

# AluMag®

Europe ■ India ■ Americas ■ Asia  
**THE MARKET DEVELOPER**

● AluMag® Worldwide



## AluMag® penetrates new markets - initiate business growth - localize & develop supply chains



Market Research

- Global Al / Mg Foundry, Forging Extrusion Databases for M&A, Supplier / Customer Localization or Competitor Analysis, ...
- Automotive & Industrial Application Research, Material & Process Trend Analyses
- Lightweight Technology Outlook in Aluminum, Carbon, Steel Composites & Magnesium
- Customized Market Intelligence
- European Automotive Forecast



Market Development

- Access & Build-Up of new Markets in Automotive, Truck [Tractor], Trailer & Bus Industries Mainly
- Analysis, Development & Execution of Market Trade-Offs & Opportunities of New Technologies
- Manage new Product Launches
- Accelerate Market Penetration & Establish a Sales Force
- Interim Sales Management



Roadshows / Events

- Organization of Technical, Commercial Roadshows & Events Globally
- Host In-House Events & Presentation Globally
- Common Technology Booth at Leading Exhibitions
- Supply-Chain Automotive Lightweight Symposium [SCALS] In EUROPE, ASIA & N.AMERICA



Strategic Localization

- Green & Brown Field Localization, from Site Selection to Foundation & Ramp-Up
- Warehousing, Distribution, Supplier & Tie-Up Localization
- Foreign Market Business Cases & their Realization
- M&A Target Research
- Interim CTO / COO & Plant Manager

AluMag® is “The Market Developer” that successfully penetrates new markets, creates business and localize leading suppliers for your company. AluMag® access any promising markets, open doors for your business in emerging and booming regions, markets, applications, materials, processes or products. AluMag® makes you successful - worldwide!

### MACRO TRENDS IMPACTING THE DEMAND FOR ALUMINUM & MAGNESIUM

#### ABSTRACT:

The rising demand for electric vehicles [EVs] is expected to suppress the demand for ICE aluminum powertrain applications. On the other hand EVs and automatic driving applications will also provide many new prospects for aluminum, as well as other lightweight materials and processes. The lecture by AluMag® will provide insight into several promising aluminum applications. But will also shed some light on the future role of AHSS/UHSS, Tailor Rolled & Welded Blanks, Iron, Composites and CFRP within a changing automotive industry where E-mobility, Autonomous driving and light weighting are major topics. Component price, weight & properties are not the only factors playing a role in the OEMs material/process decision making process. The paper is based on five recent analyses, AluMag® has executed end of 2018 / beginning of 2019.

#### COMPONENT IN FOCUS:

- BEV & PHEV battery trays
- BEV & PHEV motor housings and other parts
- BIW
- Suspension and subframes
- CMS [Crash Management Systems]

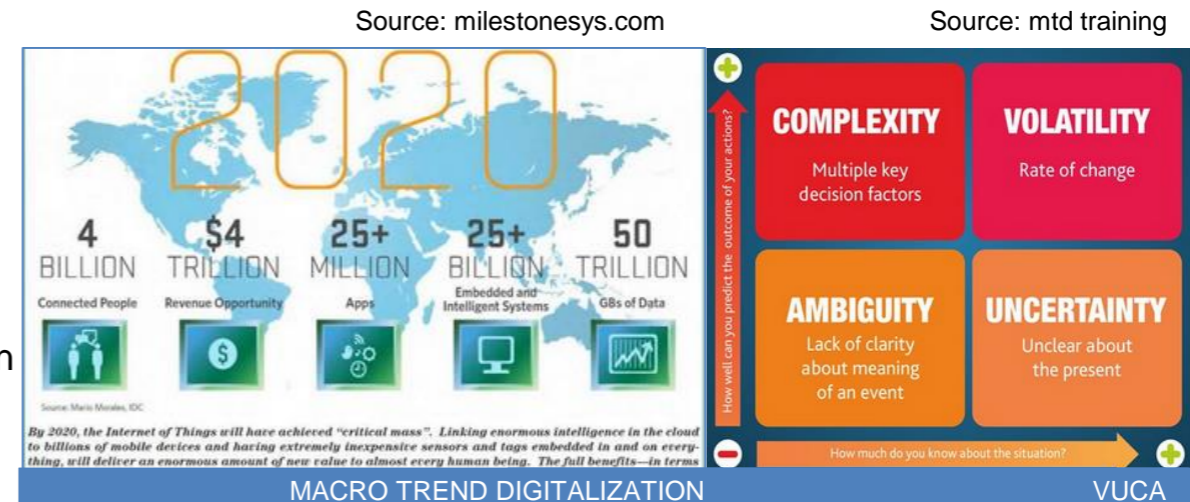
Source: AluMag®



### MACRO TRENDS IMPACTING THE DEMAND FOR ALUMINUM & MAGNESIUM

#### SELECTED MACRO MEGA TRENDS ARE:

1. DISRUPTION
2. VUCA = Volatility, Uncertainty, Complexity, Ambiguity
3. DIGITALIZATION
4. CASE = Connectivity, Autonomous, Shared Electrification
5. AUTOMOTIVE DOWNTURN



**DISRUPTION** in every industries, global regions, economies and geo-political power plays, new, different and rising forces are shaking-up the world. The speed is dramatically high, challenging to keep pace with and will bring new player on the field. Very big established once will loose importance, market share or even will expire. Business cases are changing.

The APAC Countries [Asia-Pacific Countries] respectively Indo-Pacific region is the powerhouse with the emerging economies, rapid spread of digital technologies, growing challenges to globalization, catching-up to become the technology lead, highest and partly very young population. **The gravity of Global Innovation Index [GII], Gross Domestic Product [GDP] and Purchasing-Power Parity [PPP] is on its way to the Indo-Pacific region.**

These and other global trends offer considerable new opportunities to the light weighting industries, the need to localize, attack new or un-known markets and applications such as IT, Illumination, Automatization, Energy storage and such.

**Executives with its entire management and staff have to rethink and redefine its strategy, orientate, calibrate, concentrate and guide its company into the digitalized disruptive VUCA business road ahead.**

### MACRO TRENDS IMPACTING THE DEMAND FOR ALUMINUM & MAGNESIUM

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#### MACRO TREND: 5G

**The “5G” is at the same time one of the main driver and result by the DISRUPTION, VUCA [Volatility, Uncertainty, Complexity, Ambiguity] and DIGITALIZATION.**

What is “5G”? It is the “5<sup>th</sup> generation” wireless of cellular technology, engineered to greatly increase the speed and responsiveness of wireless networks. With 5G, data transmitted over wireless broadband connections could be sent at rates as high as 20 Gbps by some estimates -- exceeding wireline network speeds -- as well as offer latency of 1 ms or lower for uses that require real-time feedback. 5G will also enable a sharp increase in the amount of data transmitted over wireless systems due to more available bandwidth and advanced antenna technology.

In addition to improvements in speed, capacity and latency, 5G offers network management features, among them network slicing, which allows mobile operators to create multiple virtual networks within a single physical 5G network. This capability will enable wireless network connections to support specific uses or business cases and could be sold on an as-a-service basis for:

- Autonomous / self-driving car from level 3 to 5
- Secure IoT [internet of things]IoT], data-only connections, cloud
- Shared / administrative services within/at any B2B, B2C, C2C, Government, ....
- Harvester
- Control processes and production
- In real time content access
- .....



### MACRO TRENDS IMPACTING THE DEMAND FOR ALUMINUM & MAGNESIUM

#### MACRO TREND: 5G

5G will be deployed in stages over the next several years to accommodate the increasing reliance on mobile and internet-enabled devices.

Wireless networks are composed of cell sites divided into sectors that send data through radio waves. Fourth-generation [4G] Long-Term Evolution [LTE] wireless technology provides the foundation for 5G. Unlike 4G, which requires large, high-power cell towers to radiate signals over longer distances, 5G wireless signals will be transmitted via large numbers of small cell stations located in places like light poles or building roofs.

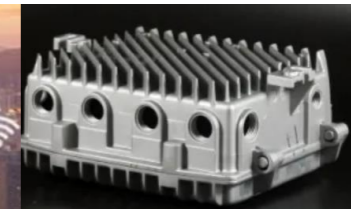
**The use of multiple small cells is necessary because the millimeter wave spectrum -- the band of spectrum between 30 GHz and 300 GHz that 5G relies on to generate high speeds -- can only travel over short distances and is subject to interference from weather and physical obstacles, like buildings. This technical circumstances will drive the needs and volume for the cell housings such as “heat sink enclosure” / “outdoor wireless AP [access point] to an interesting mass market. Beside China, South East Asia is noticed as interesting production hub.**



Cast & extruded AL heat sink / access points.



Server, Storage, & Networking



Such housings are in many cases HPDC & extruded

### MACRO TRENDS IMPACTING THE DEMAND FOR ALUMINUM & MAGNESIUM

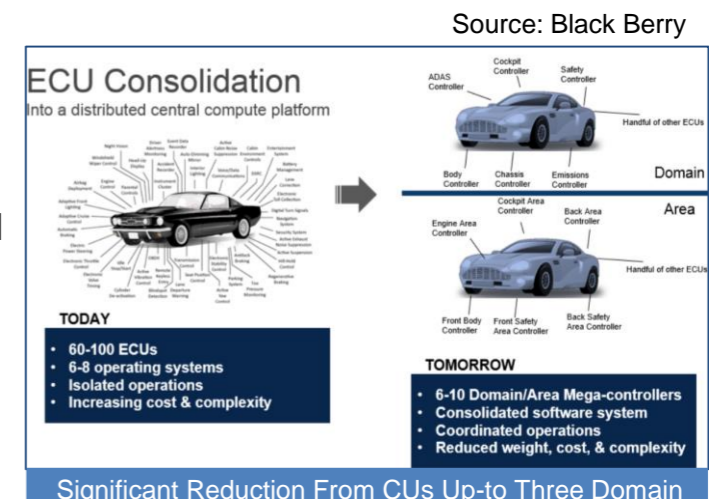
#### MACRO TREND: CASE - AUTONOMOUS DRIVING & SHARED MOBILITY

Vehicles are becoming more and more autonomous and requires a vast number of sensors, cameras, scanners and electronic control units [ECU] to drive on its own. Each sensor, camera and scanner are housed by cast AL, magnesium or iron as are their ECUs. Though the housings for these applications are small the number required for each car is high and will lead to an increasing demand for cast applications.

On the other hand the trend towards ADAS Domain ECU systems [ADAS: Advanced driver-assistance systems] will have a negative effect on the cast demand. Today each vehicle is fitted with up to hundred ECUs each controlling its own function such as cruise control or lane departure warning system. In the future these ECUs are to be replaced by three to four ADAS Domain ECUs, which will control major areas of the car, and lead to a decreasing demand for cast ECUs.

Autonomous vehicles are categorized into 5 levels depending on the vehicle`s level of autonomy. Today the most advanced vehicles on the road have reached level 3. True autonomous vehicles are expected to be ready for launch from 2020 reaching a penetration of 12.48% worldwide in 2030. Europe will play a leading role in this field with an expected penetration of 20.48% [Level 5 autonomy] in 2030, followed by N. America with 14.67% and Asia with 8.67% penetration.

Despite the current downturn in the global automotive production, forecasting institutes generally agrees that the production is expected to bounce back and return to its growth path. At least for some years as autonomous vehicles could lead to a disruption in the automotive industry.



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### MACRO TRENDS IMPACTING THE DEMAND FOR ALUMINUM & MAGNESIUM

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#### MACRO TREND: CASE - AUTONOMOUS DRIVING & SHARED MOBILITY

“The introduction of autonomous vehicles will lead to a stagnating demand for new vehicles”. That's the result of a market analysis executed by Ark Investment Management & Credit Suisse. The reason stated is mainly "Shared mobility solutions "as offered by Uber and Lyft via APP. According to figures from "Ark Investment", costs for Autonomous Taxis [per driven mile] make up only a third of private owned cars. Stagnating sales of vehicles is thereby too be expected [Up to 50% reduction in US and EUROPA in the late 1920s]. First in USA and EUROPA afterwards in the rest of the world.

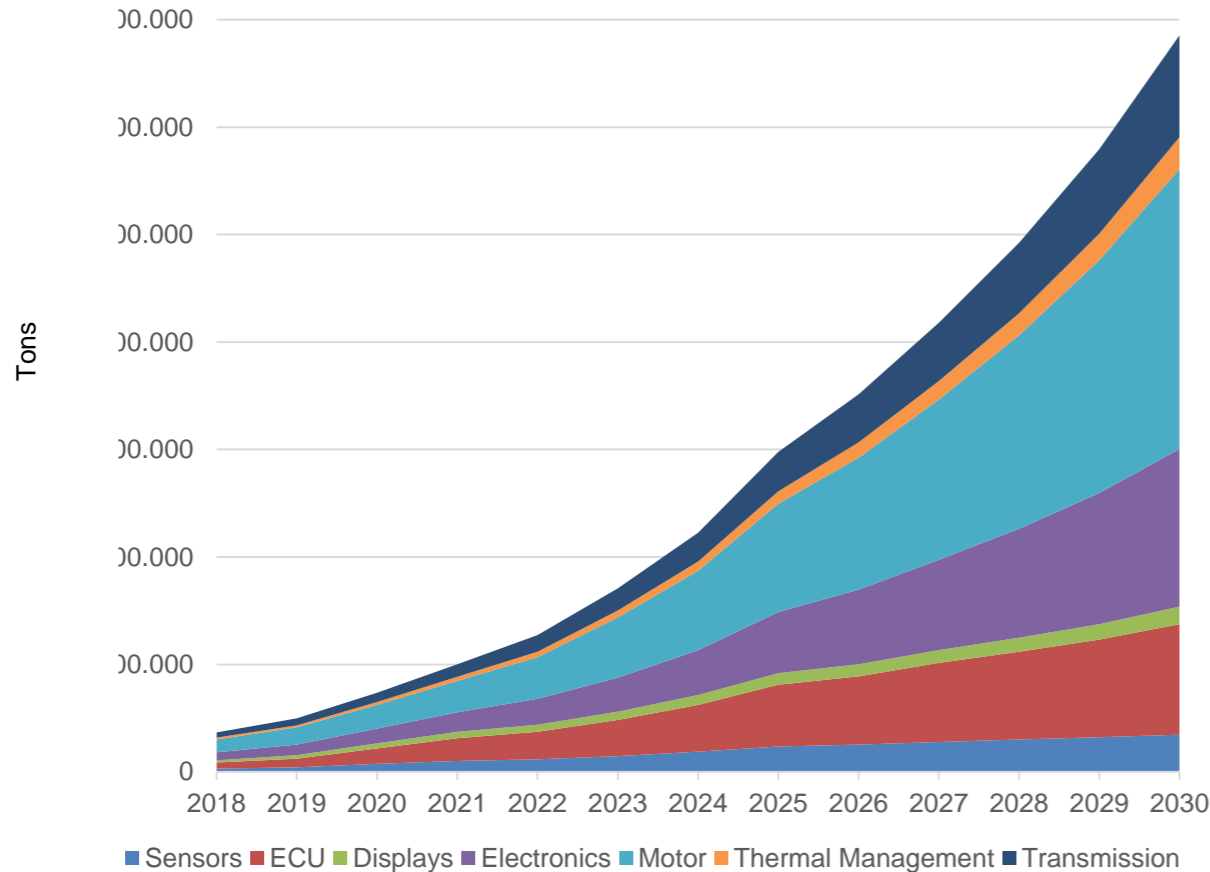
But not everybody agrees with the statement from Ark Investment Management & Credit Suisse. According to an analysis by the company PwC, autonomous vehicles will lead to rising sales figures. Autonomous vehicles will be used much more intensely than conventional cars, reducing the duration of their lifecycle and creating higher replacement demand in spite of shrinking overall vehicle fleet.

It is still too early to say whether Scenario 1 [Ark Investment & Credit Suisse] or 2 [PwC] will be the reality.

## E-MOBILITY TO SHAKE-UP THE MATERIAL/PROCESS MIX! RACE HAS BEGUN! U-TURN 2030 IS POSSIBLE!

### GLOBAL FORECAST - NEW BEV & AUTONOMOUS DRIVING APPLICATIONS [EXCL. BATTERY TRAYS]

#### MACRO TREND: CASE - AUTONOMOUS DRIVING & SHARED MOBILITY



Source: AluMag®







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## MACRO TRENDS IMPACTING THE DEMAND FOR ALUMINUM & MAGNESIUM

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### MACRO TREND: CASE - ELECTRIC VEHICLES

The trend towards electric vehicles will in the long run most likely have a negative effect on the cast aluminum [AL] demand. But with today's EV penetration rates of only a few percent globally the impact on the cast demand is still limited. PHEV still holds about 30% of overall NEV [New energy vehicle: BEV + PHEV] sales worldwide and the additional cast AL applications fitted to PHEV vehicles more than offset the decreasing cast AL demand for BEVs. According to AluMag analyses an average global ICE vehicle [4cyl 2.0L engine] contains 64.4kg cast AL in the powertrain area [Engine & Drivetrain] vs only 48.8kg in a BEV vehicle. A deficit of 15.6kg per vehicle. On the other hand PHEVs contains a whopping 91.8kg cast AL. [Regional differences should be taking into account when considering the average content of cast AL & MG in an ICE vehicle powertrain. In N. America more cast AL is used per vehicle due to the regions taste for larger engines while the opposite can be said about Asia]. AluMag expects the PHEV penetration to drop around 2025 as battery technology improves, providing BEVs the range necessary to erase range anxiety. At that time we will see a decreasing demand for cast AL applications in the powertrain area.

One may argue that the increasing use of cast AL for structural applications will more than offset a possible declining demand for powertrain applications. Structural cast AL applications are being used increasingly in the premium segments for applications such as suspension domes, longitudinal carriers, cross-members, doors / gates and A-B-C pillars. The increasing penetration of BEVs is/was expected to boost the demand for lightweight materials in structural application even further, but the fast developing battery technology has and could have a negative impact on OEMs willingness to implement these materials. When the BMW I3 was launched back in 2013 it made sense for BMW to invest in the CFRP cell for the I3 as a lighter car needs a smaller battery. The battery is the most expensive part on an electric car and the cost saved on the battery could be invested in the frame.

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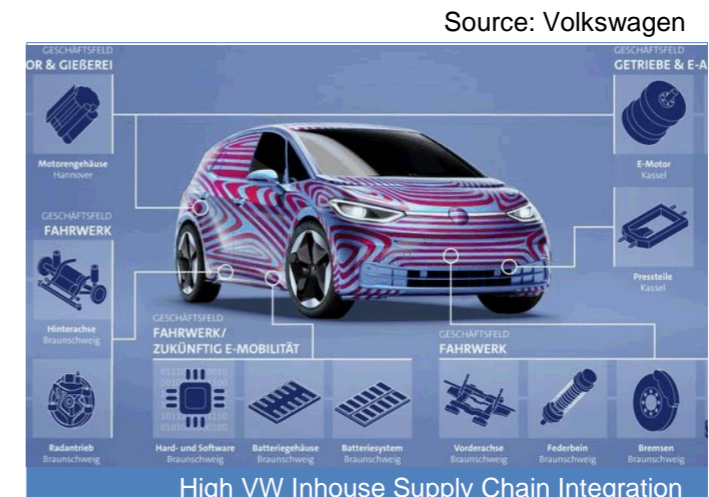
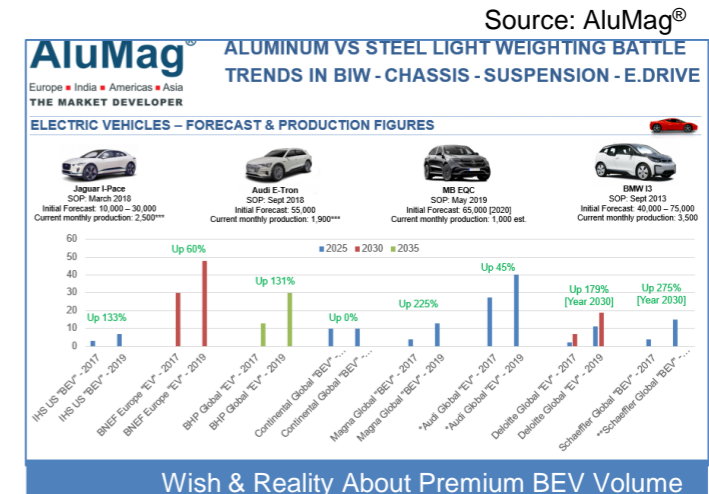
### MACRO TRENDS IMPACTING THE DEMAND FOR ALUMINUM & MAGNESIUM

#### MACRO TREND: CASE - ELECTRIC VEHICLES

In the meantime advances in electric vehicle battery technology have improved vehicle operating range by more than 50% since 2013, taking some pressure off the need to use ultra-lightweight materials like carbon fiber in the manufacturing process.

Though AL and CFRP can't be compared projected advancements in battery technology could/will limit the use of structural cast AL applications too. Two-thirds of consumers consider 300 miles / 480 km range on a single charge as sufficient [USB Study]. Next generation BEVs from VW, Nissan, Daimler and BMW are expected to have a range of up to 500-600 km.

Solid-state batteries as announced by Toyota, BMW and VW will increase range even further and bring charging times down to "a few minutes". If solid state batteries performs as projected by the OEMs, when they are launched within the next decade, one of the main incentives to use lightweight materials "powertrain efficiency" no longer fully apply and demand for automotive AL applications could decrease as a result.



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## E-MOBILITY TO SHAKE-UP THE MATERIAL/PROCESS MIX! RACE HAS BEGUN! U-TURN 2030 IS POSSIBLE!

