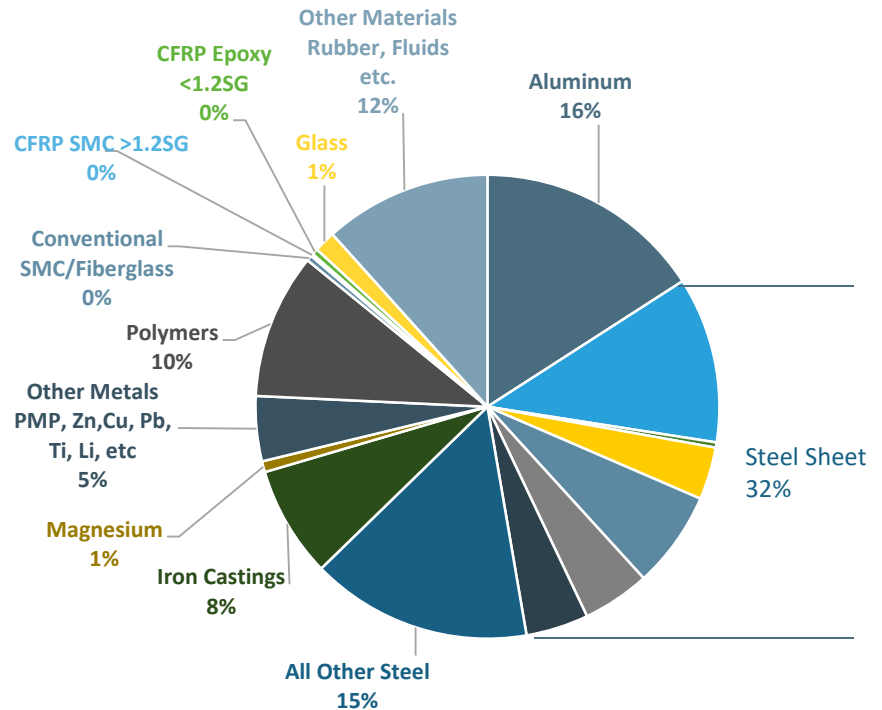
- The TAR technology implementation path provides a range of mass reduction from 0% for some cars and small SUVs to **20% for large light trucks and SUVs**, to get to an overall industry average weight savings reduction of 7% from 2015 sometime next decade
- The empirical evidence from Duckers research with the OEMs and their suppliers does not support achieving a 270 pound curb weight reduction by 2025
- Launch cadence is critical to the pace of new technology adoption. The next launch of a high volume vehicle with significant aluminum body content is in 2024
- A plethora of vehicles with significant aluminum body content are expected to launch within the 2024-2028 timeframe further indicating the need to examine attainment of mass savings goals beyond 2025
- For these reasons, Ducker believes the 7% mass reduction goal will be achieved in 2028 rather than 2025

This mix reduces 2015 vehicle weight by 270 pounds or 7% by 2025. The empirical evidence from Ducker's research supports achieving the 270 pound curb weight reduction; however, only by 2028.

Highlights:

- 565 total aluminum pounds (16% of total vehicle weight)
- Over 550 pounds per vehicle of flat rolled AHSS/UHSS steel content, but only 46% steel overall
- Twenty one pounds for CFRP Epoxy and SMC composites
- Twenty seven pounds of magnesium
- Polycarbonate windows, and fiberglass/composite leaf springs were applied where appropriate
- Aluminum hood penetration of 90% with door penetration near 60%

2025 CURB WEIGHT 3565 LBS.



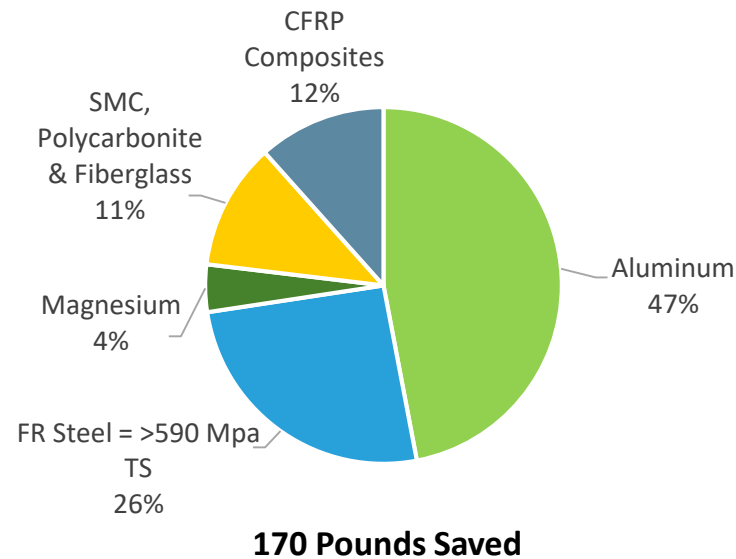
7% MASS REDUCTION BY 2028 SCENARIO DETAIL



