Light Vehicle Aluminum Content and Outlook Study

Prepared for The Aluminum Association by Ducker

April 2023

DRIVEALUMINUM

DUCKER CARLISLE

Scope of Analysis: Markets

FOCUS COMPONENTS

1. Engine Block
2. Cylinder Head
3. Subframes/Cradles
4. Road Wheels
5. Brake Calipers
6. Master Cylinders
7. HEX/Radiator
8. Body Side Panels
9. CMS
10. BIW Cross Members
11. Door Beams
12. Door Sills/Rockers
13. Front Longitudinals
14. Rear Longitudinals
15. Front-End Structure (incl. radiator support)
16. Shock Towers
17. Fenders
18. Front Doors
19. Rear Doors
20. Hood
21. Roof
22. Tailgate/Liftgate/Trunk
23. Battery Housing/Frame
24. Electric Traction Motor Housing
25. Transmission Case/EV Gearbox Housing

GEOGRAPHY

- North America (USMCA)

SEGMENTS

- Light Vehicles in NA

OEMS

Ford, Toyota, Honda, Renault Nissan Mitsubishi, Lucid, Tesla, BMW, Mercedes-Benz, GM, Stellantis, Hyundai Motor Group, Rivian, Volkswagen, Volvo

Acronyms & Definitions

AA	Aluminum Association
ABS	Automotive Body Sheet
AEC	Aluminum Extruders Council
AL	Aluminum
AHSS	Advanced High Strength Steel
AISI	American Iron and Steel Institute
ATG	Aluminum Transportation Group
B&C	Body-in-White & Closures
BEV	Battery Electric Vehicle
BIW	Body-in-White
CARB	California Air Resources Board
CFRP	Carbon Fiber Reinforced Polymers
CMS	Crash Management System
CPV	Content Per Vehicle (net lbs.)
CY	Commercial Year (relates to sales)
Demand	Gross Demand of Aluminum
DOE	Department of Energy
E-drive	Electric Motor with Gearbox and Inverter
EA	European Aluminum Association
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EV	Plug-in Vehicles BEV & PHEV (excludes FHEV)
FCST	Forecast
FCEV	Fuel Cell Electric Vehicle
FHEV	Full Hybrid Electric Vehicle - No Charging Plug
FRP	Aluminum Flat Rolled Product (see ABS)
FMVSS	Federal Motor Vehicle Safety Standards
GFRP	Glass Fiber Reinforced Polymers
HPDC	High Pressure Die Casting
HSS	High Strength Steel
HT	Heat Treated
IIHS	Insurance Institute for Highway Safety
IRA	Inflation Reduction Act
LTR	Light Truck
LV	Light Vehicle
MHEV	Mild Hybrid Electric Vehicle (48V)
MPG	Miles Per Gallon
MY	Model Year
NHTSA	National Highway Traffic Safety Administration
PHEV	Plug-in Hybrid Electric Vehicle
PFCEV	Plug-in Fuel Cell Electric Vehicle
PPV	Pounds Per Vehicle Averaged on the Total Production (net weight)
PWT	Powertrain (engine, motor, transmission)
SAE	Society of Automotive Engineers
SMC	Sheet Moulding Composite
UHSS	Ultra High Strength Steel
USMCA	United States, Mexico, Canada Agreement

Key Study Takeaways

Aluminum 2022 Market Highlights

1

Automotive BEV Growth

Proliferation of market with new BEVs have dramatically changed the NA light vehicle landscape

2022 BEV share of production was ~6%, nearly doubling its share compared to 2020. By 2030, BEVs are expected to exceed 36% share of production

The average BEV in 2022 has an average aluminum content of 885 ppv, 85% more than its non-BEV counterpart. The average 2020 BEV contained 643 PPV

2

Mix Continues to Favor Large Vehicles

The mix of passenger cars vs. light trucks highlight market affinity toward larger vehicles, also driving aluminum CPV upwards