### EXECUTIVE SUMMARY - BATTERY TRAYS

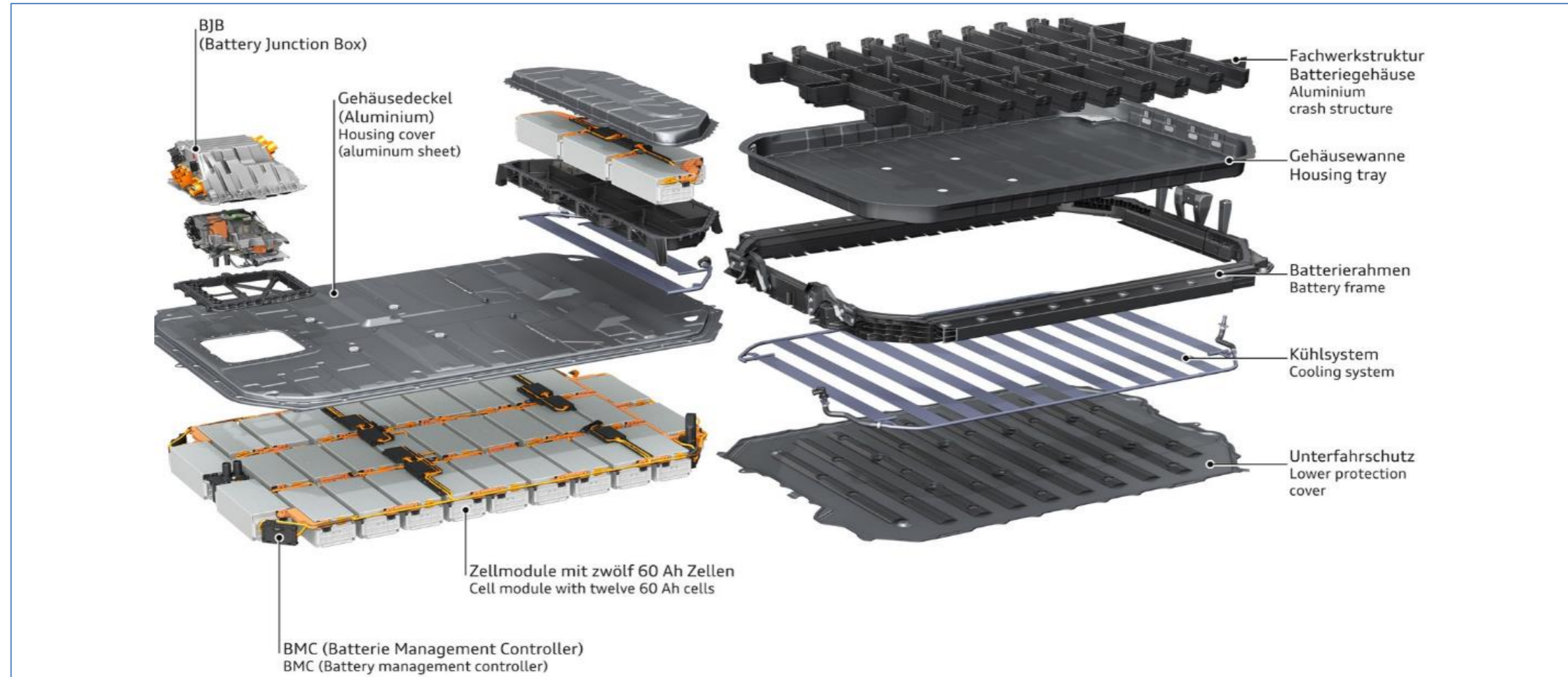
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### EXECUTIVE SUMMARY - BATTERY TRAYS

### EXECUTIVE SUMMARY - BATTERY TRAYS - MARKET ANALYSIS

Source: AUDI

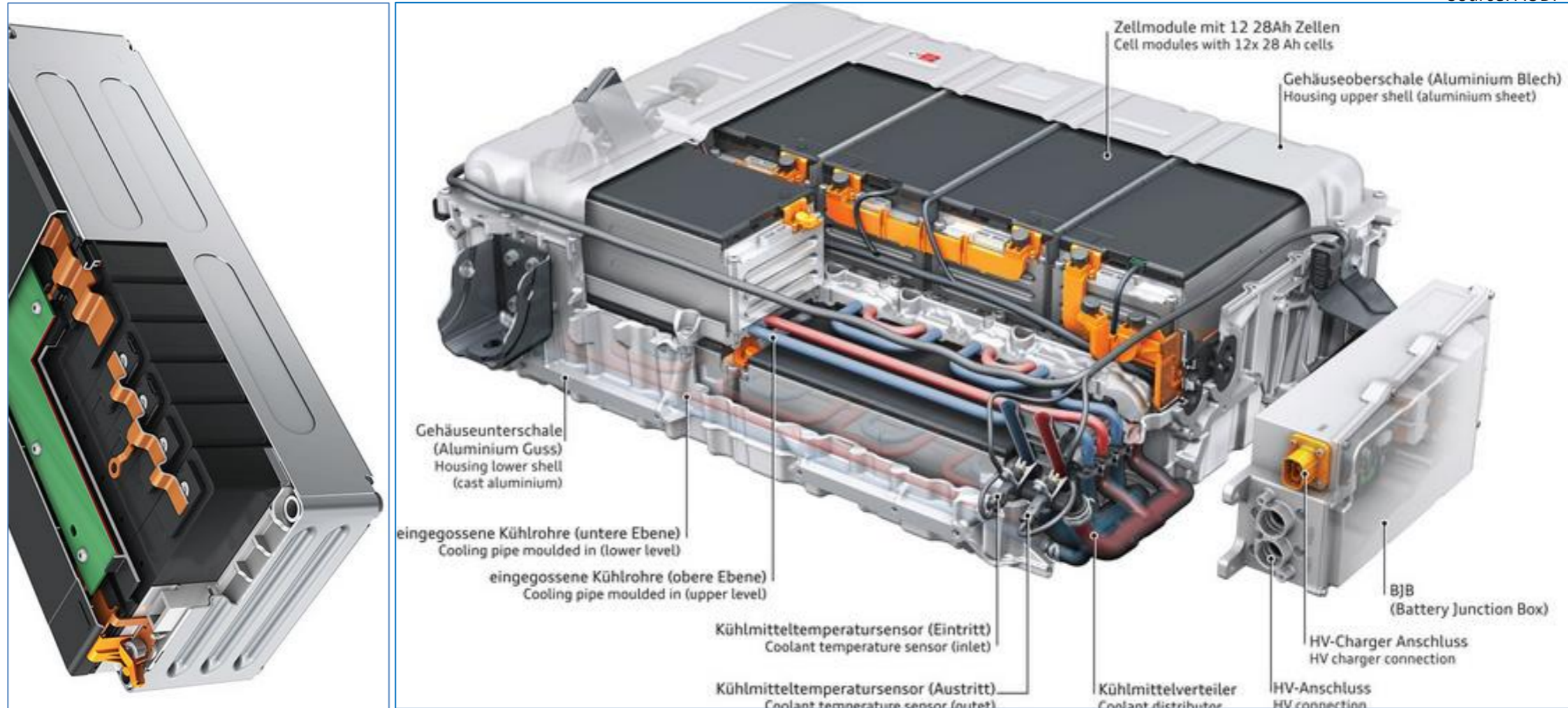


Overview How A Typical Design And Components Are Looking Like: Audi General Battery Structure And Sub Components



### EXECUTIVE SUMMARY - BATTERY TRAYS - TECHNICAL RESEARCH

Source: AUDI



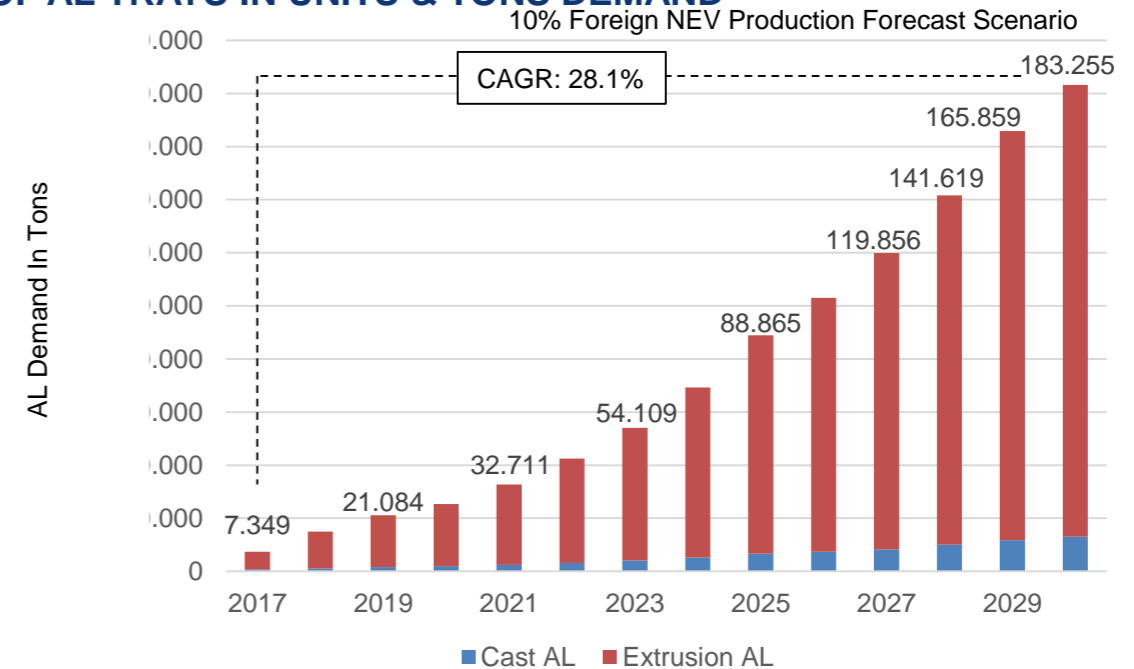
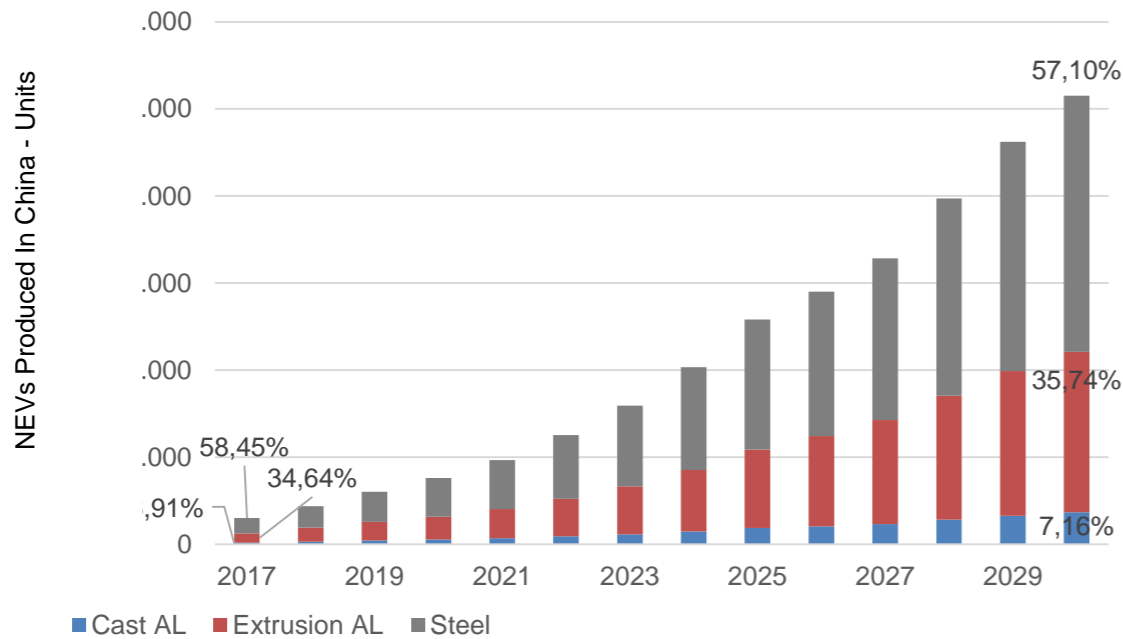
Audi Q8 Battery Cell Module

Thermal Management & Overview How A Typical Design And Components Are Looking Like: Audi Q8 Battery System & Its Components

### EXECUTIVE SUMMARY - BATTERY TRAYS - MARKET ANALYSIS

Source: AluMag®

#### CHINA NEV PASSENGER VEHICLE MARKET: PENETRATION OF AL TRAYS IN UNITS & TONS DEMAND



In 2017 42.90% of all NEVs produced in China were fitted with an AL trays. 35.74% had an extruded AL tray while 7.16% had a cast AL tray. The remaining 57.1% were fitted with steel trays. By 2030 the penetration of AL trays could be influenced by factors such as adjustment of the Chinese incentive program, introduction of solid state batteries and improved battery technology. Newly developed processes and grades of AHSS has the potential to significantly outperform AL for future battery trays as result of steel performance flexibility, lower cost, light weighting capability, safety / collision performance, reduced greenhouse gas emissions and superior recyclability. Gestamp and Benteler have been contracted by OEMs for such advanced forming and alloy grade steel battery trays.

### EXECUTIVE SUMMARY - BATTERY TRAYS - TECHNICAL RESEARCH

Source: AluMag<sup>®</sup>

#### COMPARISON AL CASTING VS AL EXTRUSION VS STEEL SHEET VS SMC

Battery Tray Requirement	Crash-safe battery protection, electric shock risks on high-voltages systems [800V batteries], fire hazards in case of lithium-ion batteries. High yield strength, high fatigue strength, sealing, heat management, anti-vibration, corrosion protection, installation or integration into the bottom body structure...			
Material	Aluminum		Steel Sheet	SMC
	Aluminum Extrusion	Aluminum Casting		
Advantage	Light weight, good heat and electrical conductivity, good formability with less welding processes, flame retardancy, long life time. The preferred material of choice among engineers and designers to satisfy expected fuel economy and emissions standards by 2025, to achieve a high range for a given battery size and weight, weight reduction of EVs is needed.		High strength and high stiffness, lower cost. EV producers in some latest models have turned back to steel with the latest generation of advanced high strength steels [AHSS].	Light weight, high strength, anti-corrosion, good electrical insulation, high fatigue strength
	Sufficient extruders/supply chain in China to achieve lower price comparing to aluminum casting	Ideal for complex and integrated design		
Disadvantage	More welding processes required comparing to aluminum casting	Higher cost due to not enough capable casting company and lower productivity, high investment in big casting machine[5000-7000?] is required.	Heavy weight, need anti-corrosion treatment	low elongation against thermal stress
Model Examples	BYD Song, Porsche Taycan, Jaguar I-Pace...		Cadillac CT6, Audi Q7 II, BMW X5...	Tesla 3, BYD E6, Roewe E950...

### EXECUTIVE SUMMARY - BATTERY TRAYS - TECHNICAL RESEARCH

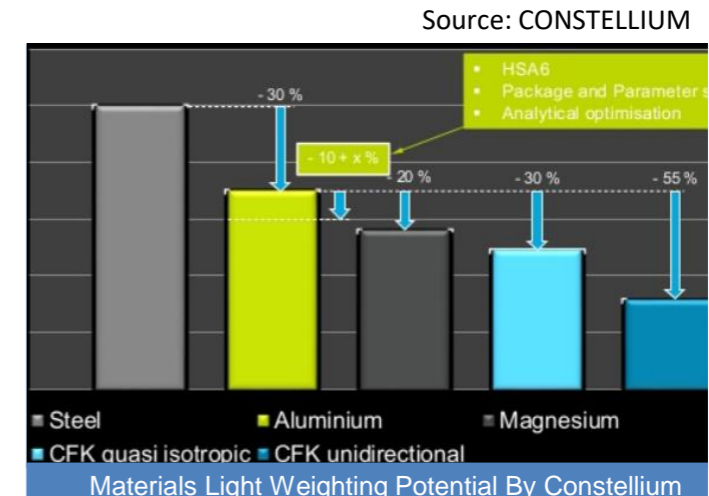
#### FACTORS WHICH INFLUENCES OEM TO SELECT BATTERY HOUSING MATERIAL

Batteries add weight to HEVs, PHEVs and BEVs. The EUR-NCAP side impact and pole impact result in a significant deformation at the state of the art car underpinning. To avoid damages by these load cases, the BEVs are equipped with a kind of 2<sup>nd</sup> side structure a "inner side sill / member" to stiffen the underpinning and protect the battery cell against intrusion which could result in a un-controllable battery fire. It is especially effective in the distribution of deformation over a wide / long side area. Even the side barrier impact test conducted by the IIHS is particularly severe, done with a mobile barrier that is 200 kg heavier than those used by EUR NCAP, 550 kg heavier than ANCAP.

One of the limitations of EVs has been the weight of the battery and extra reinforcement needed to protect it during a crash. Total weight of the battery and protection can be up to 700 kg. Positioning this mass in the vehicle has been a major challenge for car makers.

The most common approach are: advanced and ultra high strength steels [AHSS & UHSS], aluminum, composites, magnesium and plastics.

Reducing the weight of an BEV by 100 kg does improve the range by around 6 to 11 Km depending on the size of the vehicle. The above range increase can be obtained by increasing battery capacity by 1.1 to 1.2 kilowatt hours [kWh]. Car makers are recognizing this, leading to complete different concepts, partly within the same company and brand. The body and chassis of Tesla's Model 3 is a steel - aluminum hybrid and the Tesla Model S which has an aluminum body. The BiW of the Chevrolet Bolt is built of 86% steel, including 44 % AHSS.





### EXECUTIVE SUMMARY - BATTERY TRAYS - TECHNICAL RESEARCH

#### KEY MANUFACTURING TECHNOLOGIES & DIFFICULTIES & REQUIRED EQUIPMENT

Looking into the non cast trays, the weld tray out of extrusions or steel are the todays and near future predominate joining processes. Applied and planned are the three:

- TIG and MIC [e.g. Lingyun]; extremely high distortion
- LASER [e.g. Benteler]; compromise between moderate distortion and speed
- FSW [e.g. KAM]; best weld quality, no distortion but slow with max speed of 3m/min

Depending on the sealing concept, the CNC machining could be needed to prepare a tied tolerances of the sealing area. Finally, a 100% inline leakage test is obliged as:

- Air Decay by high pressure [over 6 bar] or low pressure [0 to 6 bar] or vacuum
- Helium by guide to helium leak testing or using a mass spectrometer or sniffing
- Other new leak testing techniques like high vacuum methods or water submerge



TQC In-line Leakage Test

As it comes to high volume production of battery trays, a huge investment is needed, which goes hand in hand with a fully automated process line. For high series volume, a minimum invest of app 600 Mill CNY / 75 Mill EUR / 89 Mill USD is required. According to OEM sources, Gestamp and Waldaschaff done it, Benteler has invested in South Germany also app.: 960 Mill CNY / 120 Mill EUR / 142 Mill USD

Source: TRUPF



Laser Weld Equipment by Trumpf



FSW Portal Machine By Grenzenbach

### EXECUTIVE SUMMARY - BATTERY TRAYS - CONCLUSIONS

Source: AluMag®

#### VIEWS - TOPICS - FINDINGS TO SHARE

- The next generation of PHEVs, to be designed & developed as such, are likely to have their battery more integrated into the structure of the vehicle. This could pave the way for a higher penetration of cast aluminum in PHEV vehicles in China
- All experts, AluMag has talked to/with confirmed, that cast battery trays will be not the most preferred process and see / predict that extruded Aluminum is the most suitable one. And, to manufacturer a BEV battery tray in HPDC it would require cells with clamping forces in the range 5,000 to 7,000 tons which are hard to come by. As one expert from a Chinese OEM put it: "Extruded AL is in a very advanced position against cast and steel / AL sheet". **For upper segment BEVs extruded AL housings are being preferred while steel sheet is predominantly used in lower car segments**
- Driven by improved steel sheet alloys and forming processes, light weighting based on steel is the biggest competitor to extrusion
- In China, it is a very much competitive market. Due to the OEM and Tier1 global sourcing strategy, internationalized battery tray supplier will have an advantage against Chinese local one. Only some of the Chinese battery tray supplier do / will have the management-, technology- and management resources to globalize its business
- Beside the volume of battery trays, aluminum extrusions are also applied in battery modules, thermo management land side sills. E.g. just for the forecasted VW MEB platform, one extrusion press will be 100% utilized by the side sill volume of yearly 12K tons
- BEV vehicles is likely to hold a global share of 15-20% by 2025, regardless of its environmental sustainability [battery cell materials and its processing, conventional energy mix, ...]
- The solid stake battery will be most likely a game changer. This battery type does not require such intensive thermo management and intrusion protection, for which the extrusions are one of the preferred solution provider when it come to the trays. But the solid stake is extremely easier to house, means that steel sheet and slightly aluminum sheet too, will realize a significant higher market share from year 2030.

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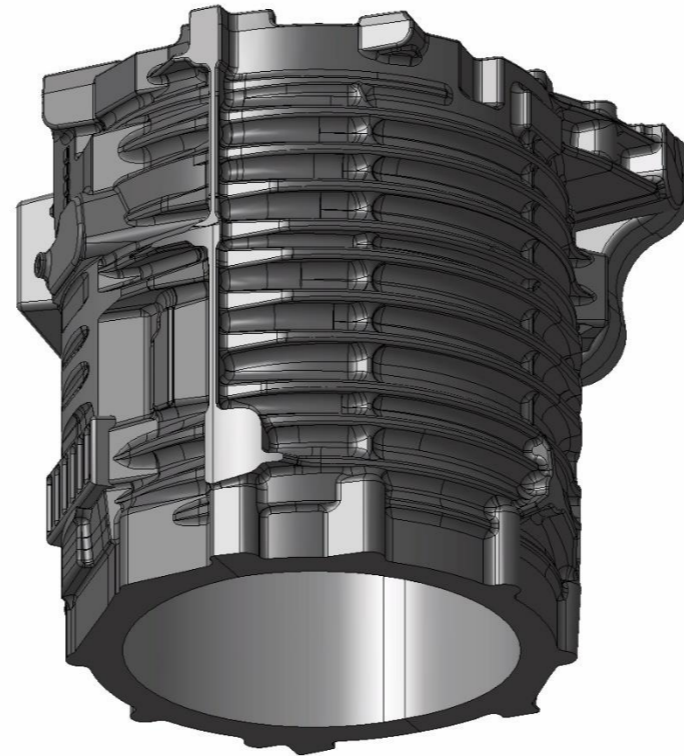
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## E-MOBILITY TO SHAKE-UP THE MATERIAL/PROCESS MIX! RACE HAS BEGUN! U-TURN 2030 IS POSSIBLE!