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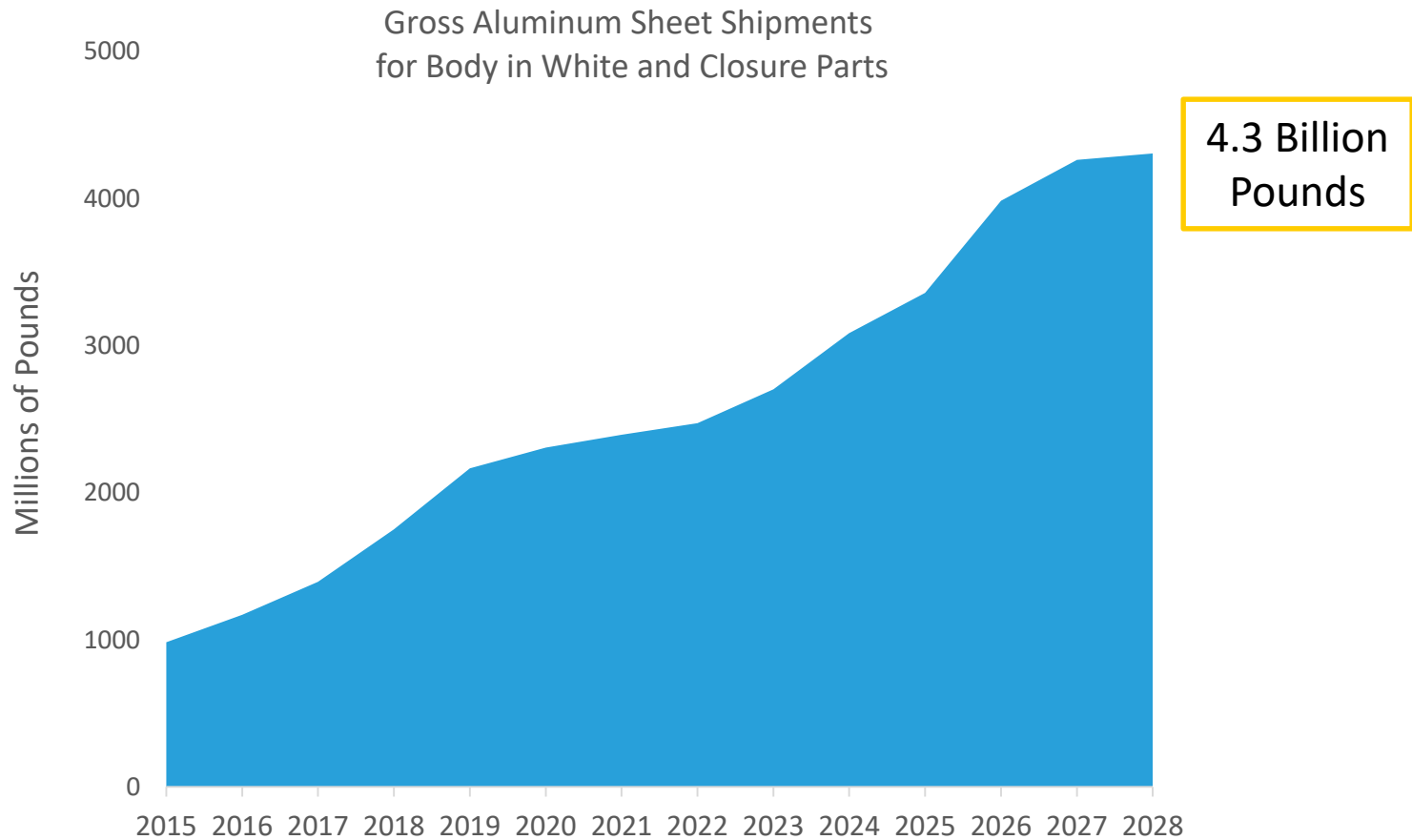
Sometime next decade(2025/2028) at least another 170 pounds of gross mass reduction needs to be achieved through material substitution. Generation 3 steels, CFRP composites, polycarbonite windows, fiberglass leaf springs and multi material body structures with significant aluminum content will drive most of the mass savings.