### EXECUTIVE SUMMARY - ELECTRIC MOTOR HOUSINGS

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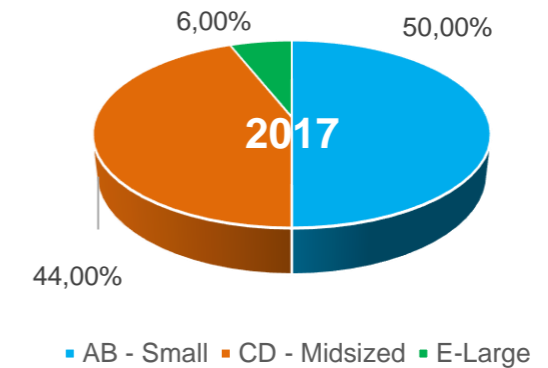
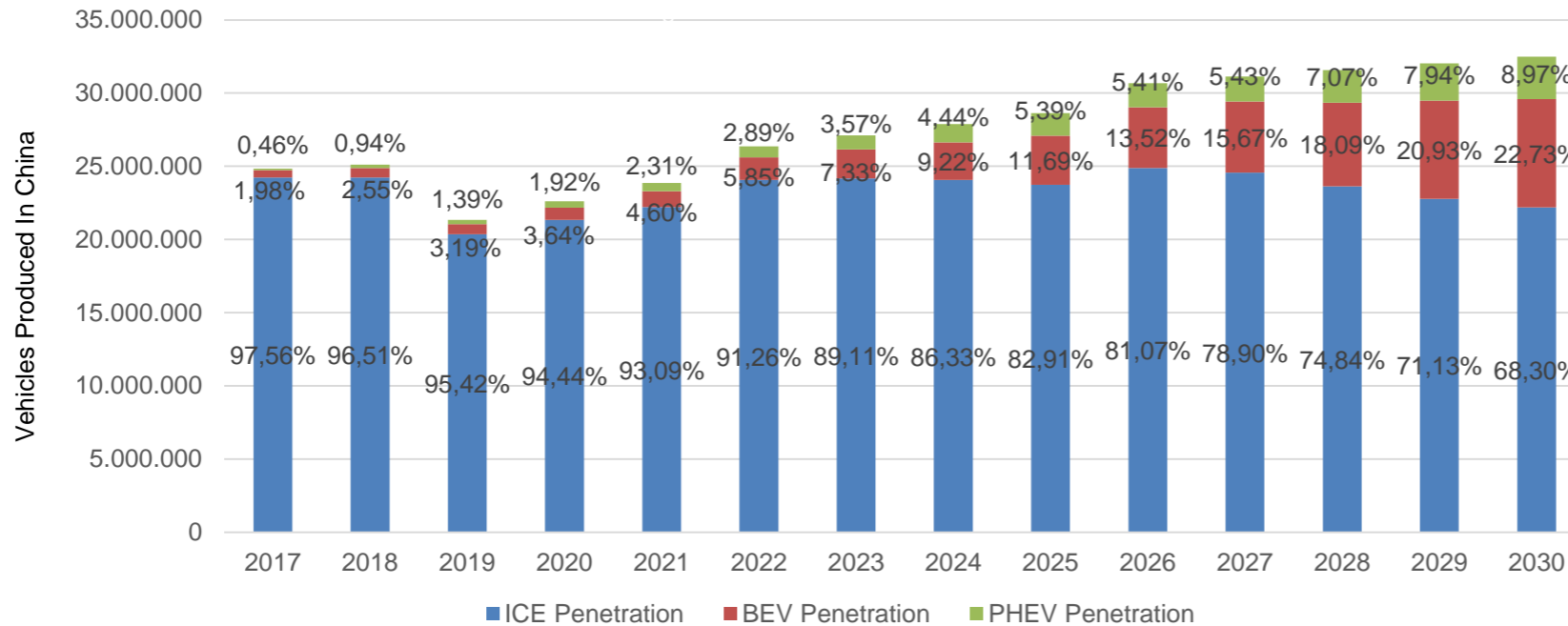
### EXECUTIVE SUMMARY - ELECTRIC MOTOR HOUSINGS

### MACRO TRENDS IMPACTING THE DEMAND FOR CAST ALUMINUM & MAGNESIUM

Source: AluMag®

#### CHINA NEV PASSENGER VEHICLE MARKET FORECAST BY PRODUCTION

#### CHINA NEV MARKET BY SEGMENT



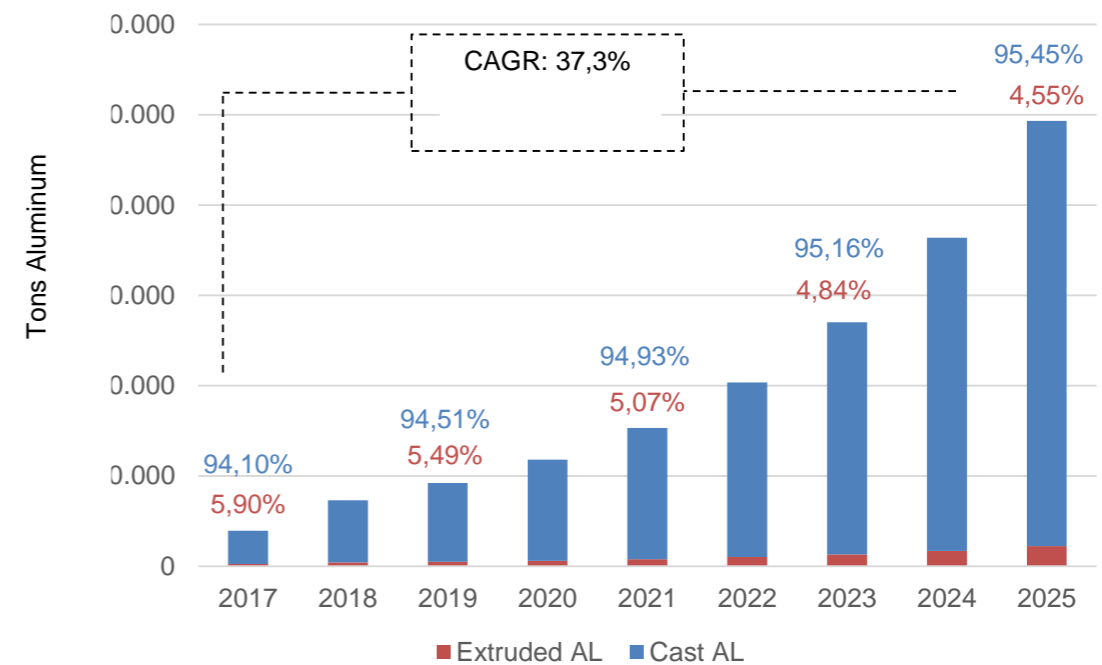
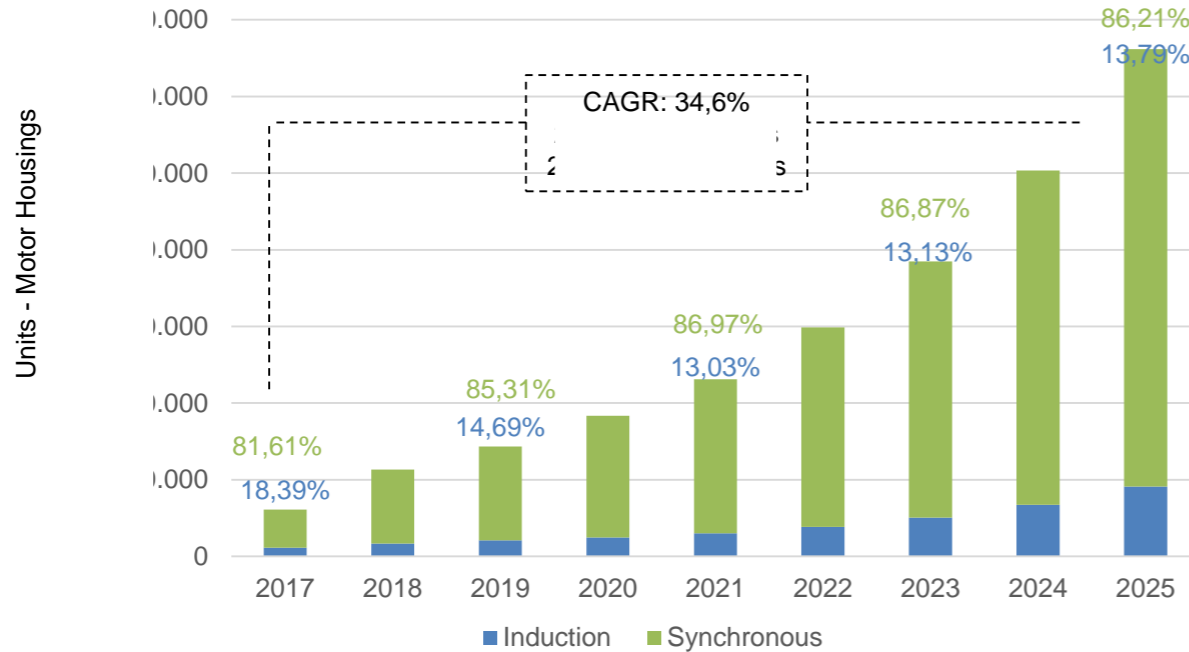
The penetration of NEVs [New Energy Vehicles = BEVs [Battery Electric Vehicles] & PHEVs [Plug-in Hybrids]] are expected to grow from 2.44% in 2017 [606,000 units] to 31.7% in 2030 [10,302,000 units]. Today 19% of all NEVs sold are PHEVs, but a new planned structure of the incentive program to take effect in 2020 will likely have an impact on this figure in the future. Foreign OEMs currently holds about 7% of the NEV market [Sales] but their market share should rise as a result of China's New Energy Vehicle mandate policy. In 2017 A & B segment cars accounted for 50% of the total NEV market, C - D segment cars held 44% and E - Large segment 6%.



### EXECUTIVE SUMMARY - MOTOR HOUSINGS - MARKET ANALYSIS

Source: AluMag®

#### FORECAST: MOTOR TYPE & MOTOR HOUSING MATERIALS IN THE TRIAD [USA, EUROPE & CHINA COMBINED]



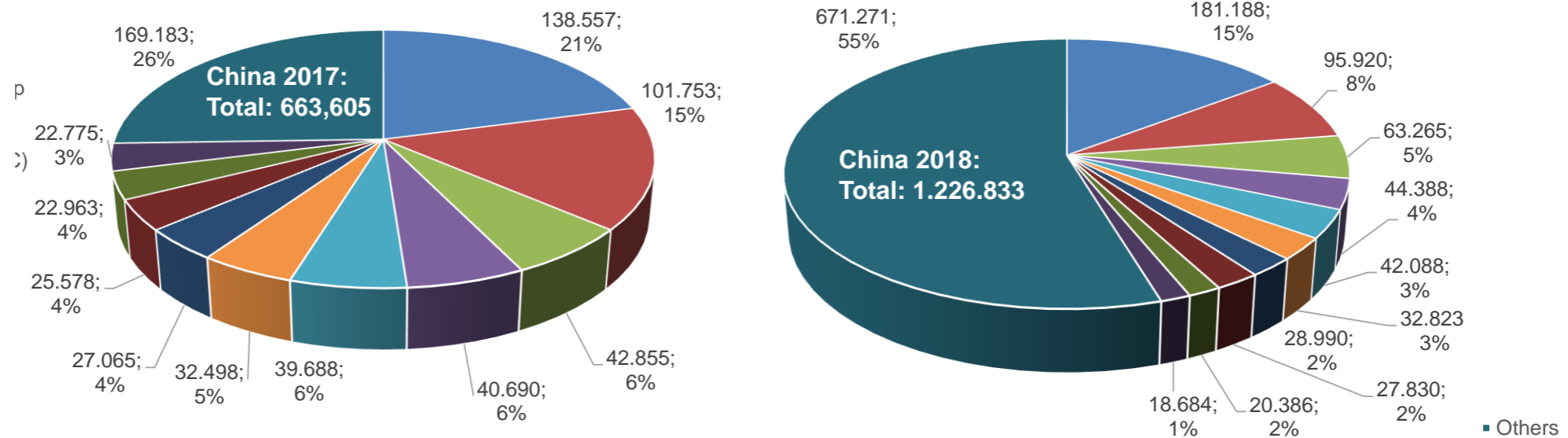
In the triad region 1,227K motor housings were produced in 2017 with cast Al accounting for 94.10% of these. [18K tons cast AL]. The demand for NEV motor housings are expected to increase by 34.6% cagr until 2025 reaching 13,233K units [247K Tons AL] in 2025. Induction motors accounts for 18.39% of the market in 2017 decreasing to 13.79% in 2025. Cast aluminum is and will remain the preferred material for motor housing over the analyzed timeframe.

## E-MOBILITY TO SHAKE-UP THE MATERIAL/PROCESS MIX! RACE HAS BEGUN! U-TURN 2030 IS POSSIBLE!

### EXECUTIVE SUMMARY - MOTOR HOUSINGS - MARKET ANALYSIS

Source: AluMag®

#### TOP 10 MOTOR SUPPLIER SHARES CHINA - SECONDARY ANALYSIS - 2017 VS 2018:



The Chinese motor market was expected to / IS increase from 664K units in 2017 to 1,226K units in 2018. According to Gaogong Research Institute the 10 biggest suppliers of EV motors accounted for 75% of the Chinese market vs only 45% in 2018. The 10<sup>th</sup> biggest supplier in 2018 “Fangzheng is expected having supplied app. 19,000 units. A sign that the market consist of multiple smaller suppliers below the top 10. A single contract can easily propel a small [In terms of volume] motor supplier into the very top of the market when considering the 19,000 units as the hurdle. BAIC, Changan and Dongfeng are bringing electric motor in-house, either though buying motor suppliers or though JV with the motor suppliers. While Geely is continuing outsourcing from Jingjin.

### EXECUTIVE SUMMARY - MOTOR HOUSINGS - TECHNICAL RESEARCH

Source: AluMag<sup>®</sup>

#### IDENTIFY THE CLASSICAL PRODUCTION STEPS AND ADVANTAGES AND DISADVANTAGES OF DIFFERENT TECHNICAL PROCESSES FOR MOTOR HOUSING & DETERMINE WHICH PROCESS/TECHNOLOGY ROUTE WILL BE THE MAINSTREAM

Design & Technologies: Today's main e.motor families are induction and synchronous with derivatives, modifications up-to hybrid / combinations. Regardless what e.motor, in the following a list of kind of e.motor housings:

1-shell cast: For simple non-performing e.motors without active liquid cooling

no / less future

1-shell extruded: For simple non-performing e.motors without active liquid cooling

no / less future

2-shell single cast: All processes which will realize a liquid cooling coat or channel by lost foam, cores, in-situ,....

prospective future

DONGFENG e.g. favors a two-opposite conical core, PORSCHE a lost core like the NEMAK / IAV concept

Considering the up-coming completeness of e.motor housings modified HPDC and LPDC are the most promising processes. CPS [Core Package Sand Casting] could be an alternative too and thin wall cast FE is also in the race

2-shell 2 cast parts joined: Very common today, two separate cast inner and out shell are joined by FST and/or

un-sure future

LASER. If the 2-shell single cast e.motor housing will be successfully in high scale implemented, the 2-shell 2-cast part version will be most likely phased out

2-shell extruded: Due to the expected increase of complexity unlikely, as the 1-shell versions

no / less future

2-shell cast - extruded joined: The highest advantage, the inner shell is extruded which provides a higher ductility compared cast once. The outer shell is cast and joined by FST and/or LASER. DAIMLER is using such a constellation at their PHEV

un-sure future

2-shell cast - sheet joined: Having applied in series production, AUDI is the first OEM until today. Therefore not able to judge yet. An aluminum sheet is applied as inner shell by adhesive to host the stator and provide the liquid cooling

potential

### MACRO TRENDS IMPACTING THE DEMAND FOR CAST ALUMINUM & MAGNESIUM

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Source: AluMag<sup>®</sup>

#### MACRO TREND: AUTOMOTIVE INDUSTRY DOWNTURN

The automotive production is down by around 5% globally as of June 2019 compared to the year 2018. Some of the factors having a negative impact on the global automotive demand and factors with the potential to make matters even worse:

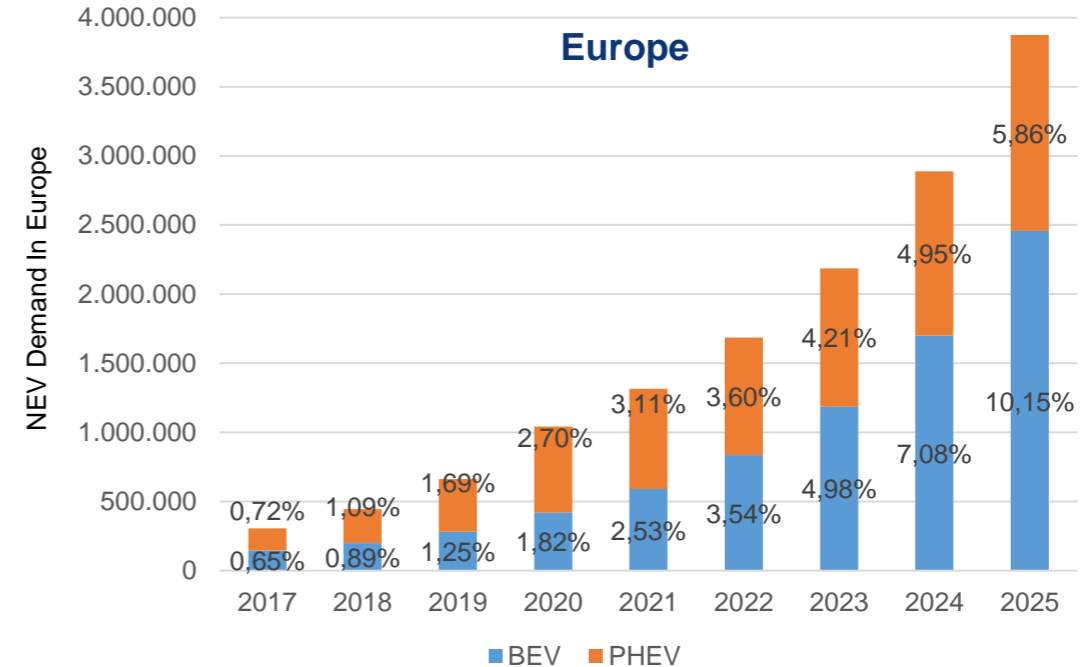
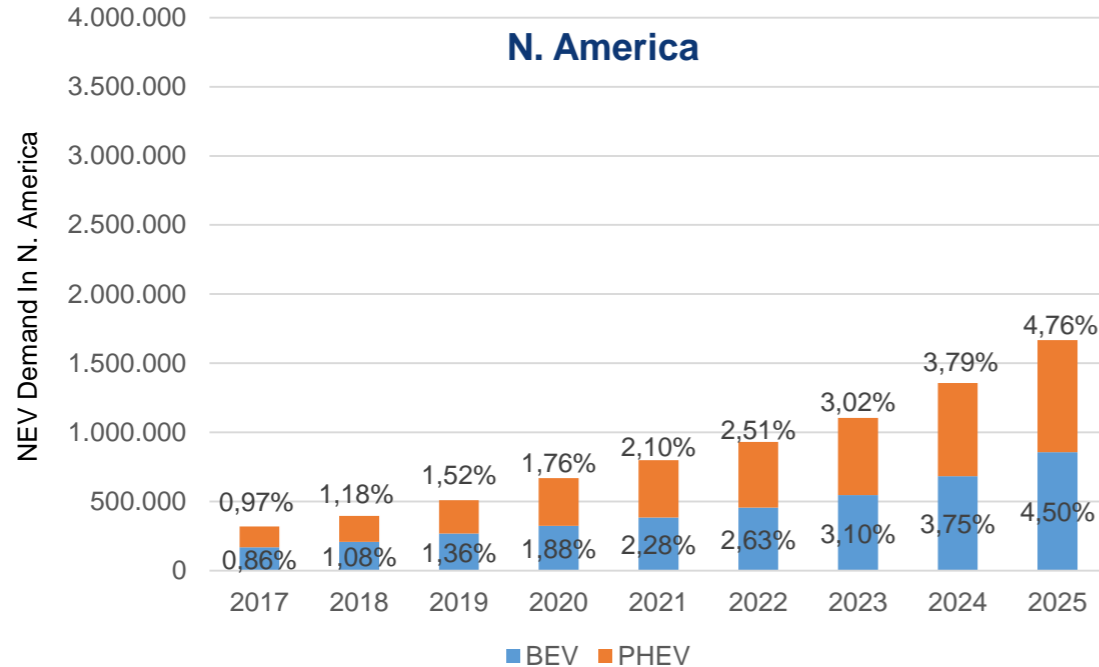
- The financial slowdown in China ,[As well as other regions] and lack of consumer confidence, accentuated by the trade war between China and USA.
- New CO2 emission standards, designed to tackle global warming are expensive for the OEMs to implement, making cars more expensive and harder to sell.
- The entry level for car buyers will shift upwards as OEMs discontinue sales of small cars in Europe due to stringent emission rules and safety regulations.
- Services such as Uber, Ola and Lyft provides sufficient transport for some consumers resulting in a decrease of automotive sales.
- Fear of a hard Brexit has resulted in investment plunging 70% in the UK. A No-deal Brexit would result in a 10% tariff on cars that are imported and exported out of the UK.
- The Italian debt crisis could turn into a new financial crisis in the Euro Zone.
- Possible punitive tariffs for car imports from Europe to the U.S.



### ELECTRIC VEHICLE FORECAST - LIGHT WEIGHT VEHICLES INCL. LIGHT COMMERCIALS

Source: AluMag®, IHS, Boston Consulting, Roland Berger, Alixpartners, Cambridge Econometrics report, FEV, J.P Morgan, Wards

#### SALES MARKET OF BEV - PHEV IN N. AMERICA AND EUROPE

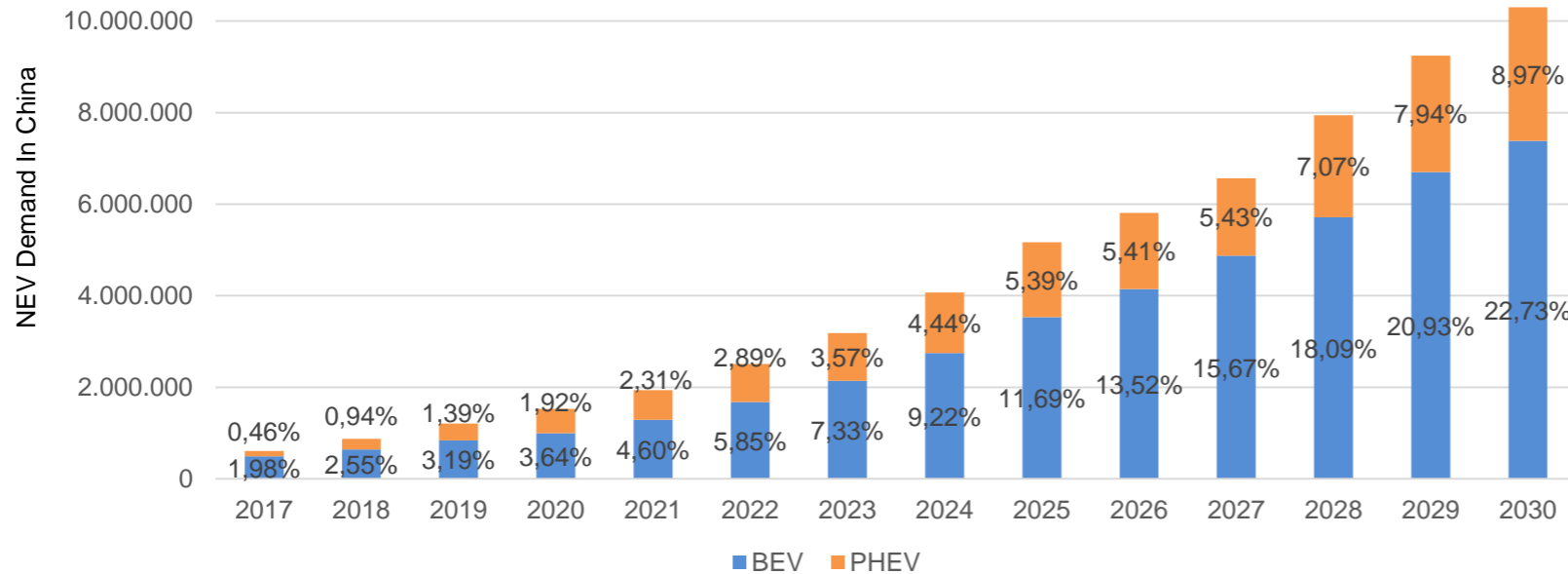


In N. America the penetration of NEVs [Battery electric vehicles and plug-in hybrids] are expected to grow from 1.83% market share in 2017 to 9.26% in 2025. For the European market the growth is expected to be even stronger reaching a market share of 16.01% in 2025 up from 1.38% in 2017. Looking beyond 2025 AluMag® expects the PHEV penetration to drop as battery technology improves, providing BEVs the range necessary to erase range anxiety. The AluMag® forecast is based on multiple outlooks from various forecasting institutes from mainly 2018 - 2019 timeframe.