Sources of Mass Savings from Material Substitution



7% MASS REDUCTION SCENARIO BY 2028

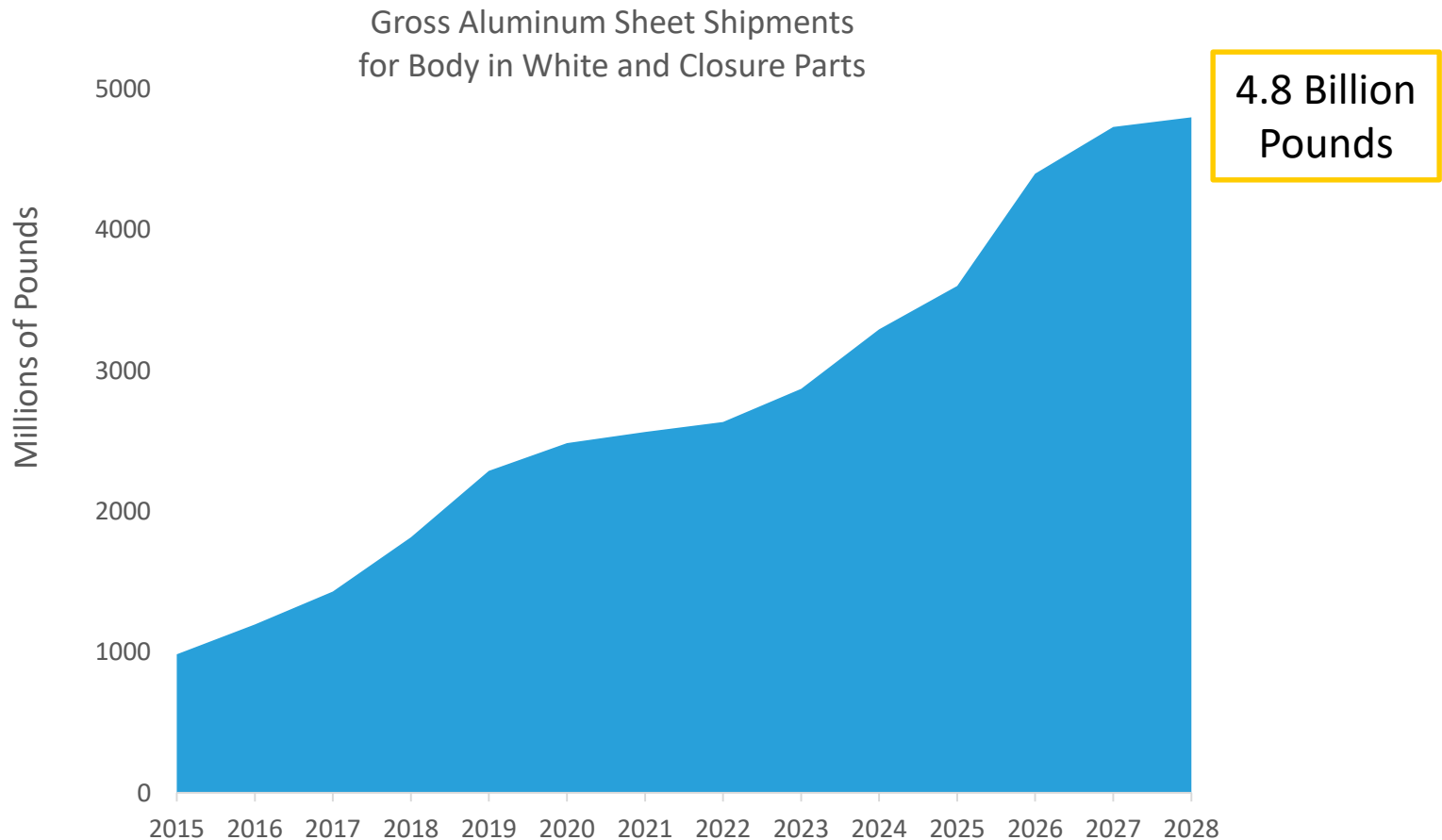
At a **constant production level** of 17.5 million light vehicles in North America, aluminum sheet shipments for body in white and closure parts are expected to grow from less than one billion pounds in 2015 to 4.3 billion pounds by late next decade