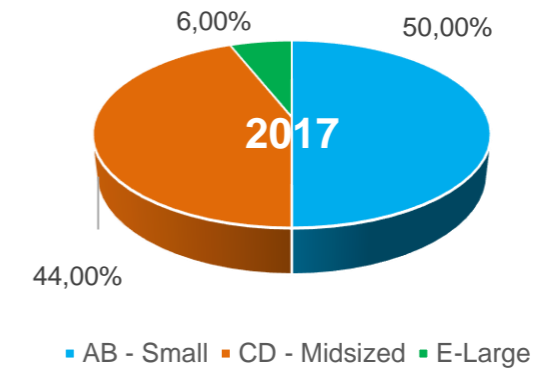
### ELECTRIC VEHICLE FORECAST - LIGHT WEIGHT VEHICLES EXCL. LIGHT COMMERCIALS

Source: AluMag®

#### CHINA NEV PASSENGER VEHICLE MARKET FORECAST



#### CHINA NEV MARKET BY SEGMENT

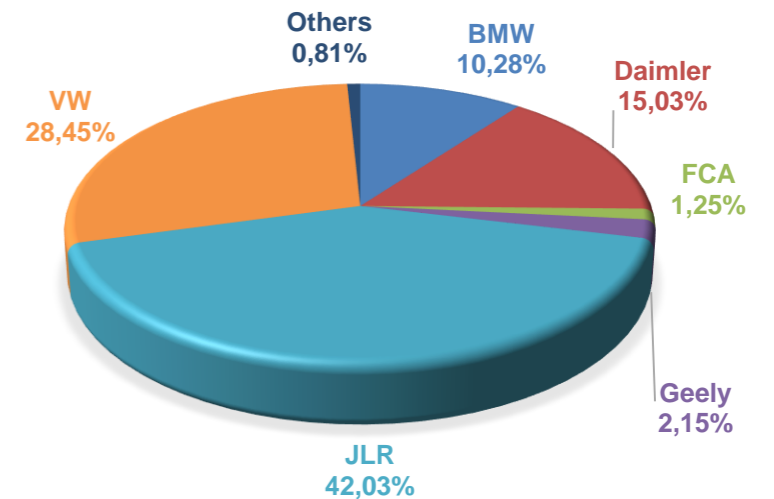
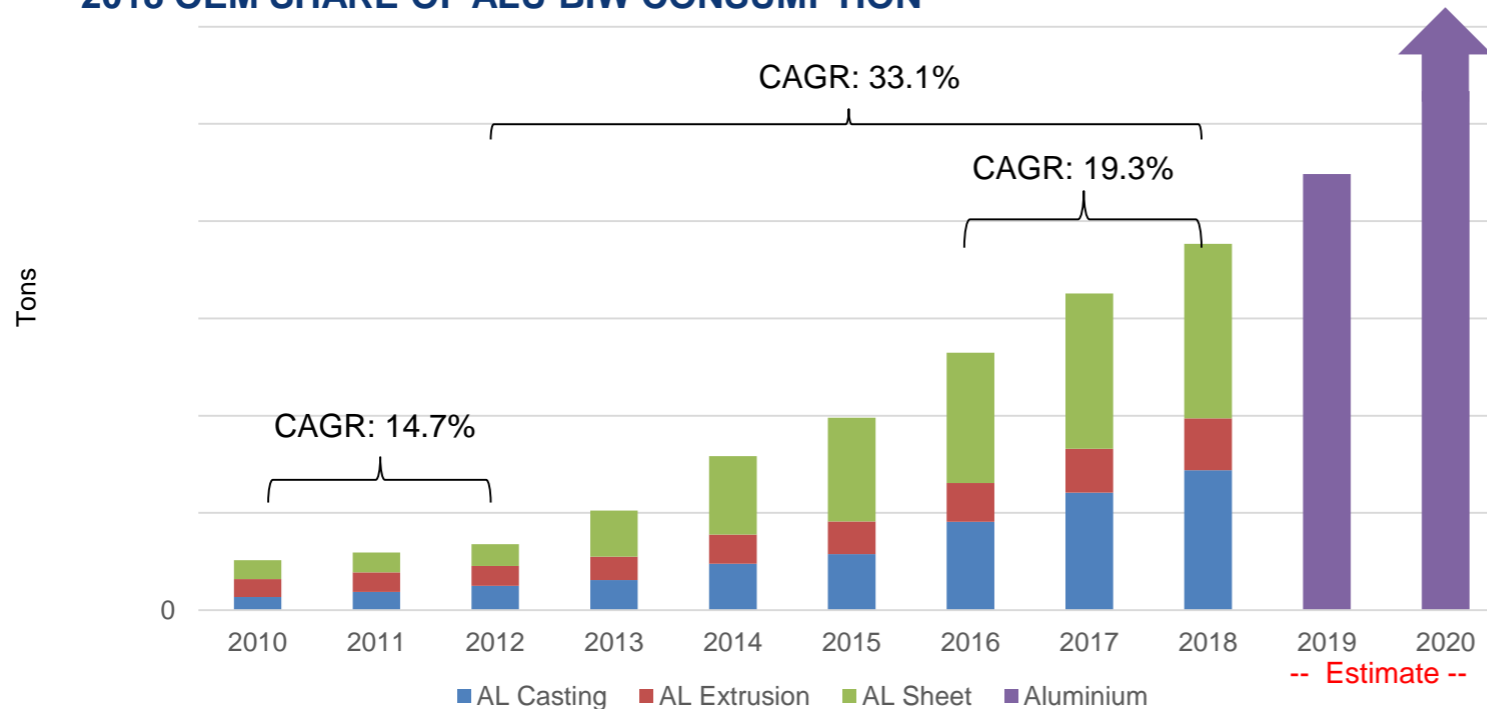


The penetration of NEVs [New Energy Vehicles = BEVs [Battery Electric Vehicles] & PHEVs [Plug-in Hybrids]] are expected to grow from 2.44% in 2017 [606,000 units] to 31.7% in 2030 [10,302,000 units]. Today 19% of all NEVs sold are PHEVs, but a new planned structure of the incentive program to take effect in 2020 will likely have an impact on this figure in the future. Foreign OEMs currently holds about 7% of the NEV market [Sales] but their market share should rise as a result of China's New Energy Vehicle mandate policy. In 2017 A & B segment cars accounted for 50% of the total NEV market, C - D segment cars held 44% and E - Large segment 6%.

### EUROPEAN ALUMINUM CONSUMPTION WITHIN BIW FRAMES [EXCL. HANG-ON & BUMPER]

Source: AluMag<sup>®</sup>

#### 2018 OEM SHARE OF ALU BIW CONSUMPTION

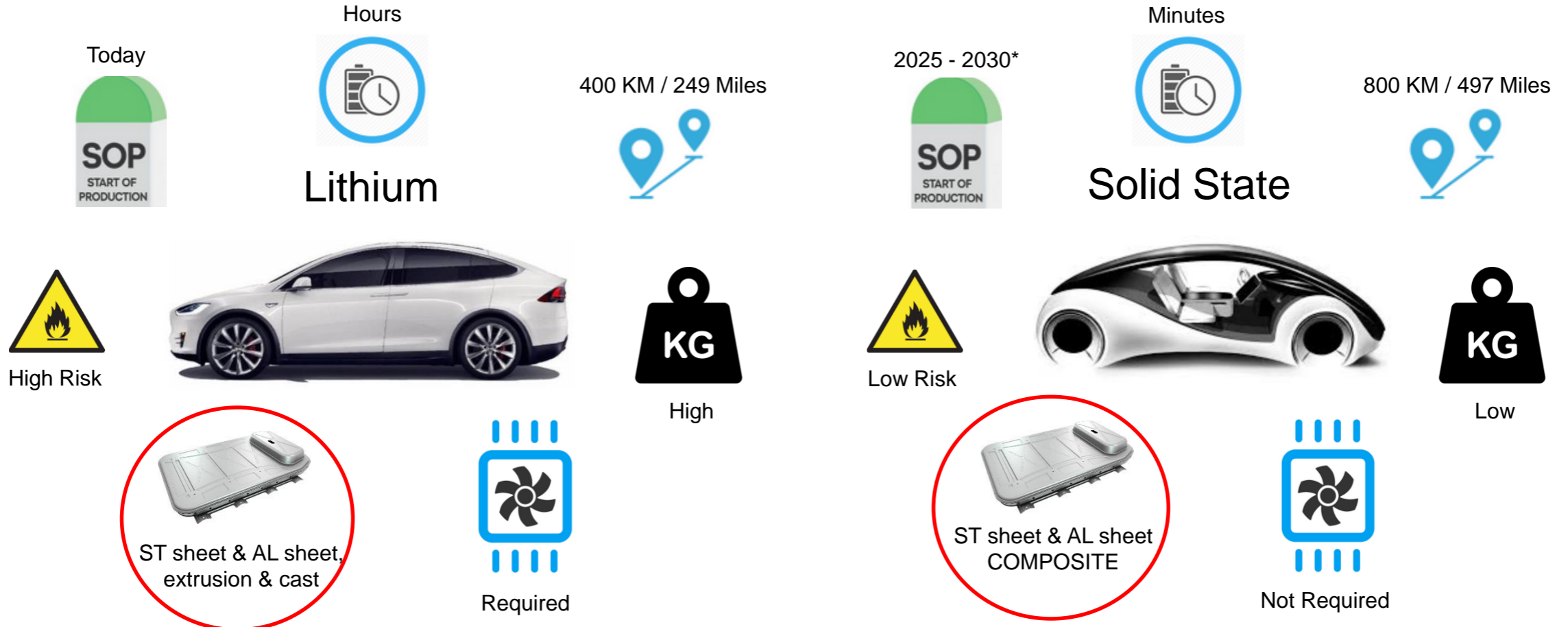


Until 2020 the increasing consumption of AL within automotive frame applications is primarily fueled by the premium OEMs eager to lightweight their vehicles. After 2020 a higher penetration of electric vehicles as well as an expected leap into the higher middleclass will keep the consumption of AL frame applications on the rise. JLR is the biggest consumer of BIW AL as it uses full AL bodies for many of its models. VW, Daimler and BMW are runner ups using mostly hybrid BIW for their premium vehicles.

### MACRO TRENDS IMPACTING THE DEMAND FOR CAST ALUMINUM & MAGNESIUM

Source: AluMag<sup>®</sup>

#### ALUMINUM BATTERY TRAYS & THE IMPACT OF SOLID STATE BATTERIES



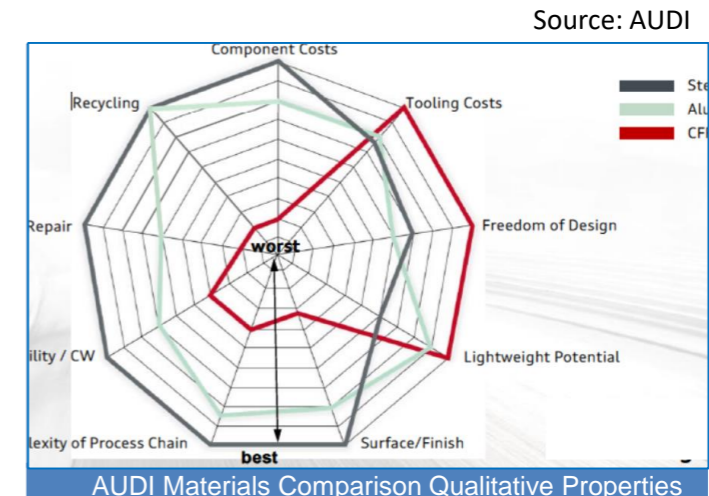


### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### PREFACE: DEVELOPMENT PROCESS LEADS IN MULTIPLE MAT & PROCESSES

General speaking about light weighting cost - performance - mass reduction compromise, AUDI has examined this very intensively and resulted in the following, described as: "Functional Body Aluminum in Comparison" for steel [ST], aluminum [AL] and fiber reinforced plastics [FRP]

	ST	AL	FRP
Density app:	5	2	1
Costs / Kg parts weight app:	2	10	50
Weight reduction potential [%] body app	100	70	60



For non of the analyzed applications, only one material and process is the sole and only alternative or choice. Each materials and processes have its pro and cons, validated and weighted different from case to case, car r car, OEM to OEM and so on.

AUDI has shown this competition of materials and processes in many cases, as well as BMW, DAIMLER, HONDA, ...:

- AUDI has switched the D4 aluminum intensive BiW into a multi material D5, which is the todays actual model
- BMW has changed the E39 48Kg fully aluminum front into a steel - aluminum E60 platform. The new i3 will not have the aluminum - carbon intensive BiW, it will be a multi material one
- DAIMLER SL has pulled away from its aluminum floor out of extrusions
- HONDA developed over more than 10 years a subframe from steel - step by step - into aluminum. The 2018 model line has again a 100% steel version and skipped the aluminum subframe for its Accord

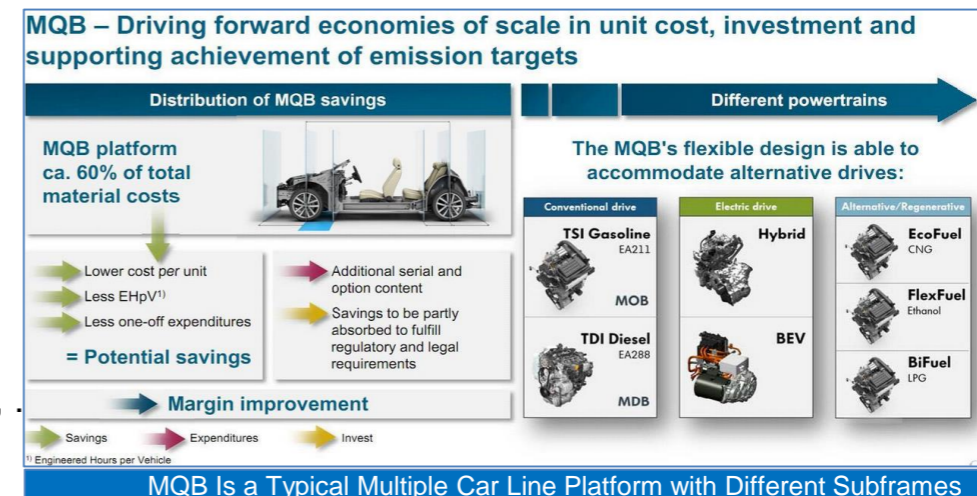
### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### OEM FACTORS TO SELECT MATERIALS - PROCESSES - JOINING - ....

The automotive industry has multiple influencing factors, which leads to materials, process and supplier decision. Out of the market know how, interviews and AluMag's own opinion / view, the following criteria are listed as factors but not exhaustive:

1. Platform and model line strategy
2. Defined car / model line performance, weight and cost targets as well as compromise
3. Region / country of production and sales
4. OEM philosophy, being a:
  1. Innovative / premium leader
  2. Sportive / performance car
  3. Main stream / mass market player
  4. Low cost / budget cars
  5. ...
5. Space, torsional stiffness, collision load paths and crash concept, ...
6. Concept / kind of power train, axle geometry, steering, NHV, acoustics, .
7. Weight pain at / with other or global car architecture

Source: VOKSWAGEN



# AluMag<sup>®</sup>

Europe ■ India ■ Americas ■ Asia

**THE MARKET DEVELOPER**

## E-MOBILITY TO SHAKE-UP THE MATERIAL/PROCESS MIX! RACE HAS BEGUN! U-TURN 2030 IS POSSIBLE!

### EXECUTIVE SUMMARY - BUMPER BEAMS

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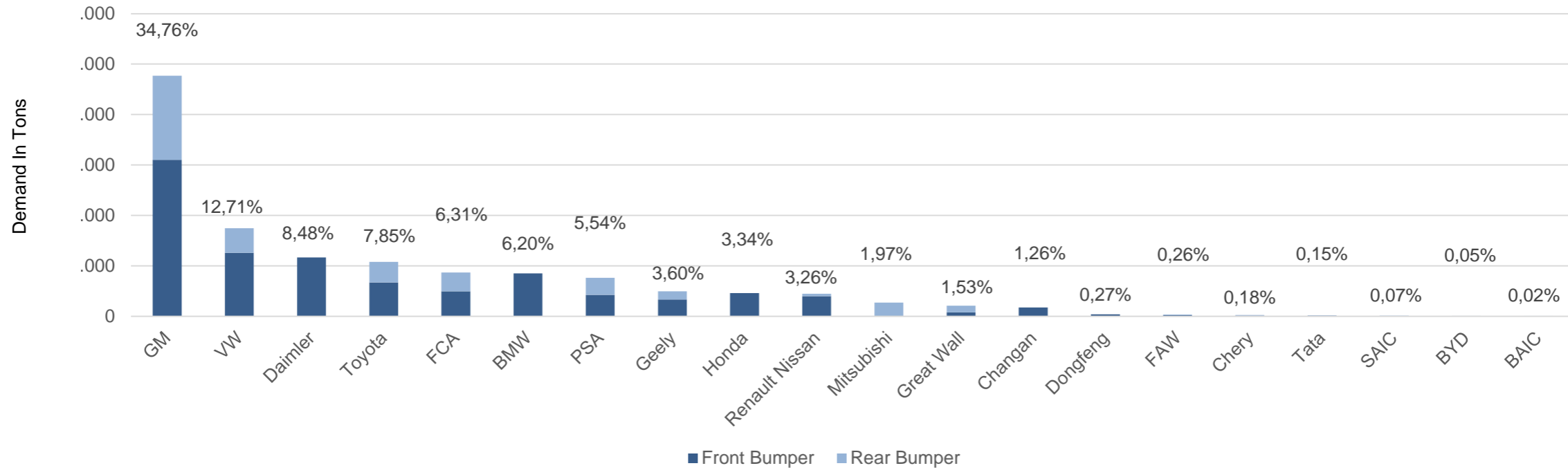


### EXECUTIVE SUMMARY - CMS / BUMPER BEAMS

### EXECUTIVE SUMMARY - BUMPER BEAMS - MARKET ANALYSIS

Source: AluMag®

#### EXTRUDED ALUMINUM DEMAND BY GROUP IN TONS & PERCENT OF TOTAL MARKET



The total demand for automotive extruded aluminum bumper beams [Incl. crash boxes] in China was 26,846 tons in 2017. With a demand of 9,542 tons in 2017 GM was the biggest consumer followed by VW Group [3,490 T] and Daimler [2,328 T]. In 2016 PSA was among the top consumers of extruded aluminum for bumper beams but a 36% dip in its market share [2017 vs 2016] has resulted in a decreasing demand. **BMW & Honda among others are utilizing steel bumper beams for their Chinese produced vehicles while the same models produced elsewhere are fitted with aluminum.** Changan, Chery, Hyundai Kia, Mazda, Nissan are such OEMs planning to increase their output of vehicles with aluminum bumper beams in China. Predominantly in the front area.



### EXECUTIVE SUMMARY - BUMPER BEAMS - TECHNICAL RESEARCH

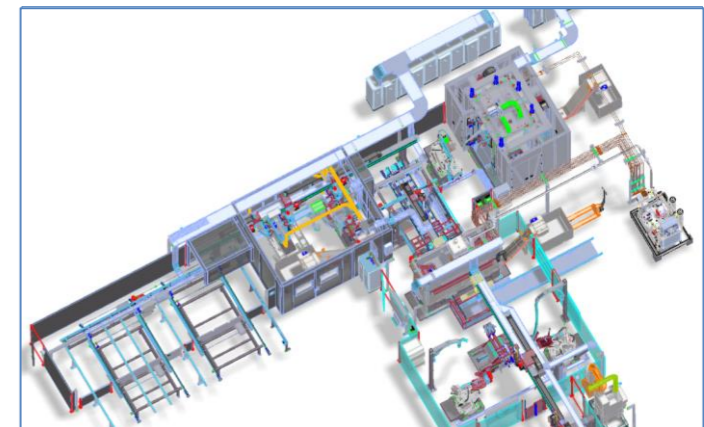
#### STEEL & ALUMINUM BUMPER BEAM IN COMPARISON

- Extruded aluminum CMS are and will be the best choice beside roll formed steel
- Precised and high repeatable / productive / utilized automated processes is the key to be a successful and profitable bumper beam and CMS supplier. Therefore after design freeze, the equipment with high productivity and OEE are the criteria, to run a profitable business
- New 6xxx alloy composition with strength UTS up-to 425 MPa in competition with 7xxx UTS up-to 500 MPa
- Increasing shape complexity with more tied tolerances at higher strength, less parts and function integration are expected
- Ideal design, cross sections and alloys of the crash boxes and bumper beams and its joining as well as the installment to the longitudinal members to provide a crash absorbing structure at the desired weight and functional by inserting technology
- Selecting and applying the most effective forming like “stretch-, press-, roll-, 3D CNC free-form-, .... Bending
- About the bumper beams for especially E-NCAP and C-NCAP cars, tendencies regarding cross sections, the extruder prepare them self to serve multi hollow with wall thicknesses down to 1.2 mm. **A bumper beam with a weight of 2Kg will be common for C- and D-Segment car lines**

Source: AluMag®

	6XXX	7XXX	HSS/AHSS
Tensile Strength [Mpa]	<=425	<=550	400~1000
Elastic Modulus [Gpa]	69	69	180-200
Weight Reduction up-to	<50%	>50%	100%
Cost depending on multiple factors	100-150%	120-200%	100%

After Forming and Heat Treatment



BMW Fully Automated Process AI-Structural Part

### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### COMPETING MATERIALS ARE STEEL & ALUMINUM FOR BIW & HANG-ON

Multiple materials and processes are in today's and future series applications for structure applications. Material, process and joining selection / definition of structural and crash management related applications and functions are the key parameter for a lightweight vehicle design in regards of the entire car performance. Engineers and designers do have the choice by using alternative materials like aluminum, magnesium, composites and steels. Main materials are steel and aluminum today. Good energy absorption by deformation and protection of the vehicle structure as well as drive line and fuel system etc. are the main role. Magnesium and composites incl. reinforced plastics could attack in future the stronghold of aluminum [up-to 550 MPa] and martensitic steel [up-to 1700 MPa].

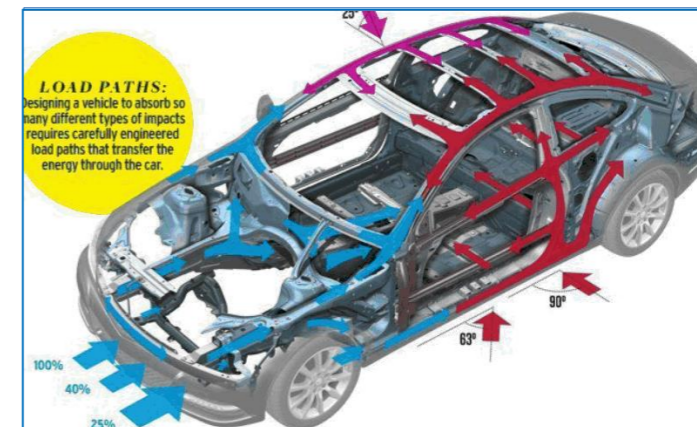
High-strength aluminum 6xxx/7xxx alloys have realized a weight reduction of approximately 30% compared to conventional 6xxx.

The new generation of AHSS represents the best of the hard and modestly formable first generation and the more highly alloyed but more formable second generation. The properties of AHSS result from careful control over factors such as the cooling time of the metal and impurities that are added intentionally to the alloy.

Source: BMW



BMW 5 Series



Car Structure with Illustrated Load Paths

### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

Source: AluMag<sup>®</sup>

#### COMPARISON CAST ALUMINUM

- + weight saving up-to 40% in comparison to steel
- + hollow LPDC and HPDC opens new / further engineering and design freedom
- + cast as near net shape with function integration
- + hollow LPDC with additional cost of 8.00 CNY/Kg very moderate compared to single solid LPDC
- + highest grad of topology optimization
- higher wall thicknesses needed
- as non hollow but single cast part less torsional stiffness and no undercuts
- no alloy grad developments with significant improvement
- no ability to engineer modular systems for various drive train, wheel base, center distance
- no alloy grad mix possible

#### VS. EXTRUDED ALUMINUM

- + weight saving up-to 50% in comparison to steel
- + relatively thin wall results in less space needed
- + easy combination of different alloy grads and families
- + alloy mix with tubes, extrusions and sheet
- + hydro forming gives an additional advantage with high grad of the geometrical optimization
- + advanced welding technics lower the hurdle and broaden the availability
- + ability to engineer modular systems for various drive train, wheel base, center distance
- less topology optimization possible
- intensively forming, joining processes and multiple parts are needed

#### VS. TRB / TRT - AHSS - UHSS

- + weight saving up-to 30%
- + thin walled results in less space needed
- + easy combination of the alloy grads
- + alloy grad mix with TRB and TRT
- + hydro forming gives an additional advantage with highest grad of the geometrical optimization
- + most cost effective light weighting
- + advanced welding technics lower the hurdle and broaden the availability
- + ability to engineer modular systems for various drive train, wheel base, center distance
- less topology optimization possible
- High spring back is relatively difficult to control respectively to avoid
- UHSS susceptibility to crack therefor an extraordinary appropriate welding parameter / control is needed

### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

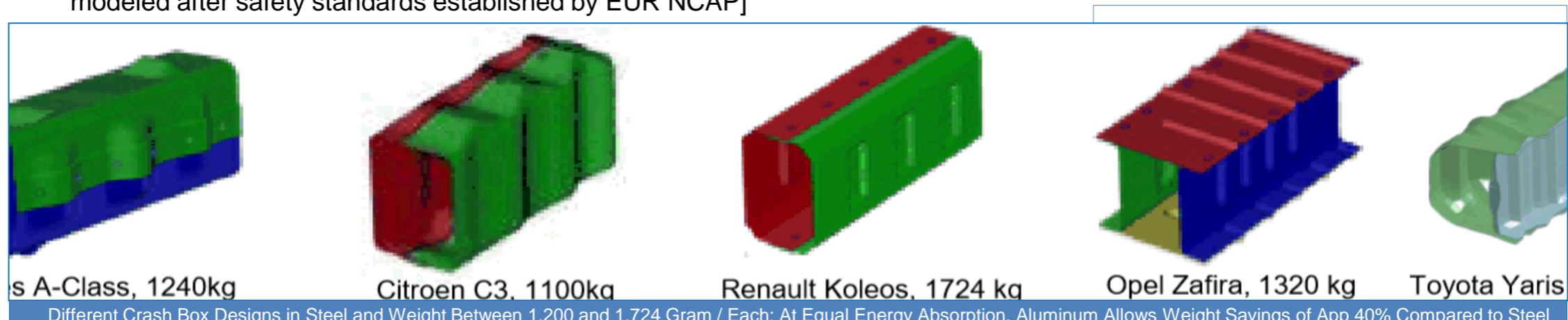
Source: AluMag<sup>®</sup>

#### NCAP WILL INFLUENCE STRUCTURE APPLICATIONS AND CMS DESIGN

The Global New Car Assessment Program [Global NCAP] was established in 2011 to serve as an international platform for cooperation amongst NCAPs and to promote their development worldwide. In this role, Global NCAP has given financial and technical support to new NCAPs in the emerging markets such as of South East Asia and Latin America to support safer cars. This new crash regulations, fuel efficiency mandates, emission norms, with these legislations targeted at passenger cars, the OEMs are equally excited to look at new and competitive light weighting technologies. Due to these, the OEMs will put even more focus and effort on the car structures over the next five to ten years.

Today, e.g. two totally different crash load cases with similar names, both showing a different crash behavior:

- US-NCAP full frontal crash, 56 km/h
- EUR-NCAP ODB [offset deformable barrier] crash 64 km/h [The C-NCAP, Chinese car safety assessment program is primarily modeled after safety standards established by EUR NCAP]





### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

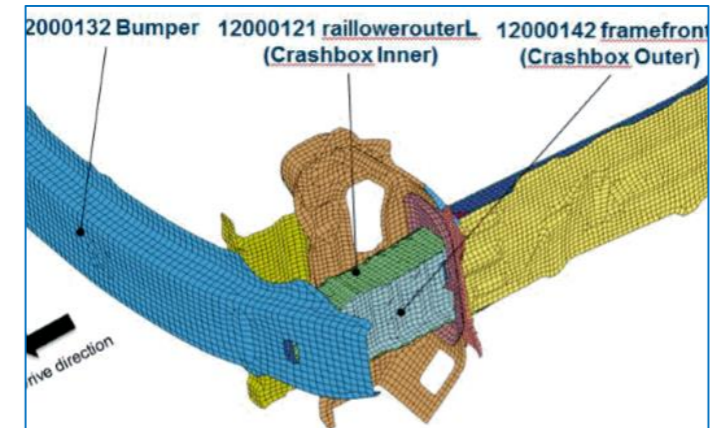
#### NCAP VS IIHS

A today's front structure can easily absorb the kinetic energy of a US-NCAP full frontal crash, even without the use of an additional crash box [the crash box is located between the side member and the bumper beam to absorb kinetic energy in case of accidents at low speeds, the side member experiences only elastic deformation, to reduce the repair costs and allow a better insurance classification]. The mean deceleration of the structure is around 30 g. The deformation of the passenger compartment is small, at around 70 mm.

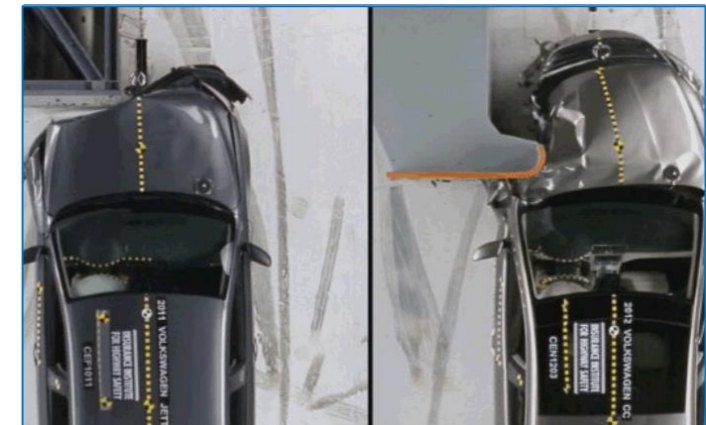
With the EUR NCAP-crash, there is a larger deformation of the impacted side, which is expected. The energy absorption of a today's front structure is still sufficient. The mean deceleration is slightly lower, compared to the US-NCAP full frontal test, at around 25 g.

The USA Insurance Institute for Highway Safety [IIHS] for example, places very high importance on passive safety, which is rather odd. The particularly demanding small overlap front collision [25% frontal offset] test, done with a rigid barrier, is only conducted in the US.

Source: NK



Visualization of the Front Crash Structure



IIHS 50% Offset IIHS Small 25% Overlap

### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

Source: AluMag®

#### BUMPER BEAM AS AN EXAMPLE OF OEMS MATERIAL SELECTION

- The main users of sheet aluminum bumper beam are JLR, Audi & GM
- According to AluMag sources sheet aluminum bumper beams [7xxx alloy as sheet pre-material by Novelis] is an interesting alternative to steel & extruded aluminum bumper beams and the penetration could increase in the future. But a boom is not yet to be seen. Audi A4 B10 is planned [not confirmed] with steel beams replacing the B9 model with aluminum sheet beams, the former B8 had a front extruded aluminum bumper beam and rear steel beam with extruded crash boxes. Furthermore Jaguar XE & XF both have front aluminum sheet beams but the recent launched F-Pace has an extrusion beam which could be a sign of a general switch towards extrusions at JLR.
- BMW replaces its 5-Series PL6 generation [front alu / rear steel beam] with the new 5-Series [CLAR] which is fitted with front and rear extruded bumper beams in Europe.
- Finally the former Buick Regal rear aluminum sheet bumper beam [5<sup>th</sup> generation] was recently replaced with an extruded beam on the 6<sup>th</sup> generation Regal.
- Hot formed AHSS and UHSS could be replaced by less expensive DPS [Dual Phase Steel], which does not need the hot forming according to an insider information [Benteler and Mubea]

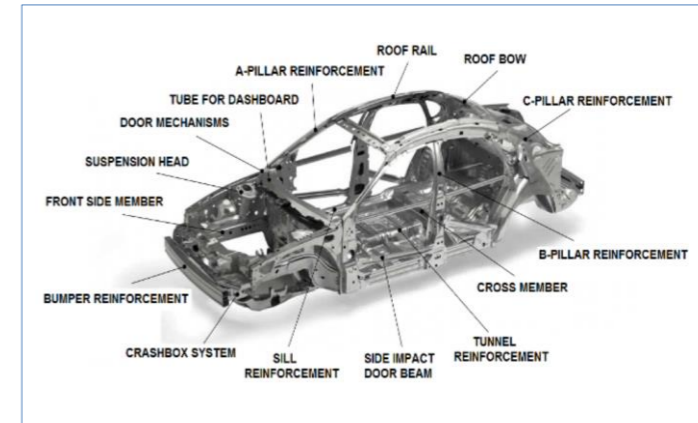
### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### BIW WILL UTILIZE HIGHER VOLUMES OF ST FOR EV MASS MARKET PLATFORM

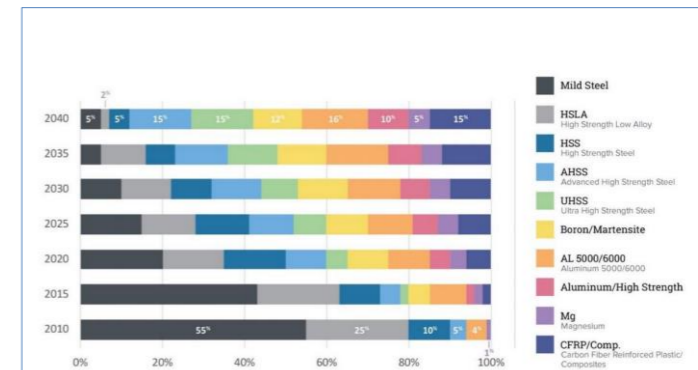
Automakers are integrating e-mobility into their future strategies, with electrified vehicles no longer residing as just a premium option. With the arrival of more efficient batteries, weight saving to improve electric driving range will become less important. Automakers will utilize materials that offer the most cost efficient solution for the vehicle structure. Elements of an EV that have more recently been constructed with aluminum for weight saving purposes[e.g. doors, wheels, BiW] could be monopolized by steel for mass market platforms. A tunnel in the underbody structure caters for both the ICE and its driveline, and also for the battery packs of an EV. Due to the weight of these batteries, the gravity point of the BiW is lowered, and the underbody structure must be redesigned to optimize crash safety. With the higher weight of the batteries more advanced high strength steel could be a solution, in particular hot stamping, in the underbody structure. It also probably leads to a situation of the wheels and chassis, where need to be reinforced.

The next generation BMW i3 is set to return to a steel-intensive design under the guise of the iX1, a similarly sized five-door crossover EV. The Volkswagen ID hatchback, slated to enter production in 2019, will be based on the brand's new MEB architecture with a mix of steel, aluminum and magnesium. The Tesla Model 3 also features a steel-intensive body structure in contrast to the primarily aluminum Model S.

Source: NK



U/AHSS Implementation Locations on Structure



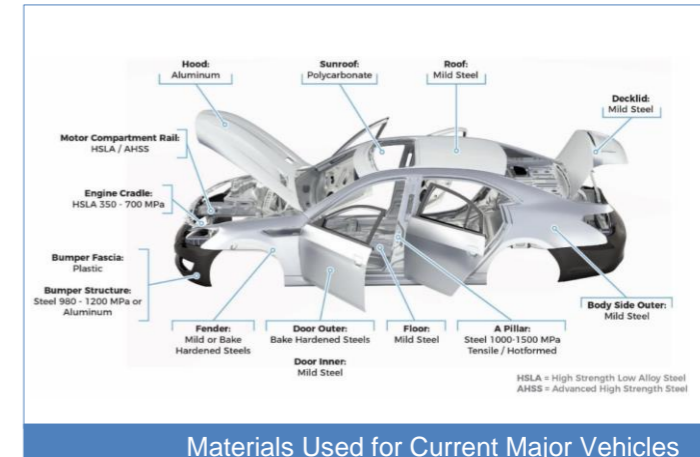
Material Distribution in US in BiW

### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

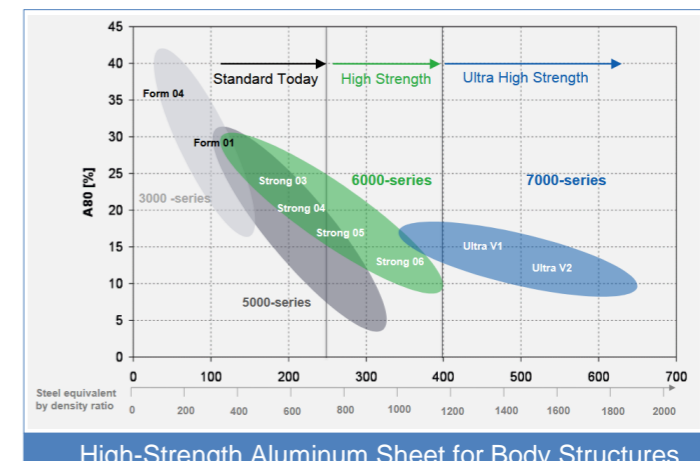
#### ALUMINUM 6XXX/7XXX SHEET FOR STRUCTURAL APPLICATIONS AND CMS

- Structure applications alloys are found in space frames, crash systems and shock towers. 5xxx/6xxx aluminum alloys are used for sheet applications in car body. New 6xxx alloy composition with strength UTS up-to 425 MPa in competition with 7xxx UTS up-to 700 MPa. 6xxx and 7xxx for structural applications including B-Pillars, intrusion beams, bumpers and crush/impact applications.
- High strength AlZnMg [Cu] alloys of the 7xxx series with UTS up to 700 MPa are transferred from aerospace industry and adapted to automotive industry
- New 6xxx alloys have advantages against 7xxx in terms of price, handling, welding, recycling, productivity and availability
- Increasing shape complexity with more tied tolerances at higher strength, less parts and function integration are expected
- Precise and high repeatable / productive / utilized automated processes is the key to be a successful and profitable supplier. Therefore after design freeze, the equipment with high productivity and OEE are the criteria, to run a profitable business
- Ideal design, cross sections and alloys of the crash boxes and bumper beams and its joining as well as the installment to the longitudinal members to provide a crash absorbing structure at the desired weight and functional by inserting technology
- Hot forming high strength AL can be used as a cost effective replacement for high AHSS
- Extruded AL CMS are and will be the best choice beside roll formed steel currently

Source: NK



Materials Used for Current Major Vehicles



High-Strength Aluminum Sheet for Body Structures



### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### NEW 6XXX SERIES ALUMINUM ALLOYS APPLICATIONS

Constellium's Strongalex<sup>®</sup> is a 6xxx balanced property alloy with good formability in T4 temper and a yield strength of 270 Mpa [UTS>300MPa], using fast bake hardening to increase strength and reduce thickness on inner panels. For extrusion-based CMS, BiW structural components and battery enclosures, Constellium's new generation 6xxx alloys [2017] HSA6<sup>™</sup> allows designers to optimize extrusion shapes and reduce wall thickness to achieve weight savings of 15-30% compared to conventional aluminium alloys, with UTS higher than 400MPa. Constellium HSA6<sup>™</sup> also provides enhanced recyclability, machinability and corrosion resistance. Alternately, Constellium HSA6<sup>™</sup> can provide 15-30% additional strength to reduce intrusion in the event of a crash, thereby enhancing protection of batteries, cooling systems and other critical vehicle systems. Constellium HSA6<sup>™</sup> is in production for several 2017 and 2018 model year vehicles, including the MINI Countryman.

Hydro's High Strength 400 aluminium alloy [HHS 400] is based on the 6082, achieves yield strengths above 370MPa, UTS greater than 400 MPa, and elongation at A5 of 8% on sections ranging from mean thickness substantially lower than 3 mm. Applications would include anti-vibration components such as engine mounts, side members for doors and crash management systems, such as front bumpers.

Source: CONSTELLIUM



Constellium's 6XXX AL Strongalex<sup>®</sup> Bumper Beam



Constellium HSA6 High-Strength 6xxx Alloys



### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### 7XXX SERIES ALUMINUM ALLOYS APPLICATIONS

7xxx alloys have high to ultra high strength, are transferred of adapted aerospace grades to the automotive business. 7xxx alloys have limited cold forming ability, require heat supported forming procedures, have inferior corrosion performance, need coating and certain temper. 7xxx sheet are using for replacing press hardened steel in automotive components like B-pillars or side impact beams, crash management systems.

Constellium, AMAG and Novelis have developed, beside the high strength 6xxx also new 7xxx crash alloys. Novelis does consider 7xxx seriously as sheet warm and roll formed. Hoshion has developed a very light CMS [Beam, Crash Box, Plate] which weight around 4kg with an extruded wall thickness of 1.2mm. The Opel Corsa C had already an EN AW-7108 mono rear bumper beam, the Corvette C7 very long crash boxes in 7xxx. So, applying 7xxx alloys in bumper and crash boxes is already common and its penetration will be increased most likely.

Constellium and UACJ developed 7xxx alloy against stress corrosion cracking for B-pillar. AMAG TopForm® UHS is an AA7075 type alloy [AlZn5,5MgCu], with guideline values for T6 could have UTS 575MPa.

Novelis “Hot Form Quench” technology is combining their high or ultra high strength aluminum alloy with hot stamped technology. HFQ was used in Aston Martin DB11 A-pillar, also a friction stir-welded cross member and door inner using the process.

Source: NOVELIS



Corvette C7 Crash Box In Extruded 7xxx



Novelis Hot Form Quench UHS aluminum

### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### 2019 AUDI Q8 WITH MIXED-MATERIAL AND WITH 14,4% HOT-FORMED STEEL

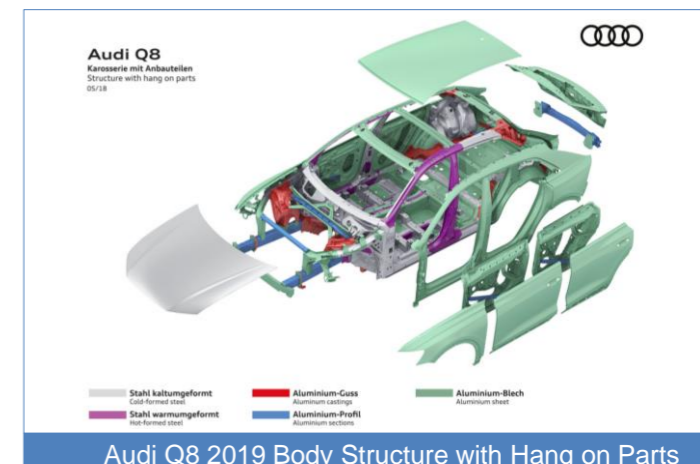
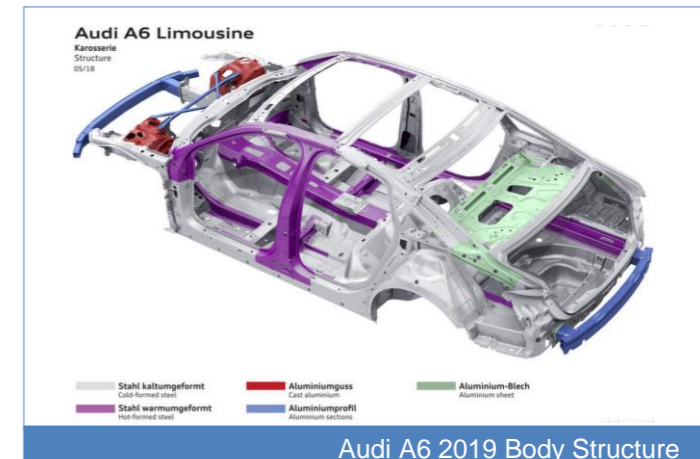
Audi Q8 built on a steel-and-aluminum body-in-white. The BiW is 14,4% hot-formed steel [which is often ultra-high-strength steel], primarily in the driver- and passenger-side door rings and transmission tunnel. [Hot-formed steel parts] are used in the lower section of the bulkhead, in the side sills, the rear longitudinal members, the B-pillars and the front zone of the roof frame. In some areas, Audi uses blanks with tailored, variable wall thicknesses between barely one and a good 2mm. These tailored blanks combine low weight with high strength.

The exterior is all aluminum except for a steel hood. The side panel as well as large areas of the floor, the rear wheel housings and the roof consist of aluminum plates, just like the frameless doors, the front fenders and the tailgate make up 23,7% of the body-in-white.

Another 15% is cast aluminum, including the suspension strut towers and the connections between sills and longitudinal members. 2,4% is the aluminum profiles that make up the front sections of the longitudinal members.

The bumper beams and door inners are also aluminum, including the door inner reinforcement beams. The Q8's curb weight tops out at 2145kg with a mild hybrid powertrain configuration is used, according to Audi. That's lighter than the current-generation Audi Q7, which is 6,6cm taller but 2,8cm thinner.

Source: AUDI

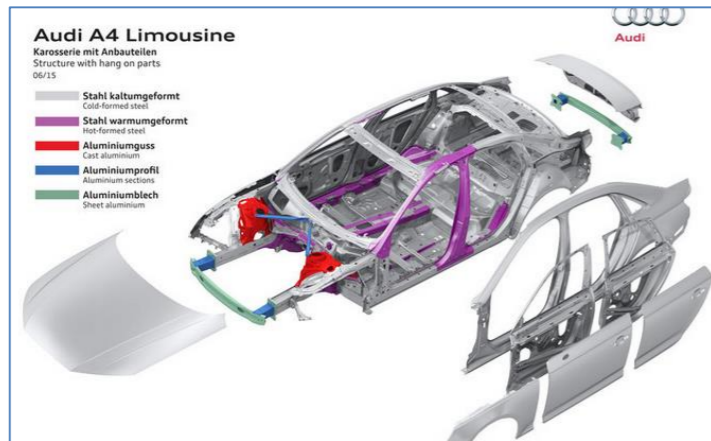


# AluMag<sup>®</sup>

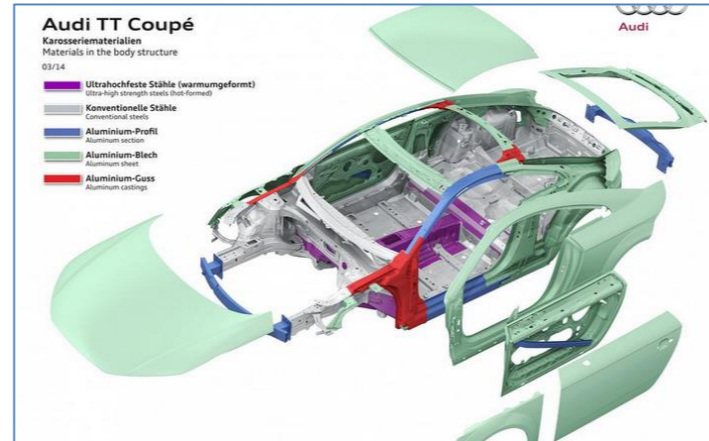
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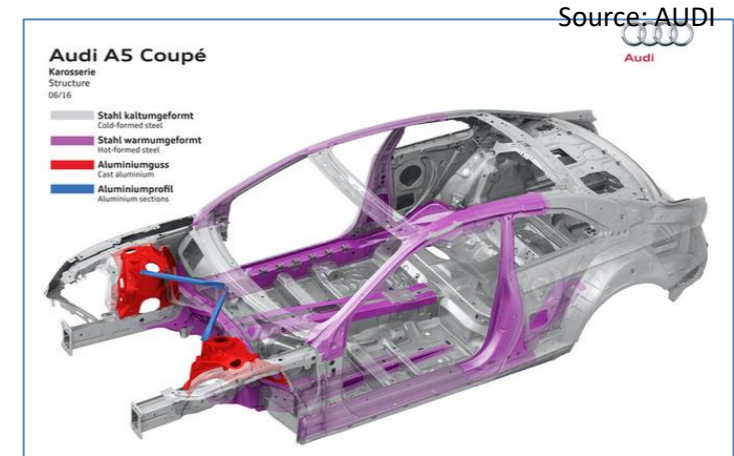
### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS



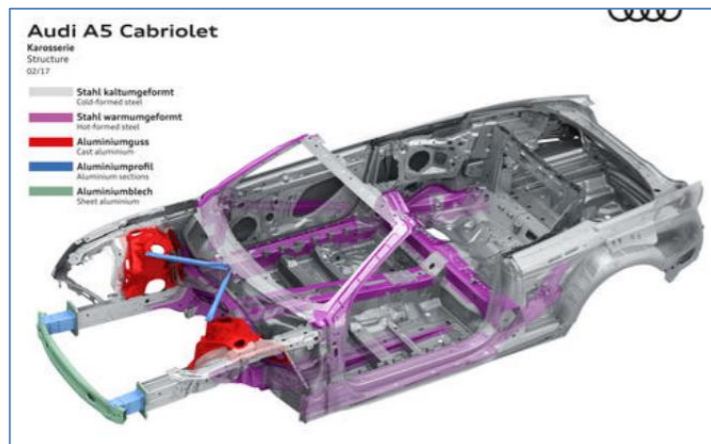
Audi A4 Limousine



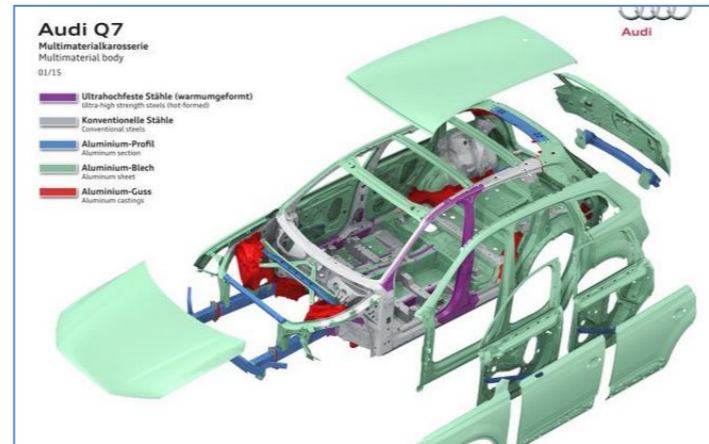
Audi TT Coupe



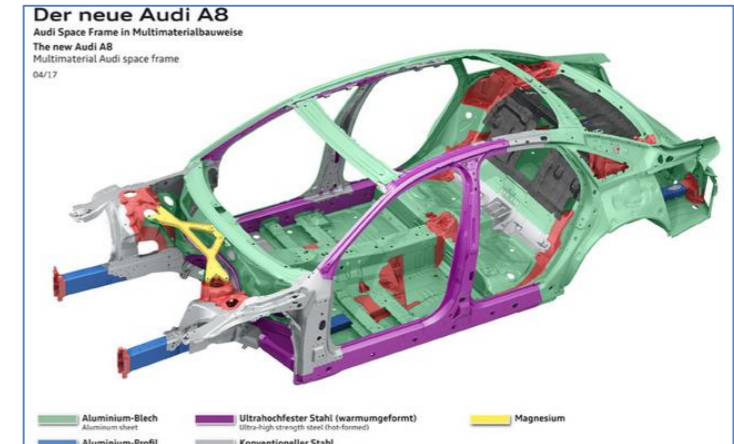
Audi A5 Coupe



Audi A5 Cabriolet



Audi Q7



Audi A8



### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

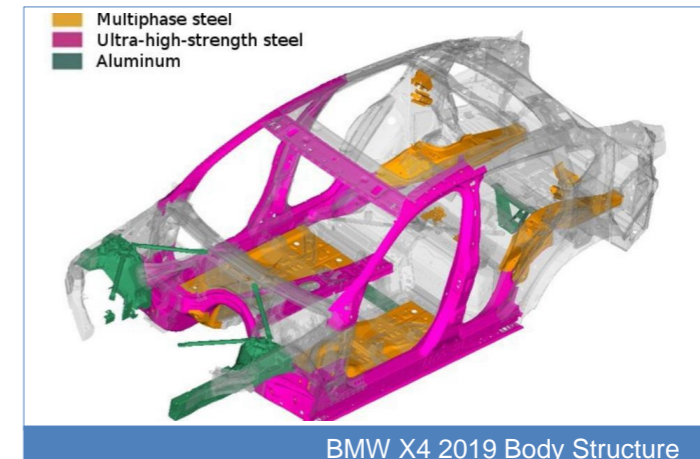
#### BMW

2019 BMW 3 Series cut 20kg out of the BiW, increased use of high-strength steels over the sixth-generation 2012 edition, which itself had been light weighted and engineered with “high and ultra-high tensile steels, a hot-stamped B-pillar, plastics and state-of-the-art composites.” The new 3 Series use aluminum hood and fenders.