4.3 Billion
Pounds

7% MASS REDUCTION SCENARIO BY 2028

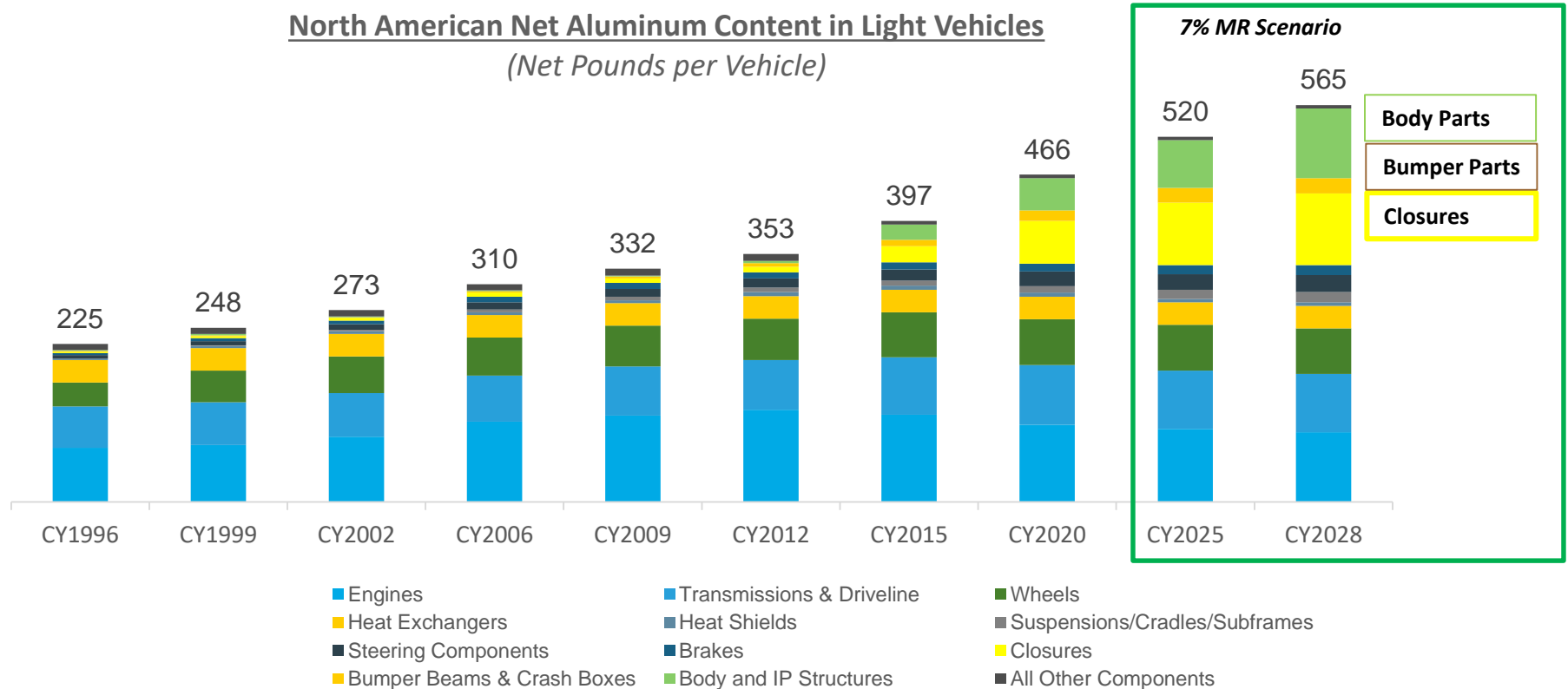
At a vehicle **production levels of 19.2M vehicles by 2028 (I.H.S. 4Q2016)**, North American light vehicle aluminum sheet shipments for body in white and closure parts are expected to grow from less than one billion pounds in 2015 to 4.8 billion pounds by late next decade



4.8 Billion
Pounds

7% MASS REDUCTION SCENARIO BY 2028

Twenty years of NA Light Vehicle Aluminum Content Research performed by Ducker is shown below. The 7% mass reduction scenario, which is based on meeting the TAR technology path by 2028 rather than 2025 yields 565 pounds of 2028 aluminum content.