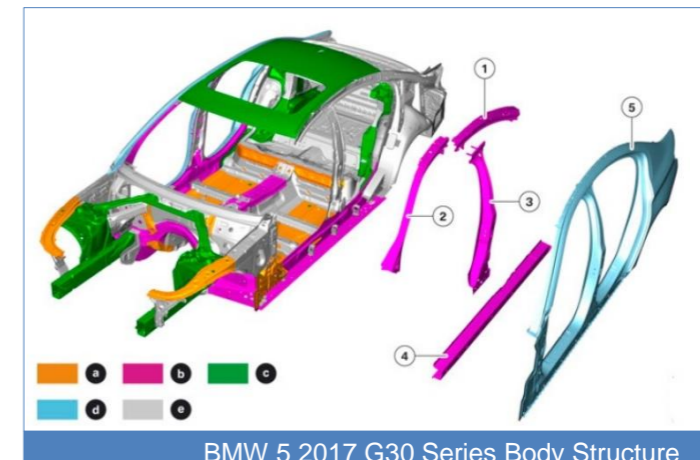
The 2019 BMW X4 has higher-strength steels and some aluminum in the body-in-white. BMW used an increase in the proportion of aluminum as well as high-strength and ultra-high-strength grades of steel in the body structure. The diagram provided by BMW shows aluminum elements and the door rings, rocker rails extending back to the quarter panel, both kick pans, the suspension tunnel and a roof frame cross member are among the ultra-high-strength steel parts. Multiphase steel elements include the floor pans and roof frame rails.

The 2017 5 Series builds on this past generation[doors, hood and front fenders in aluminum], further with its first completely aluminum trunk lid, engine cross-member, rear side-members, roof and doors. HSS and UHSS [roof, side members and rear] appear throughout the vehicle, but more UHSS than its previous-generation, and even the lower-strength steels moved up to stronger, lighter high-strength classes. BMW says the body is optimized for other vehicles’ safety. Deformation spaces are optimally designed and utilized, the aim was to split up the main load paths so that the impact forces are dispersed over as wide an area as possible by the time they reach the extremely rigid passenger cell.

Source: BMW



BMW X4 2019 Body Structure



BMW 5 2017 G30 Series Body Structure

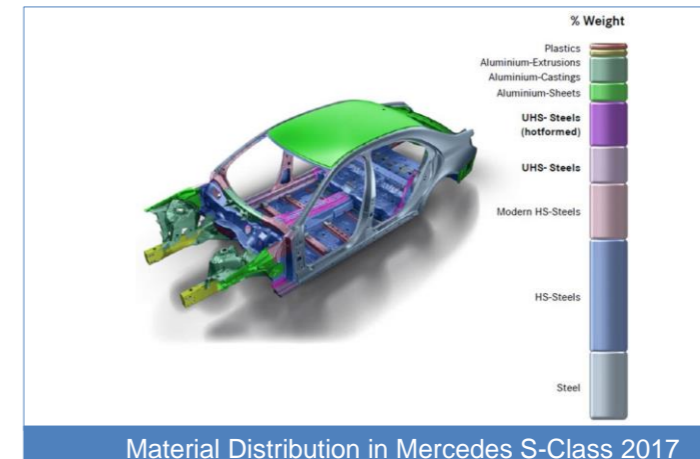
### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### DAIMLER

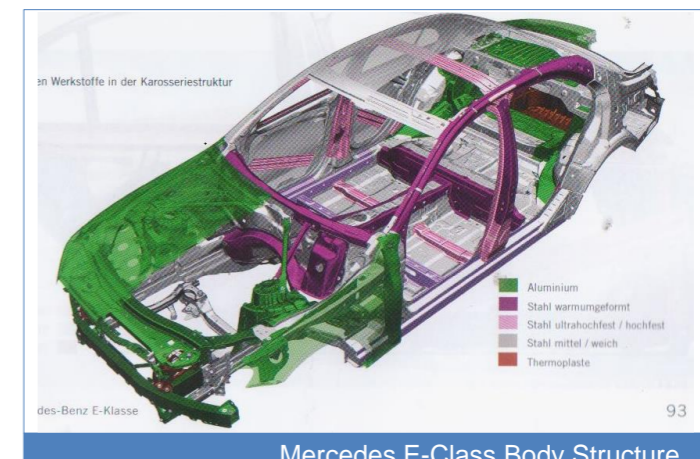
For structural components in the automotive industry there are high demands in terms of safety, weight reduction and cost optimization. The choice of a suitable material or material combination aims at attaining: high crash and durability requirements, good formability, good weldability, and the applicability of all conventional coating methods for corrosion protection. In the case of the integral support of the new Mercedes-Benz E-Class, the required criteria were achieved by choosing a very strong, yet ductile steel. The integral support made of high-strength steel is fixed to the side rails bolted to the body, so it also serves as an important element of the front crash structure of the new E-Class. A body shell with a far higher proportion of aluminum and UHSS components than its predecessor. The front wings, bonnet, boot lid and large sections of the front and rear ends are made of sheet or cast aluminum.

Half of the body shell components of new S-Class are of high or higher-strength, high-tech steel alloys which offer maximum strength with minimum weight. The bonnet, front wings, boot lid and other components are made of aluminum.

Source: DAIMLER



Material Distribution in Mercedes S-Class 2017



Mercedes E-Class Body Structure



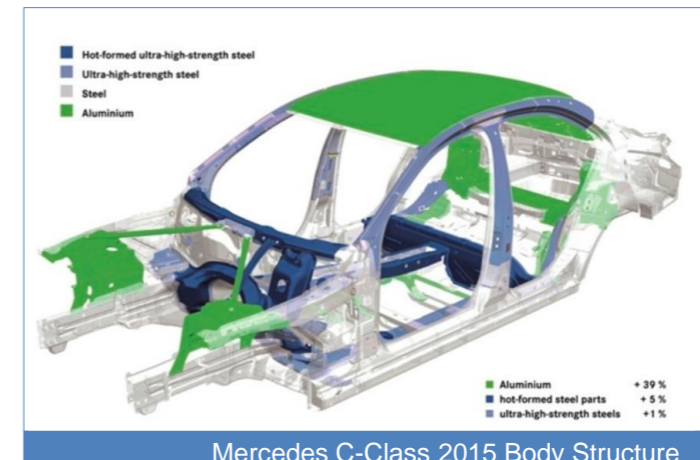
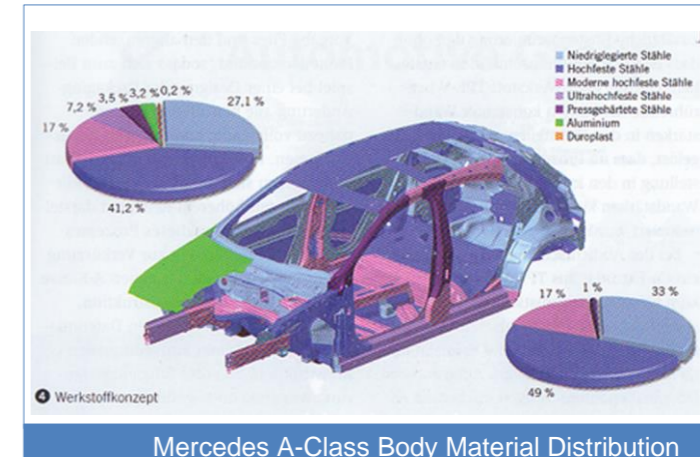
### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### DAIMLER

Mercedes new A-Class has the proportion of HSS and UHSS of 68,9%, and major safety-related components of the body structure are now made out of this high-tech material. Plus, innovative high-strength glued joints increase the long-term durability of the body-shell structure. Two straight, UHSS side members with pre-emptive crash boxes made from HSS and a box-shaped cross section in extruded aluminum. The main floor section consists of several metal panels with differing material strengths, which are fixed together by laser welds. In a world first, Mercedes-Benz also uses this beneficial tailored-blank technique for HSS panels, ensuring maximum strength in areas which play a crucial role in providing occupant protection.

The body structure of the 2016 Mercedes-Benz C450 uses a larger amount of aluminum along with HSS and UHSS, the front fenders, hood, doors, trunk lid and roof panel are made of aluminum. Strategic reinforcements are made of die cast, extruded and stamped aluminum, as well as heat-treated steel and laser-welded, varying-thickness steel.

Source: DAIMLER



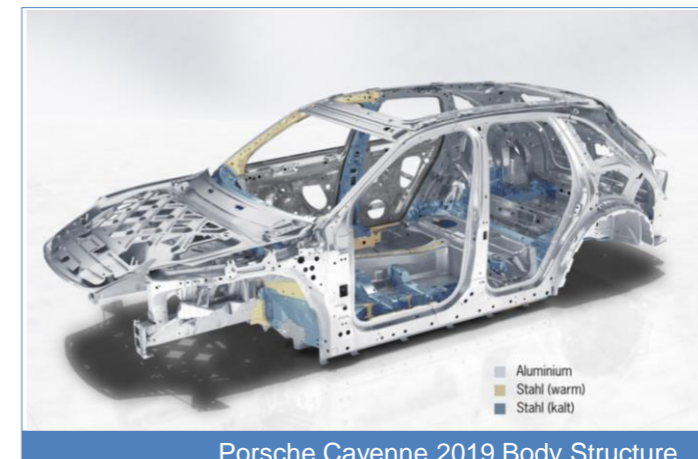
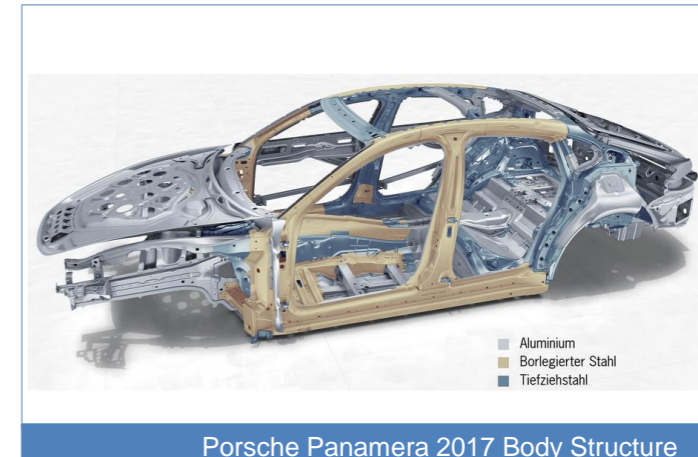
### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### PORSCHE

The 2017 Porsche Panamera body structure is the first car built using VW Group's MSB platform architecture, but using much more aluminum to enable for a lighter, more efficient frame. The basic structure comprises a mix of aluminum and high-strength steels. Nearly a third of the 335kg body-in-white is composed of aluminum. The previous generation had an aluminum hood, doors, and front fenders. The 2017 Panamera's entire body side stamping and roof are now comprised of aluminum. Aluminum is also used for the front crash structure and suspension mounting points to reduce front-end weight. The floor stampings are also composed of aluminum, and much of the passenger cell structure is steel. Attaching aluminum parts like the entire body side to the steel skeleton requires a process that uses adhesive to bond and separate the two materials to avoid corrosion, along with a rolling process that crimps the aluminum skin to the steel skeleton. Porsche claims that its laser-welded roof panel and aluminum skin contribute to a 30kg weight reduction and results in an overall increase of structural rigidity by 8%.

The new 2019 Cayenne's body, whose complete outer shell is made of aluminum, including hood, roof, floor pan assembly, doors, and also front section, rear hatch, and virtually all the chassis components. 42% of the new Cayenne's body is made of conventional sheet steel, 31% is of aluminum sheet, 13% is aluminum casting, 11% is hot formed steel, and 3% is extruded aluminum.

Source: PORSCHE



### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### PORSCHE'S PROVISIONS FOR SMALL OVERLAP CRASH TEST

Porsche new Cayenne 2019 added 45kg weight to BiW for the highway safety's small overlap crash test [which involves a vehicle crashing only one quarter of its frontal width into a barrier].

The first provision was steel bolstering in the wheel well to reduce intrusion into the driver's foot well.

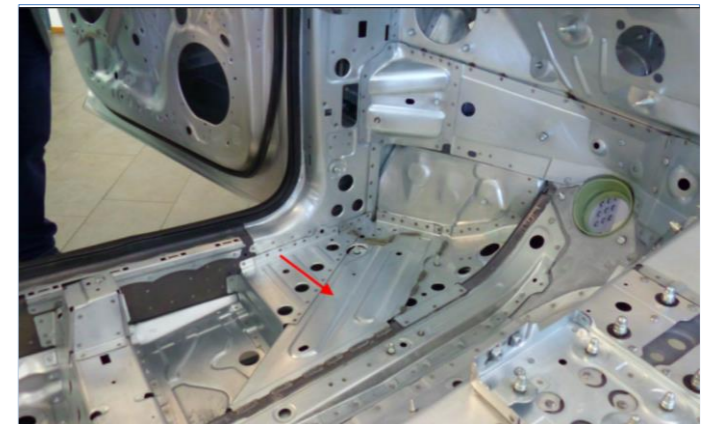
The second provision was a diagonal member that ties that bolstered wheel well structure into a central longitudinal beam. The idea is that the energy from the crash that pushes the inside of the wheel well will be transferred through that diagonal member, into the strong longitudinal beam, reducing intrusion.

In addition to the provisions on the body, the front subframe was designed in such a way that it precisely orients the wheel during a crash to help minimize intrusion into the cabin.

Source: PORSCHE



Steel Bolstering to the Wheel



A Diagonal Member



### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

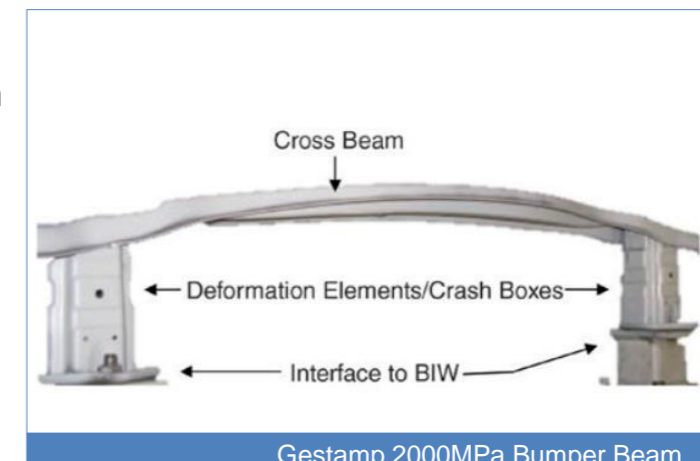
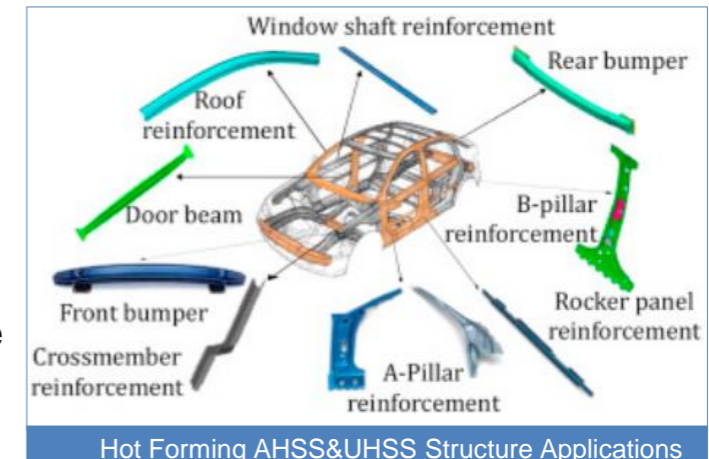
#### HOT FORMING/PRESS HARDENING UP-TO 2000 MPA, AHSS, UHSS

Hot-stamped, high-strength steel components and assemblies are pervasive in nearly all vehicles today. The hot stamping process enables the use of high-strength steels for products particularly critical in occupant safety, such as pillars, roof cross member, door rings, door beams, side sill reinforcement and front & rear bumpers. The high strength-to-weight ratio of the UHSS used in hot stamping enables better crashworthiness performance ratings while often decreasing or maintaining weight neutrality.

Tier 1 supplier Gestamp relayed that several OEMs have used hot-stamped bumpers to reduce weight. Gestamp conducted tests comparing bumpers manufactured by press hardening the front bumper cross beam to 2,000MPa and three-layered 1,200MPa material crash boxes; roll forming the front bumper cross beams and press-hardening the crash boxes; and press-hardening a rear bumper beam with 2,000MPa tensile strength with patch technology. The 2,000-MPa tensile strength press-hardened beam and crash boxes reduced the bumper weight by 15 percent, compared to a benchmark bumper.

Many other suppliers such as Kirchhoff, ThyssenKrupp and ArcelorMittal's hot forming steel could also reach 2000MPa.

Source: GESTAMP



### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### BUMPER: [HOT] PRESS FORMING

Hot stamping bumper beams with ultra high strength steel after forming have a significant light weight advantage which have already a significant application penetration in passenger cars of different classes, such as Honda Fit, Skoda Rapid and Volvo XC90 with:

- low barrier about air flow for radiator / cooler
- good crash energy management system possible without foam
- design flexibility with cross sectional changes in all direction "X -Y - Z"
- very high formability with complex geometries and high sweeps, bends,... possible
- low weight with low stack-up / space needed
- for UHSS and advanced aluminum 6xxx and 7xxx with good dimensional tolerances
- multiple joining technologies applicable
- app 55 CNY/4 Kg Bumper beam in 1.2mm wall thickness, AluMag has been told

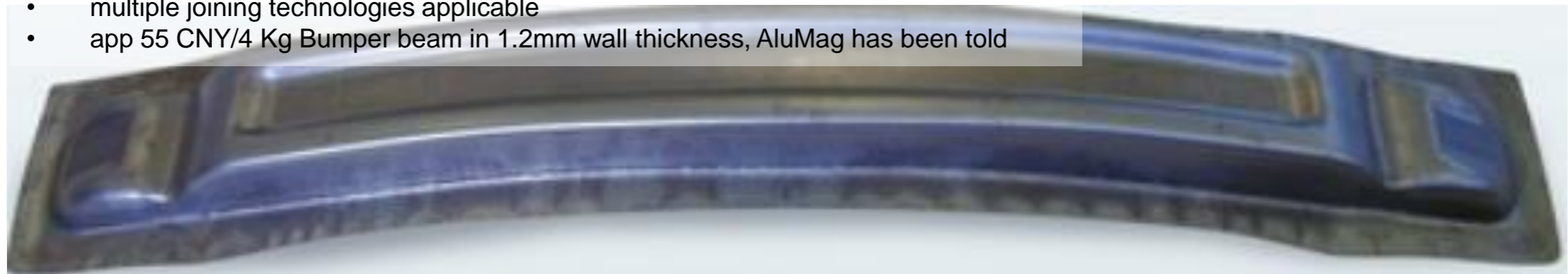
Source: GESTAMP

#### Rear Bumper Beam

- Thickness 1.2 mm
- Weight 9.59 lb (4.36 kg)
- Lasercut trim and holes



Volvo XC90 Hot Formed Boron Steel by Gestamp



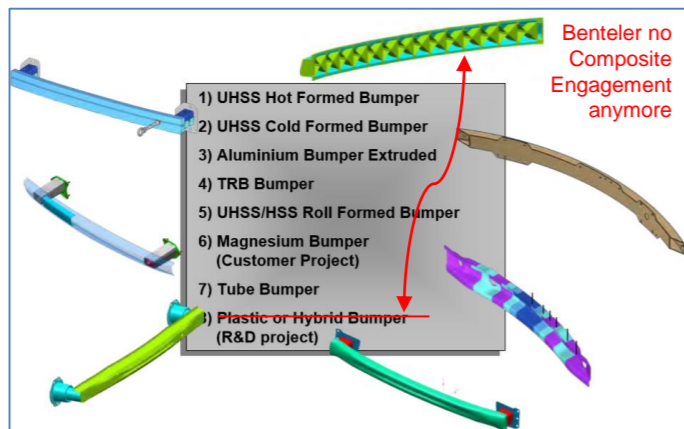


### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### ROLL FORMING

Aluminum and high strength steel are currently employed as an international standard to make structure applications, door frames, crash bars [tubes]. Advanced roll forming lines for CMS, e.g. bumpers, with integrated uncoiling / feeding, welding or adhesive, punching, cutting and roll bending in line are the state of the process and in competition to warm / hot forming, for both, aluminum and steel sheet. The bumpers are subject to very tight tolerances and therefore they need high quality equipment. Such lines could be operated with a speed up-to 40 m/min. Such roll forming process with sheet are common in use by Japanese and Korean OEMs and its tiers.

High strength aluminum sheet in 6xxx and 7xxx are expected within future model lines.



Benteler Does Offer the Multiple Processes & Mat.

Roll forming continuously shapes a strip of sheet using sets of roller dies called a flowering pattern. It lends itself to punching and sweeping before cutoff. Compared to the other methods, it can shape higher strength sheets easily. The process required in the past a constant cross section. Today's advanced lines are able also variable cross sections. The major advantage is high productivity which leads to cost reduction per part through higher throughput.

Source: NK



Advanced Roll Forming Line



Buick LaCrosse Roll Formed Bumper/Extruded C.Box

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### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### SPECIAL PROCESSES - ACCRA<sup>®</sup>

ACCRA<sup>®</sup>, developed by Linde+Wiemann is a forming technology to process completely or partially hardened, profile-like components with any type of cross-section or contour. It leverages the advantages of hydroforming and press hardening, is a technology for producing complex, hollow-profile, fully-martensitic structures at 1500+ MPa strength; well-suited for:

- high structural performance [comparable to hot stamping/PHS] within tight space
- light weighting and high crash / collision performance with moderate cost
- design & cross section flexibility with dimensional accuracy
- closed-section [closed box design] assemblies with no heat-affected zones
- aggressive / advanced bends / sweeps / indents
- variability based on profile cut length for medium to high volume production



Process Line at Multimatic

Companies like Multimatic and Linde+Wiemann [Inventor] are having it in series production. The idea behind the use of this type of metal forming by hot blowing is the possibility of using high strength steels, which allows obtaining parts with high mechanical performance using a minimum of material. This implies that, in case this type of processes and materials can be used, it could translate in the reduction of both the section of the part and its weight.

Source: LINDE + WIEMANN



Ford F150 & Tesla Model S Equipped by Multimatic

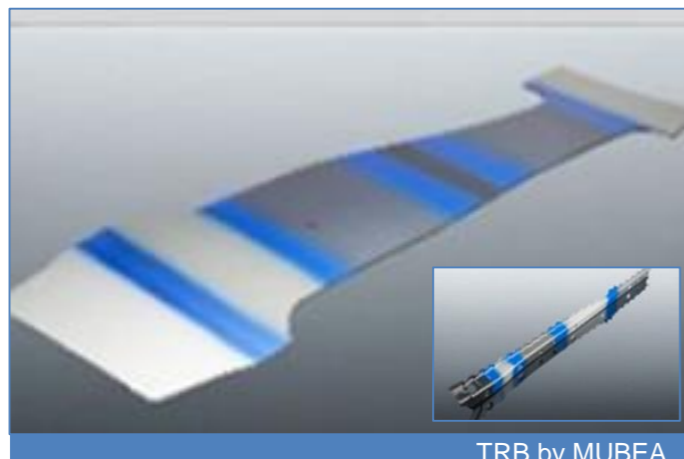


ACCRA with Global OEM Customers

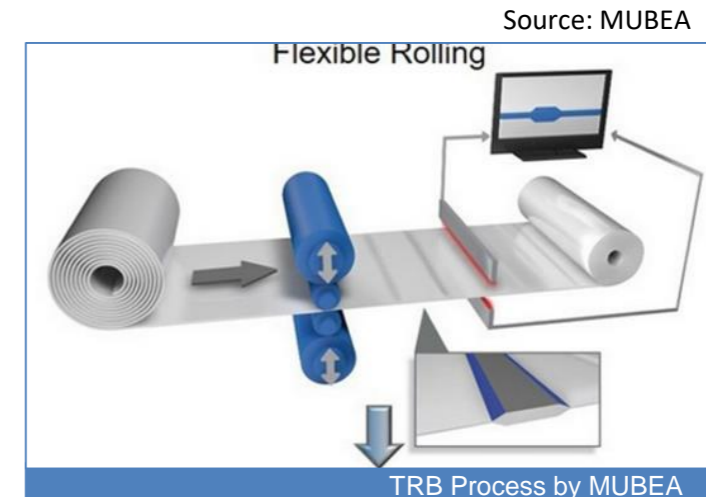
### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

#### SPECIAL PROCESSES - TAILOR ROLLED BLANKS [TRB<sup>®</sup>]

MUBEA has worked on a project with FORD and Constellium to transfer the flexible rolling technology originally developed for steel to aluminum. This technology for the production of TRB is a cold rolling process in which variable sheet thicknesses are set by means of a variable roll gap according to the locally required geometry, strengths and stiffnesses. This tailor-made material solutions allows sheet thickness differences up to 50% within a single component. The aim was successfully reached, the industrial production of tailor-made sheets for the realization of weight-optimized structural components made of high-strength 6xxx alloys. The called "FLEX rolling" is the key process and equipment invention, leads over the subsequent heat treatment, cold forming over the artificial aging of the component to the joining technique.



And, up to the crash behavior of the component. The flexible rolling with the 6xxx were promising; achieves high strength with sufficient ductility. Now, the actual project is a 7xxx [AlZnMg [Cu]] to obtain ultra high strength components. Since high performance materials are only suitable for cold forming to a limited extent, hot forming is a must. Combined with heat treatment after quenching, the weight specific strength of these Tailor Rolled Blanks could match that of press hardened steel.

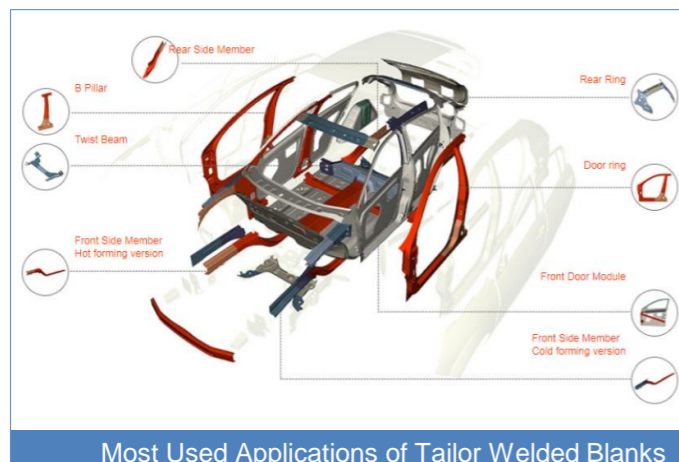




### SCOPE I - LIGHT WEIGHTING IN BIW AND STRUCTURAL APPLICATIONS INCL. CMS

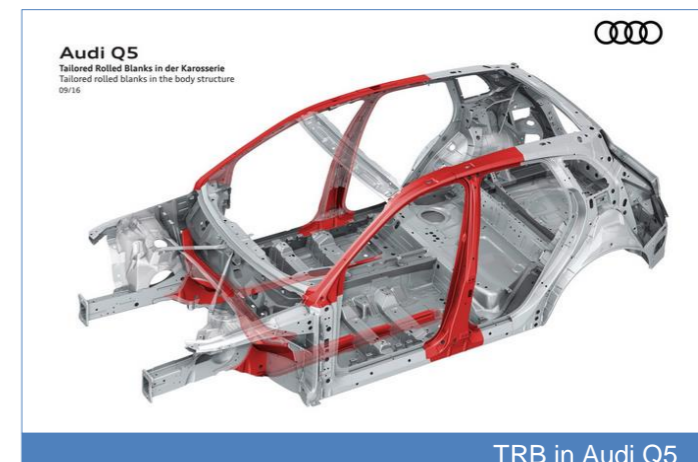
#### SPECIAL PROCESSES - TAILOR WELDED BLANK [TWB]

TWB is the most common process for tailored blank applications, due to its high welding speed, high precision, low heat input and ease of interface with robots. TWB is welded from different sheets of different thickness, strength and coating in the butt joint configuration. This is normally achieved by laser welding [exotic: electron beam or friction stir welding].. This manufacturing process allows for flexible part design and ensures the right material is used in the right place. Thicker or higher-strength material can be used in highly stressed areas while thinner sheets or deep drawing grades can be used in others. OEM only use expensive materials where they are needed. TWB can be combined with any types of material for cold forming and press hardening. TWB is not limited to flat material welding and is used also to weld different parts into an assembly.



Recently fiber laser has become as the prime choice for welding applications because of its high power, excellent beam quality and high energy efficiency. TWBs of aluminum alloy and Zn-coated steel have been considered as a cost-effective solution to the car body mass reduction and to the increase of the structure strength and durability. However the formation of brittle IMC [intermetallic compounds] as a result of poor miscibility and solubility of steel and aluminum is challenging.

Source: MUBEA



### TECHNICAL RESEARCH - PROCESSES

#### BUMPER: COMPOSITE & HYBRID

In China every Hyundai Kia is equipped with a composite rear bumper beam. With Hanwha and PlasticOmnium [PO], Hyundai Kia has created and successfully executed the world's first composite and hybrid front bumper beams. The PO solution consists of a composite insert over molded with plastic resin. The insert, obtained using the world's first Curved Reactive Thermoplastic Pultrusion process [CRTP], is composed of unidirectional glass fiber roving [is a long and narrow bundle of fiber], glass textiles and the optional use of carbon fiber. Weight is 3.6 Kg, equals a reduction of 43% compared to the steel version. The Hanwha is a hybrid bumper beam created by inserting a steel frame into glass-mat-reinforced thermoplastic [GMT] a lightweight, flat, composite material made from polypropylene and glass-fiber, improving crashworthiness of vehicles and are also 12%



lighter than the comparable steel bumper beam. The Hanwha hybrid front bumper beam is applied to Hyundai Kia cars, like Kia K4 which are manufactured and sold in China since the second half of 2014.

As far as AluMag is informed, the PO hybrid front bumper beam concept is not in series production yet.

Source: HYUNDAI





### TECHNICAL RESEARCH - PROCESSES

#### BUMPER: CARBON COMPOSITE

Shape has been licensed for the Thomas Technik's curved pultrusion process for the automotive applications like bumper beams and structural parts. Shape remains on track to install the first curved pultrusion machine and being in preparation for 2019 model year production. Shape does believe on the lookout for this innovative and light weighting process application.

According to Shape and Thomas Technik, the "Radius Pultrusion™" process offers numerous benefits for those seeking advanced composite solutions.

Shape is able to process closed box sections as well as multi hollow sections, which leading to increased torsional stiffness and crash performance, reduction in mass and cost.

**Situation Bumper**  
Composite in an Automobile/ BMW M3



71% Weight saving:  
Composite: 3,2 kg

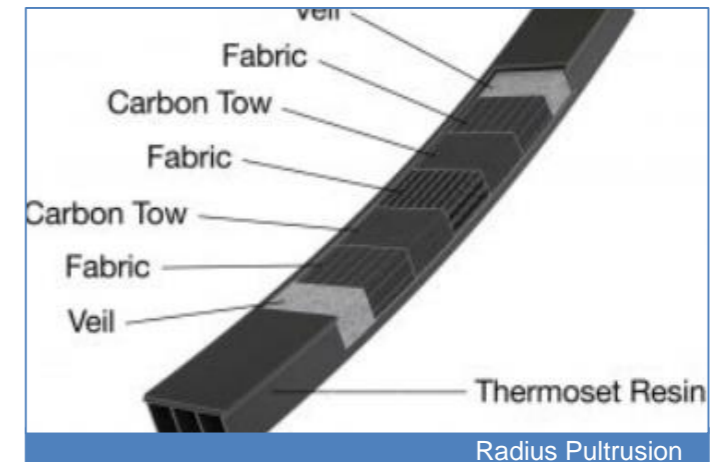
Bumper (rear)  
Steel, 11 kg

BMW M3 Project Steel 11Kg vs 3.2Kg Composite

Radius pultrusion is a continuous and highly automated process without the need for additional labor or floor space. Varying lengths can be produced from the same tooling.

Disadvantage is, radius pultrusion could not provide function integrations and varying cross sections over the length.

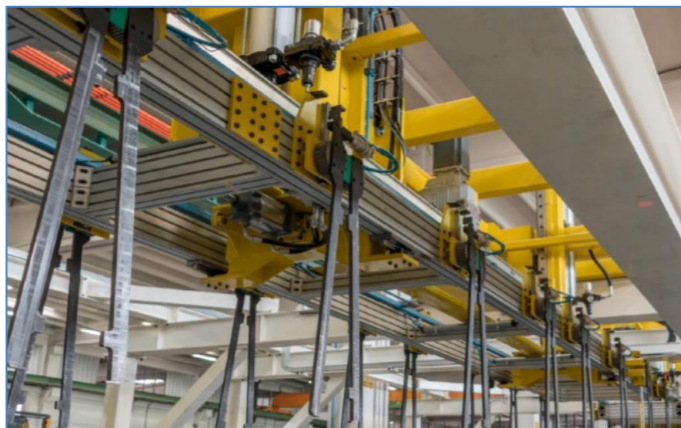
Source: SHAPE CORP.



### TECHNICAL RESEARCH - PROCESSES

#### BUMPER: DEDICATED EXTRUSION PRESS BY SMS – OMAV

As efforts towards lightweight solutions increase, aluminum bumper assemblies based on extrusions are becoming main stream for weight benefits that aluminum represent and its ease of manufacturing. Aluminum extrusions can be produced in varying cross sections along with various alloys. Today, the beam accounts for 60% - 70% of the mass of the CMS assembly. So, it is important to identify bumper beam designs that represent the lowest mass and cost. The crash boxes dominate the high speed performance and have not been include in the study virginly. Beside the best engineered compromise between mass, function integration, crash performance and cost, the bumper beam needs to be produced and processed as effective as possible. Enabling this, a mono application engineered extrusion and post extrusion process line is needed, which should consider beside others the below:



Double Profile Stacker System

- Tapered billet heating by induction or hybrid
- Idealized [long] length of the billet container
- 45MN SMS OMAV Extrusion Press with various cooling procedures
- Double puller and flying saw
- Idealized 60 m length of the run-out table corresponding with the 1,500 mm billet length
- In process flow behind the run-out table the post extrusion processes incl packaging

Source: SMS



Ideal SMS OMAV 40 - 55MN Press For Bumper



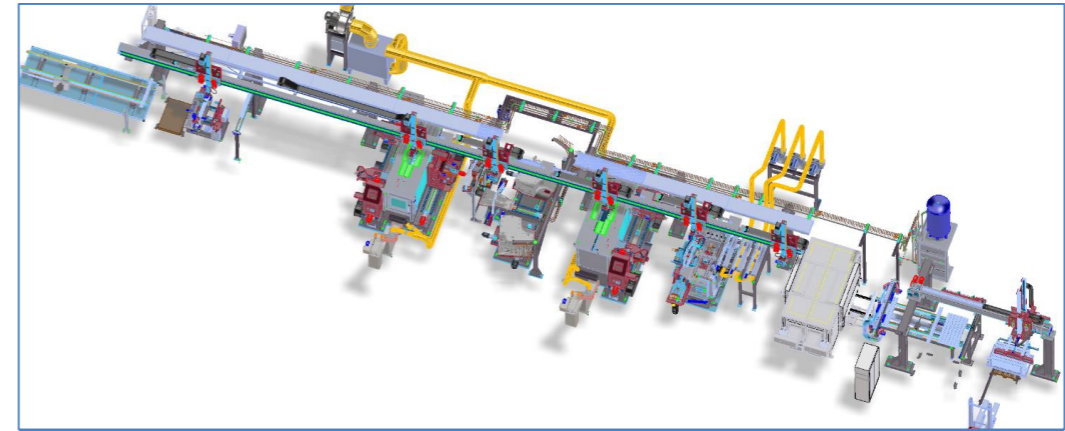
SMS HybrEx Ordered Recently by UACJ & THOENI

### TECHNICAL RESEARCH - PROCESSES

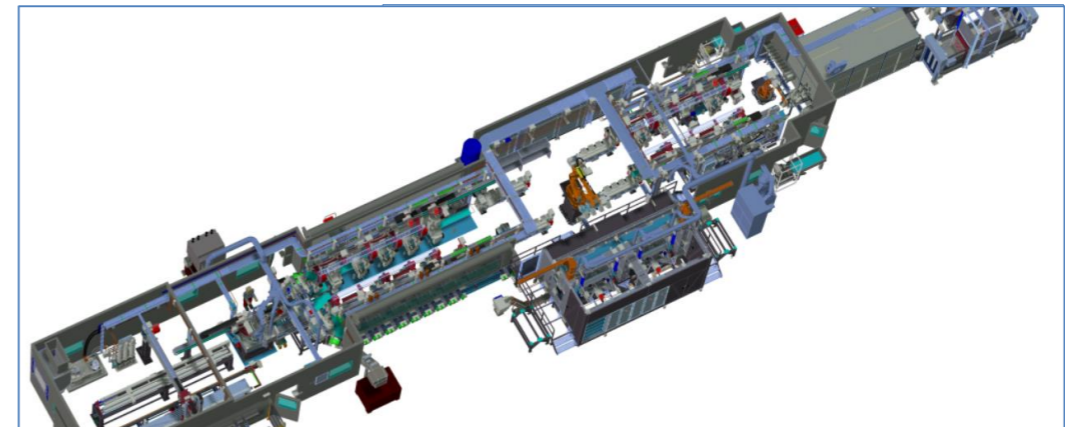
#### BUMPER: DEDICATED MACHINING PROCESS LINE BY FILL

1. automatic destacking of the raw bars [mostly finished length]
2. length measurements, check cross section and hardness
3. heating up with subsequent active cooling of the components
4. insert core parts into the hollow chambers with fixation
5. forming processes
  1. pressing [100-250T] incl. Tools [swaging, stretch bending, embossing]
  2. NC stretch bending
6. punching processes
7. calibrate and align
8. machining [drilling, milling]
9. mount add-on parts [blind rivet nut, press-in nut, punch nut, blind rivet bolt, ... ]
10. wash components
11. testing and marking stations [contour checking, presence of all holes / milling]
12. overhead handling systems [station to station]
13. Stack automatically into customer transport containers

Source: FILL



Visualization Of A Fully Automated Bumper Beam Process Line In Taijing, China



Visualization Of A Fully Automated Crash Box Process Line In Germany



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### EXECUTIVE SUMMARY - SUBFRAMES

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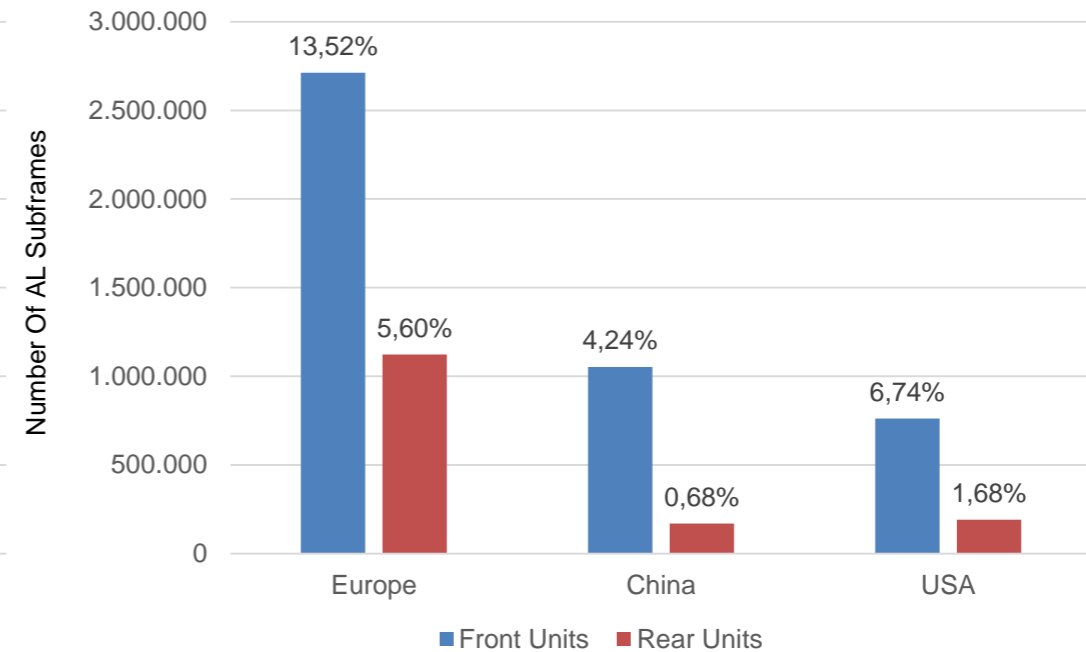
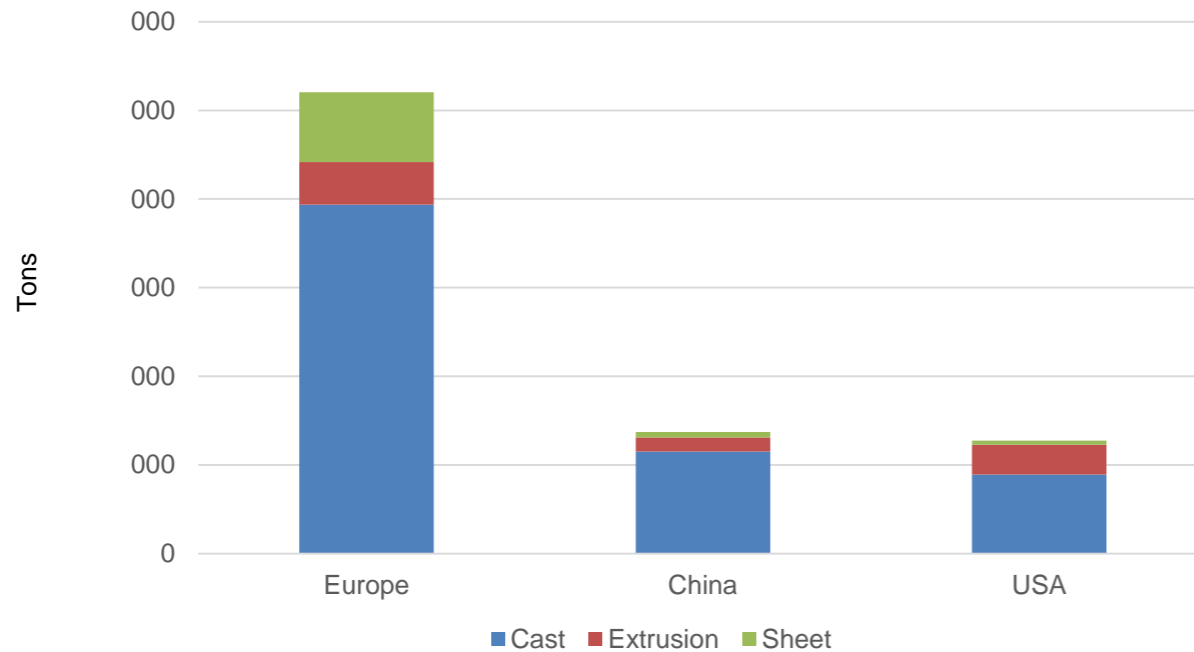
### EXECUTIVE SUMMARY - SUBFRAMES



### EXECUTIVE SUMMARY - SUBFRAMES - MARKET ANALYSIS

Source: AluMag®

#### AL DEMAND BY REGION & PENETRATION OF AL SUBFRAMES BY REGION - 2017

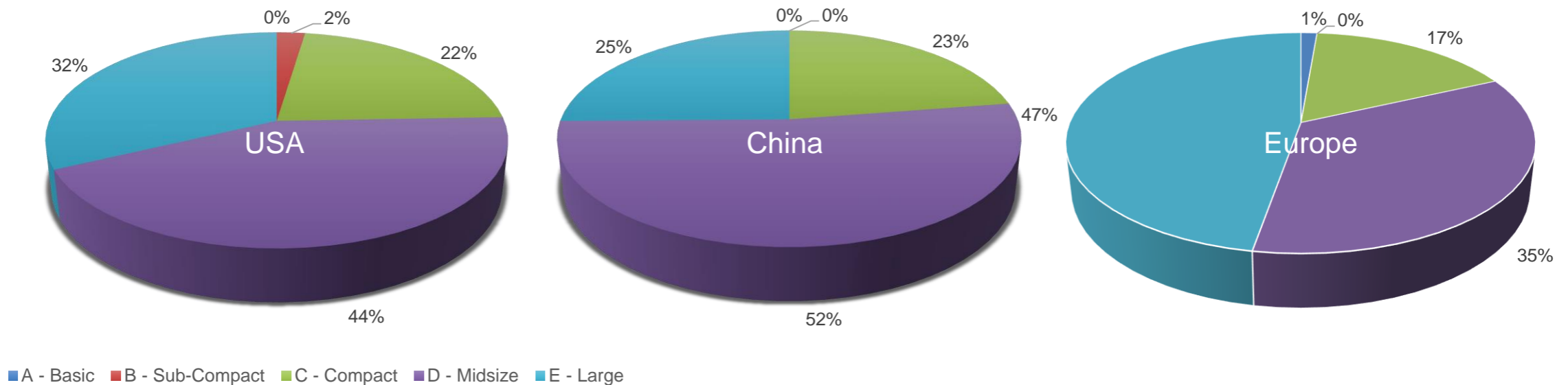


Of the three analyzed regions Europe has the highest penetration of aluminum subframes in regards to subframe units and in percent of total car production. In Europe 13.52% of all produced vehicles are fitted with a front aluminum subframe in 2017 compared to 5.6% for the rear axle. USA has a higher penetration of aluminum subframes than China percentage-wise but more aluminum subframes [Units] are inserted in China. **Foreign brands like BMW & VW accounts for the majority of inserted aluminum subframes in China.** 52,038 tons of aluminum was consumed in Europe in 2017 for the production of subframes followed by 13,725 tons in China and 12,729 tons in USA.