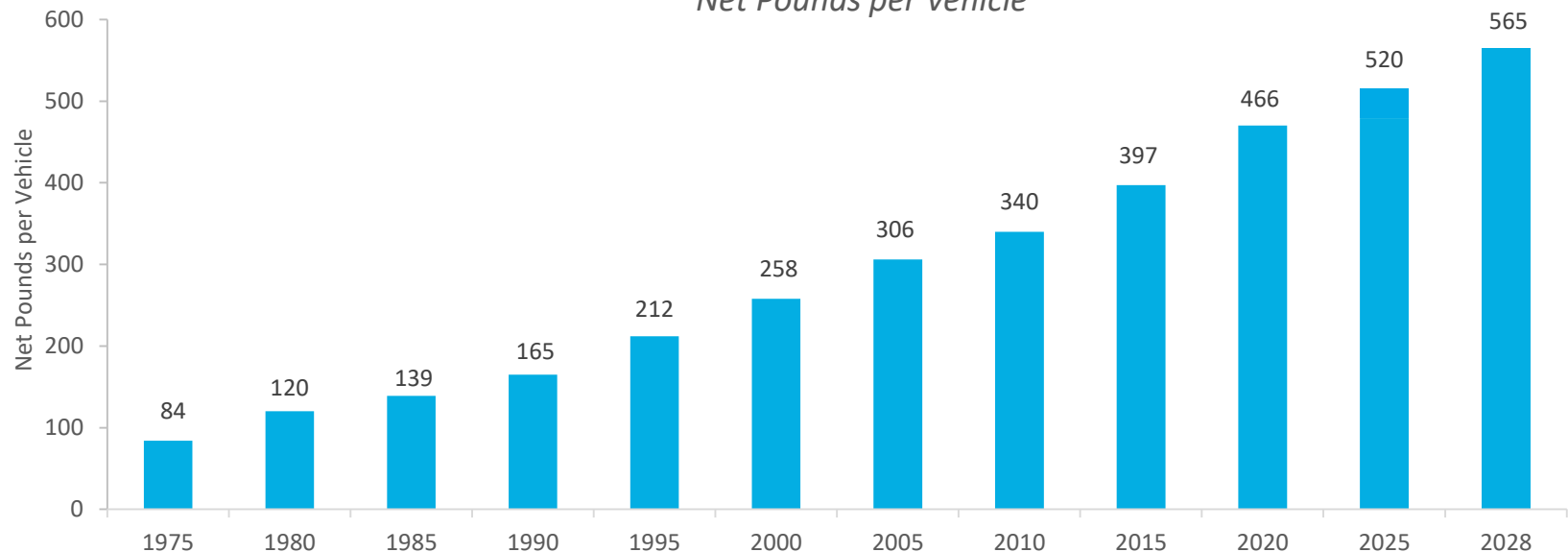


Under all the mass reduction scenarios, aluminum content in North American light vehicles will continue to show uninterrupted growth well into the next decade.