### EXECUTIVE SUMMARY - SUBFRAMES - MARKET ANALYSIS

Source: AluMag®

#### TOTAL NUMBER OF ALUMINUM SUBFRAMES ALLOCATED BY SEGMENT FOR THE YEAR 2017 [UNITS FRONT & REAR]

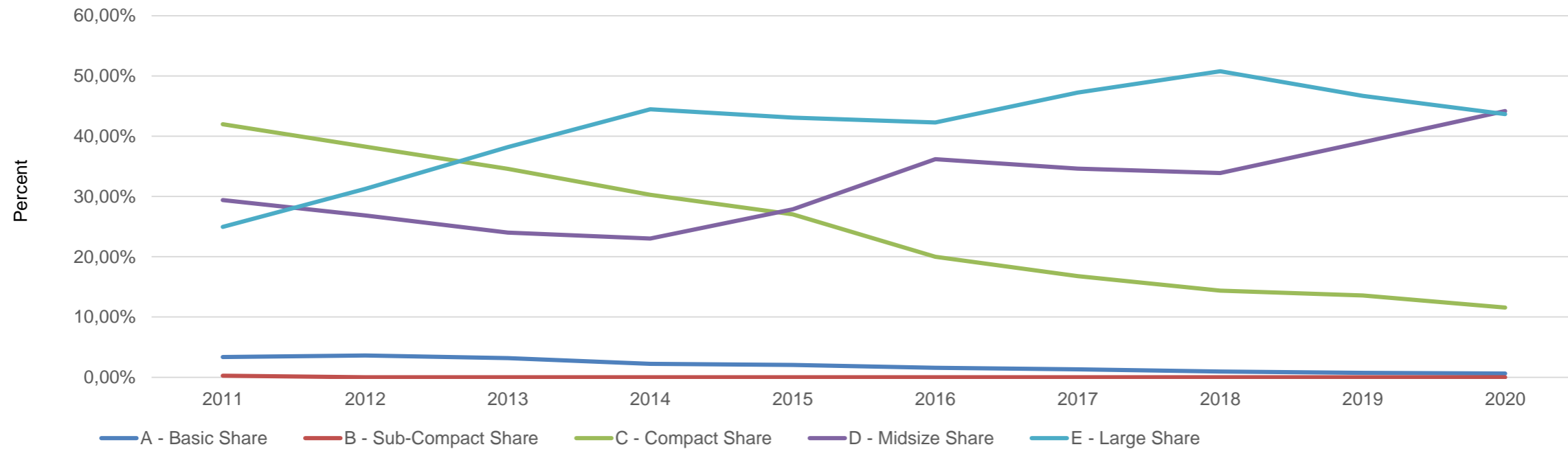


In Europe the E-Large segment account for 47% of all aluminum subframes inserted compared to only 32% in USA and 25% in China. This can be explained by the high concentration of E-Large vehicle production in Europe by JLR, BMW, Daimler & VW Group which makes up a relatively big share of the total production. For all three analyzed regions only a few “A - Basic” and “B - Sub-Compact” vehicles are fitted with aluminum subframes and these two segments only account for a few percent overall.

### EXECUTIVE SUMMARY - SUBFRAMES - MARKET ANALYSIS

Source: AluMag®

#### EUROPEAN DEVELOPMENT OF ALUMINUM SUBFRAME SHARE BY SEGMENT

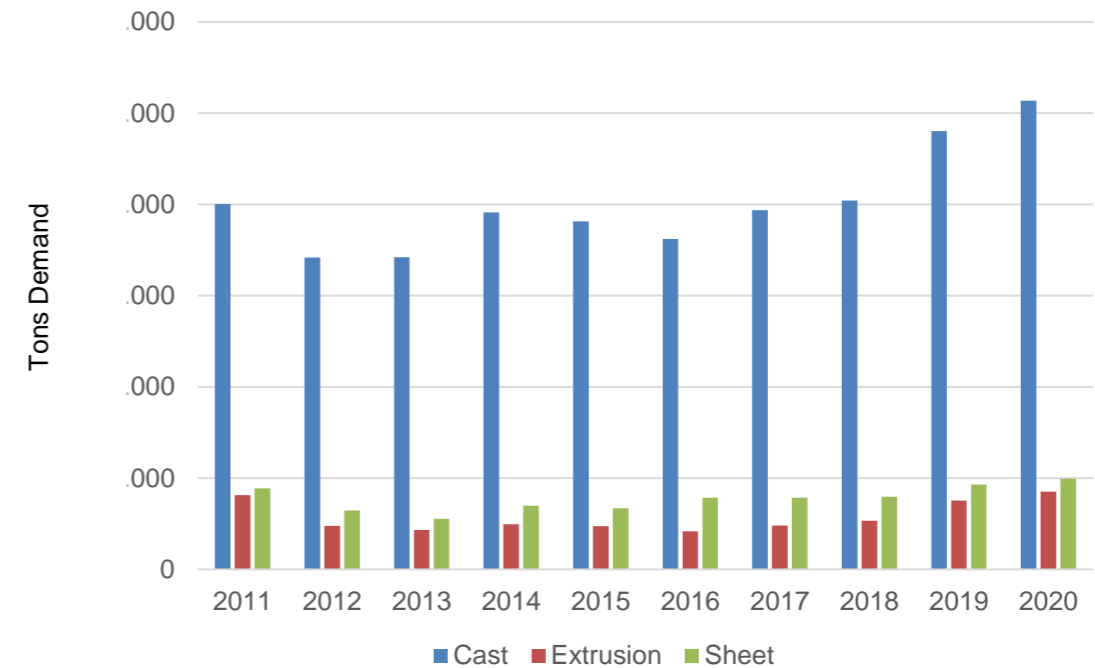
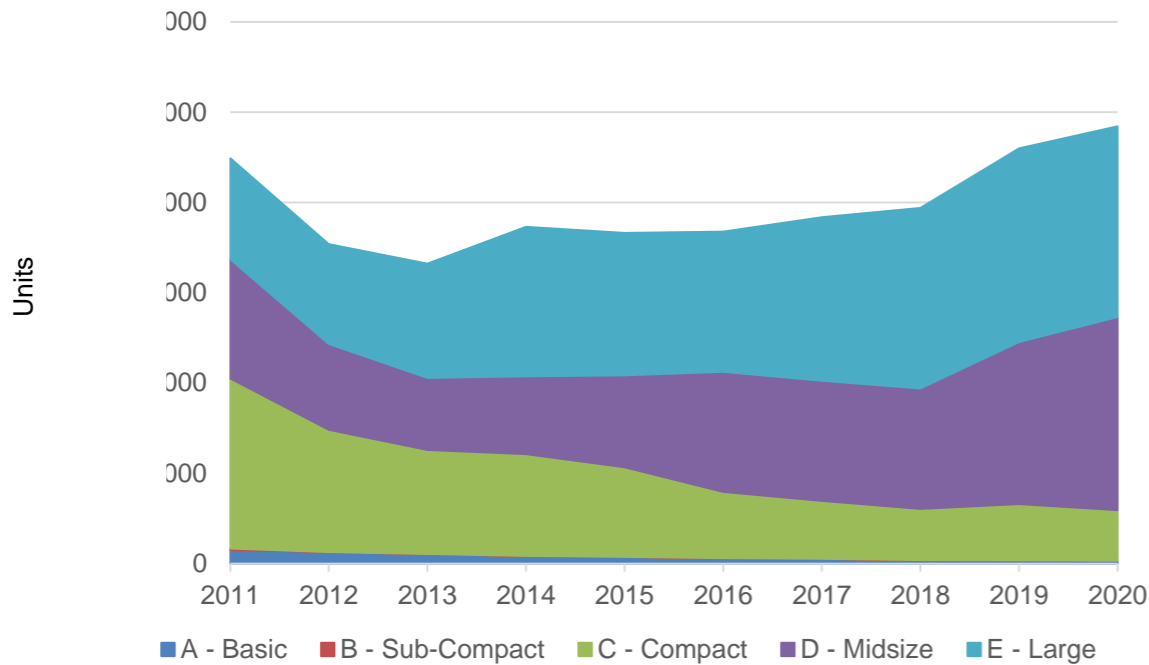


In 2011 the „C-Compact“ segment accounted for 41.99% of all aluminum subframes inserted on the European market dropping to 16.80% in 2017 and is expected to decrease further by 2020. The main driver behind the erosion of the C-Compact segment is VW decision to implement more steel for its MQB platform compared to the former PQ35 platform. In general the market for aluminum subframes is increasing but the growth is taking place in the upper segments and predominantly by the premium brands. OEMs like PSA, VW, & Honda are today implementing more steel for their C-Compact and lower „D - Midsize“ segment cars replacing aluminum subframes with steel on models like the VW Golf, Honda Civic, Peugeot 407/C5 & Honda Accord.

### EXECUTIVE SUMMARY - SUBFRAMES - MARKET ANALYSIS

Source: AluMag®

#### EUROPEAN DEVELOPMENT OF ALUMINUM SUBFRAME MARKET BY SEGMENT & MATERIAL DEMAND



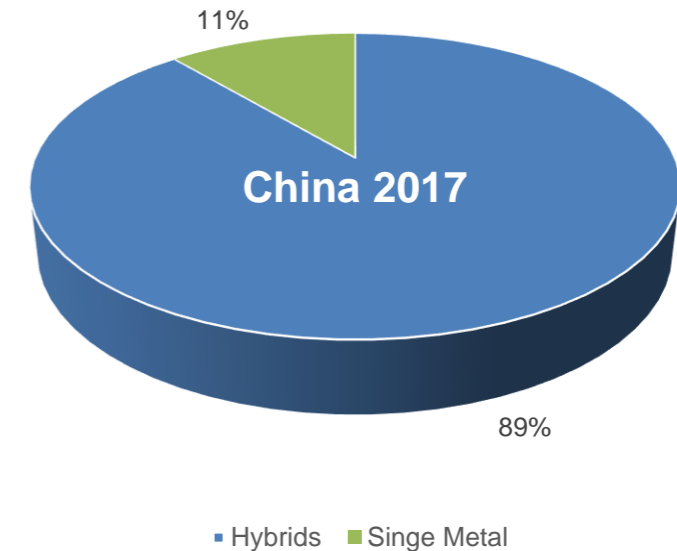
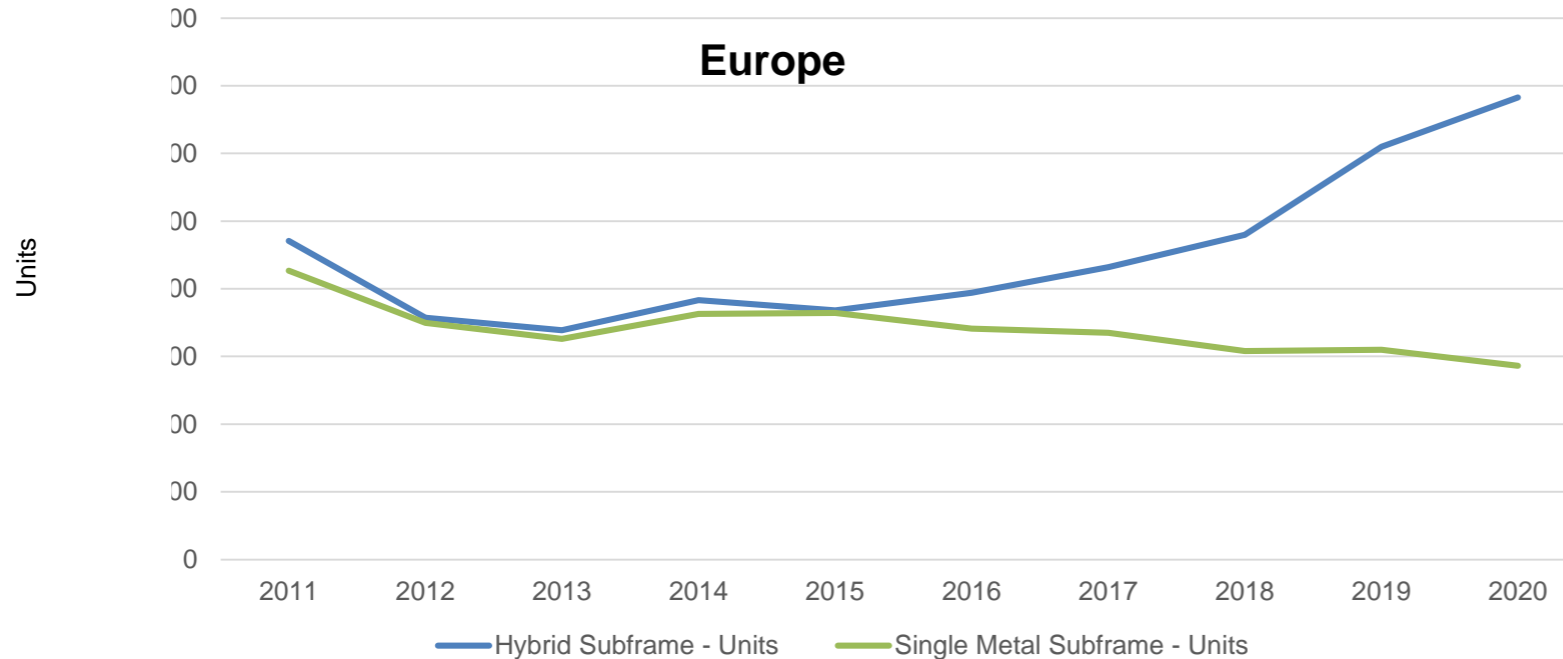
The European aluminum subframe market saw a decline in the period 2011 - 2013 decreasing from 4.5 million units in 2011 to 3.3 million in 2013. **The market is expected to recover to over 2011 level in 2020 mainly due to a higher penetration of aluminum subframes in the premium segments.** Today and in the future a low penetration of aluminum subframes is expected in the “A - Basic” & “B - Sub-Compact segments”. From 2013 - 2017 the average growth rate for aluminum subframes [Units] in Europe was 3.66% and is expected to increase to 8.09% for the period 2017-2020. Since 2013 the demand for aluminum within subframes has increased with a CAGR of 4.25% in Europe. [CAGR: 2013-2017: Extrusion: 2.87%; Cast: 3.58%; Sheet: 9.08%]



### EXECUTIVE SUMMARY - SUBFRAMES - MARKET ANALYSIS

Source: AluMag®

#### EUROPEAN DEVELOPMENT OF ALUMINUM SUBFRAME MARKET: PROCESS HYBRID VS SINGLE PROCESS / METAL



From 2011 to 2015 the market penetration of process hybrid vs single processed metal aluminum subframes was stable with hybrid subframes holding about 50 - 53% of the European market vs single metal constructions with a share about 47 - 50%. **Since 2015 hybrid constructions have been preferred by the OEMs seeing the penetration rising from 50.24% in 2015 to an expected 70.46% in 2020.** Main driver behind this development in the aluminum subframe market is the launch of VW MLB-Evo, BMW CLAR & MB MRA platforms featuring hybrid aluminum subframes. **In China 89% of all aluminum subframes were hybrid construction in 2017.**

### KEY FINDINGS RELATED TO THE DEMAND FOR ALUMINUM & MAGNESIUM

Source: AluMag<sup>®</sup>

#### VIEWS - TOPICS - FINDINGS TO SHARE

- All experts, AluMag<sup>®</sup> has talked to/with confirmed, that cast battery trays for BEVs will be not the most preferred process and see / predict that extruded AL is the most suitable one. And, to manufacturer a BEV battery tray in HPDC it would require cells with clamping forces in the range 5,000 to 7,000 tons which are hard to come by. As one expert from a Chinese OEM put it: “Extruded AL is in a very advanced position against cast and steel / AL sheet”. For upper segment BEVs extruded AL housings are being preferred while steel sheet is predominantly used in lower car segments.
- Solid state batteries does not require cooling/heating like todays lithium batteries and are less likely to catch fire. New battery housings are therefore likely to be utilized in plastic, steel and AL sheet.
- In China the next generation of PHEVs, to be designed & developed as such, are likely to have their battery more integrated into the structure of the vehicle. This could pave the way for a higher penetration of cast AL in PHEV vehicles in China where the current penetration is very low.
- OEMs and suppliers are working on new integrated solutions for BEV powertrain, inserting more applications and functions in one housing to reduce weight, cost and space. Inverters with converters are integrated in one unit instead of two components and housings for engine and transmission are partly combined. This trend will, if it prevails, mean larger but fewer parts. Furthermore, these integrated complex parts, housing several functions, are getting more and more challenging to cast by HPDC. LPDC and CPS core package sand casting are likely to be preferred over HPDC due to the complexity and cooling requirements of these parts.
- Cast AL powertrain applications such as manifolds, oil pans, cylinder head cover and timing chain covers are increasingly being substituted by plastic/composite.

### FURTHER IMPRESSIONS - OPINIONS TO THINK ABOUT

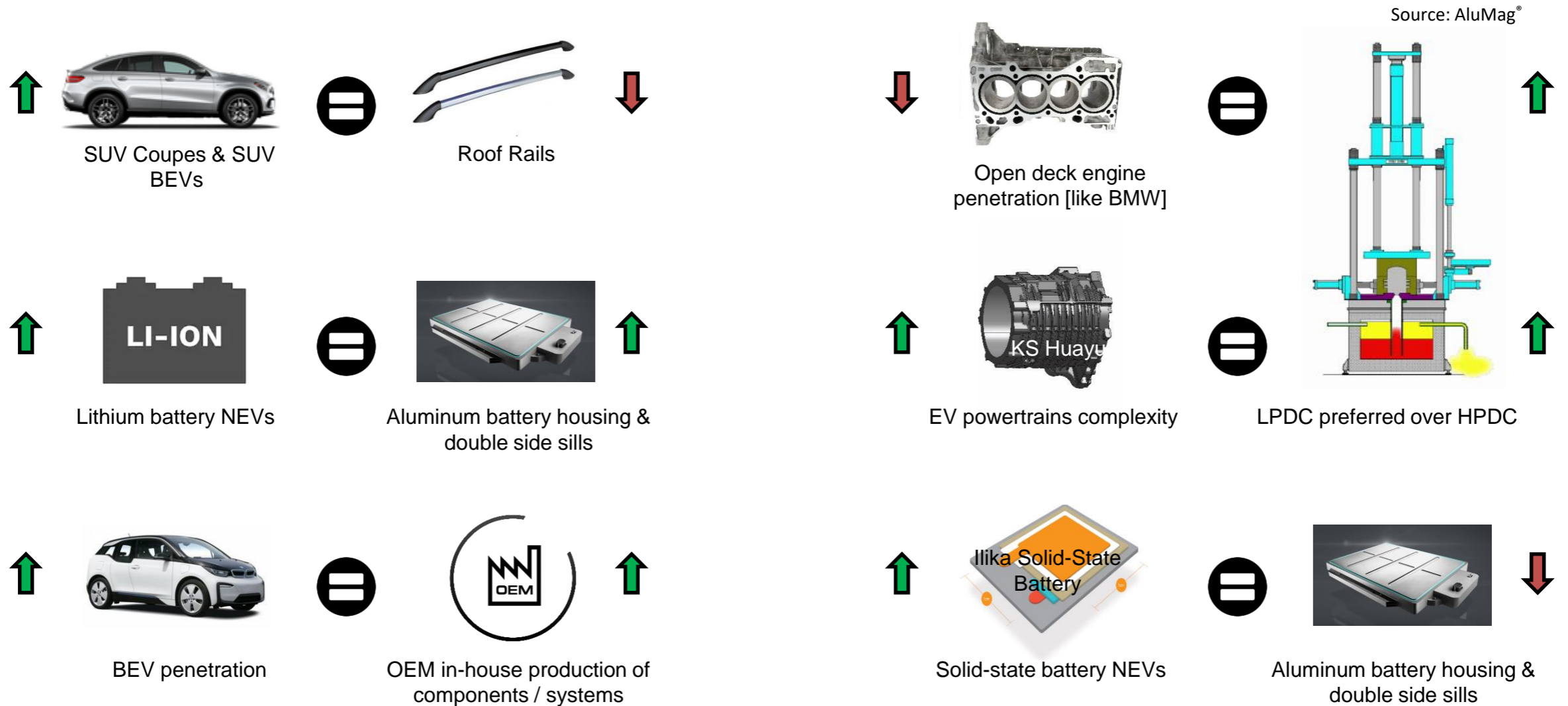
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Source: AluMag<sup>®</sup>

#### VIEWS - TOPICS - FINDINGS TO SHARE

- Right now, we see over-heated markets and a consolidation:
  - Cooling down of the stock exchanges, global economy and automotive market as well as equipment / machinery, ...
  - Interest on capital is still too low
  - Booming real estate market in many European regions and NA, but an overflooded in China and India the luxury flats
- Within the next 20 years, countries and regions like India, South Asia, Middle East, Africa and Latin America will be most likely not part of the BEV market
- Beside the ICE and E-Drive, the Fuel cell could be the third power unit in cars but unlikely; Highly potential for road and public transportation applications
- In the short to [max] mid run the demand for automotive cast aluminum applications will increase, fueled by the growing global vehicle demand, an increasing use of cast aluminum structural parts as well as a growing penetration of PHEV vehicles. In the mid run, the need for cast filter-, pump-, control unit- housings will melt down.
- Free capacity for larger HPDC applications will become scarce as the demand for large BIW cast aluminum applications together with battery housings and EV motor housings increases. But around 2025 / 2030 pure BEVs will account for the vast majority of total EV sales resulting in decreasing automotive cast aluminum demand, within powertrain applications
- The penetration of CFRP applications will grow moderate but the fast decreasing EV battery prices may have a negative effect on the demand for ultra-lightweight materials
- A fully developed EV technology [Range of 800 km / 500 Miles] **could have** a negative impact on the automotive demand for lightweight materials in general. One of the main incentives to use lightweight materials powertrain efficiency [beside driving performance] **would no longer fully** apply. Importance of the aero dynamics does increase

### ILLUSTRATED OBSERVATIONS





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