55 Years of Uninterrupted Growth

North American Light Vehicle Aluminum Content

Net Pounds per Vehicle



4.5% MASS REDUCTION SCENARIO DETAIL



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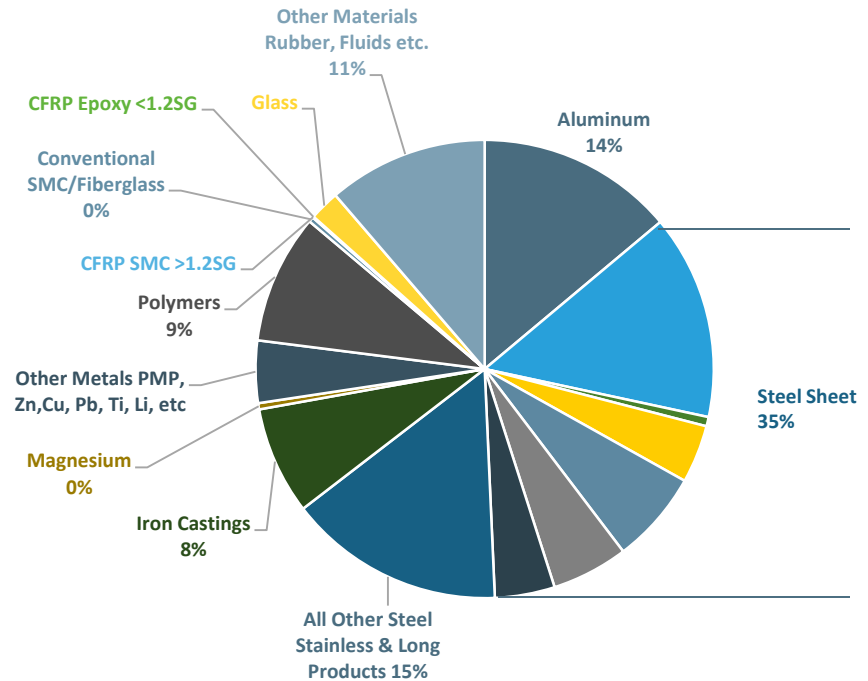
4.5% MASS REDUCTION SCENARIO - LOW ALUMINUM GROWTH AFTER 2020

The low aluminum growth scenario assumes that there is very little growth for aluminum body parts after 2020. The aluminum share of total vehicle weight will only grow to 14%.

Highlights:

- This scenario only achieves a 4.5% mass savings from 2015 even with over 160 pounds per vehicle of new AHSS/UHSS parts added after 2020
- 494 total aluminum pounds (14% of total vehicle weight)
- At least 4.9 million high growth aluminum content vehicles (>400 lbs.)
- Over 550 pounds per vehicle of flat rolled AHSS/UHSS steel content, but only 46% steel overall
- Twenty one pounds for CFRP Epoxy and SMC composites
- Twenty seven pounds of magnesium
- Polycarbonate windows, and fiberglass/composite leaf springs were applied where appropriate
- Aluminum hood penetration of 90% with door penetration near 60%

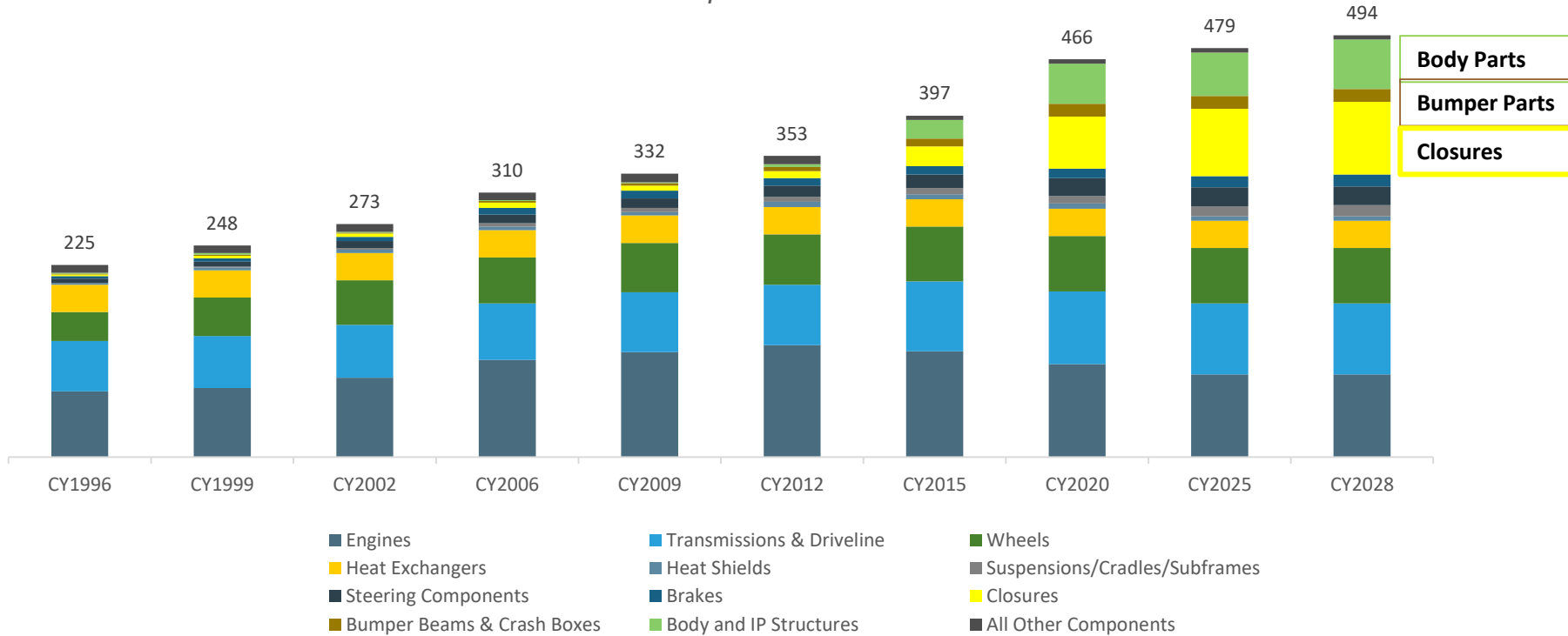
CURB WEIGHT 3655 POUNDS



4.5% MASS REDUCTION SCENARIO - LOW ALUMINUM GROWTH AFTER 2020

Total aluminum content will only increase by 28 pounds under the 4.5% mass reduction scenario due to less weight savings and aluminum losses to engine resize and magnesium substitution.

North American Net Aluminum Content in Light Vehicles
Net Pounds per Vehicle



FINAL COMMENTS



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- It is unclear, as yet, what the results of the 2018 Mid Term review will do to the technology path shown in TAR for 2025. It is possible that there will be no change from TAR. Ducker does believe that the effort to achieve U.S. energy independence along with a competitive market place will keep the pressure on the auto industry to keep improving the material efficiency and other characteristics of their vehicles in spite of any changes in the TAR technology path
- Assuming a curb weight reduction from 2015 of 5% or more is needed, aluminum content will continue to grow over the next ten to a fifteen years. The amount of growth will depend on the concentration of the weight savings on specific vehicle classes. 20% - 25% mass reduction on 20% of the vehicles is much better for aluminum than 5% on all the vehicles. Aluminum content growth will also depend on how much weight creep must be offset, and any improvements in the value proposition of other material relative to aluminum. Finally, an increase in the target mass reduction is estimated to be worth 30 pounds of increased aluminum content for every 1% the target mass reduction percent is increased over 5%
- Since the Ducker study for the ATG three years ago, there have been some significant changes. The most important change is in the timing of exactly when new aluminum closure and body parts are added, particularly for large trucks and SUVs. The emerging pattern has more aluminum added with each model change over a ten to fifteen year period until all the closures are aluminum and at least 50% the body is aluminum. This is a much different timing pattern than Ford exhibited on the F-150
- The consequences of this new pattern, which better manages the cost increases associated with aluminum BIW & Closure parts, gives competing materials and electrification a greater opportunity to impact the final outcome. Multimaterial body structures, with innovative joining methods, are much more likely than they were three years ago, and alternative powertrain technology continues to surprise everyone. Given enough time it would be a mistake to underestimate competing materials or the progress of competing technologies
- All things considered and after looking at the problem and the research from every angle, it has become clear that there is no affordable way to maintain vehicle size and achieve a 7% mass savings with concentration on light trucks without a very significant increase of high growth aluminum components
- Steel, magnesium, CFRP and polycarbonate additions are critical. Aluminum BIW & Closure parts, however, are the key to achieving both regulatory and OEM goals for vehicle improvements over the next ten to fifteen years

THANK YOU.

This concludes our presentation. Today's presentation was prepared by Ducker Worldwide LLC. Opinions and estimates constitute judgment as of the date of this material and are subject to change without notice. Any interpretations derived from this document are the sole responsibility of the client. Reproduction without the explicit consent of Ducker Worldwide LLC is strictly prohibited.

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