2020 Car vs. Light Truck mix: 25% / 75%
2022 Car vs. Light Truck mix: 19% / 81%

The average light truck in 2022 contains over 30% more aluminum per vehicle than passenger vehicle

3

Regulations Including the IRA are Key for Aluminum Growth

Regulations stick with CO_2 and MPG targets, EVs are required to meet goals. Non EVs still adopting aluminum for mass savings

EPA and NHTSA are likely to introduce new CO_2 and MPG targets for 2027 to 2030 and beyond – further cementing EV contribution for CAFE goals

IRA stipulations include USMCA manufacturing requirements and material localization goals

4

Aluminum CPV Outperforms Near Term Expectations

Aluminum CPV continues its uninterrupted growth with a net gain of 59 pound per vehicle between 2020 and 2025

2022 CPV is 501 net PPV, resulting in 8.2 billion pounds of gross aluminum demand (for 14.2 M vehicles)

Aluminum CPV will grow by almost 100 net PPV between 2020 and 2030 *(base scenario)*

5

Near Term Aluminum Growth Led by Extrusions and Sheet

Aluminum extrusions grew by 13 PPV between 2020 and 2022, while sheet grew by 26 PPV

Extrusions have demonstrated significant growth within the BIW, accounting of 11 PPV growth. ABS and sheet for thermal management account for most all of the 26 PPV growth

The average BEV in 2022 contains 492 PPV of castings, compared with only 290 PPV for its non-BEV counterpart

Source: Ducker

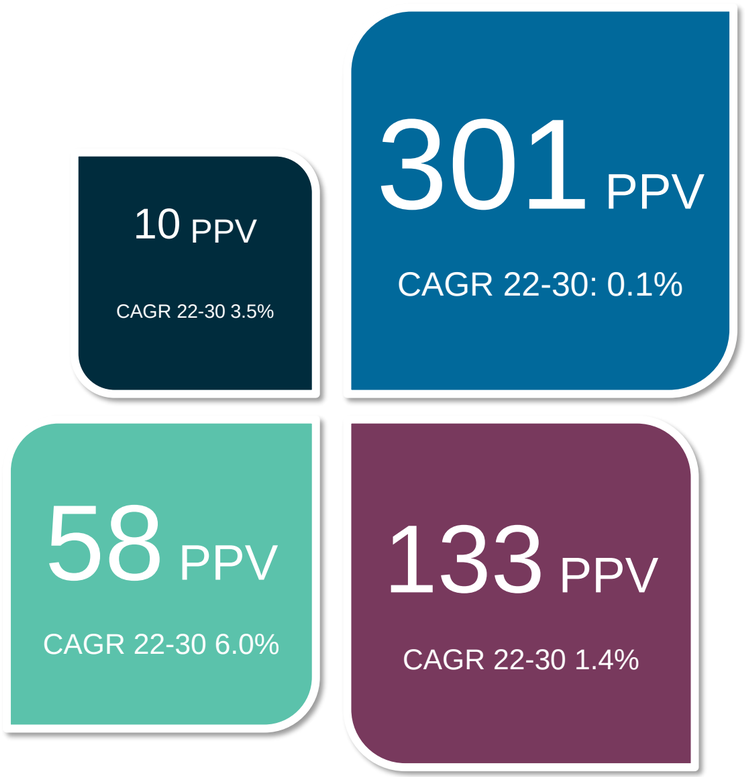
Aluminum Product Form Content (2022)

Forgings (+3 PPV by 2030)

Forgings benefit from the necessity to offset EV increasing weight and performance specifications

Extrusions (+34 PPV by 2030)

The fastest growing product form due to increasing penetration in body-in-white and CMS



Content per vehicle in 2022 & CAGR between 2022 and 2030

Castings (+3 PPV by 2030)

Remains the largest product form for aluminum components as powertrain and transmissions components are compensated by the new EV components (e-drives, high voltage devices, etc.) and structural casting for body-in-white

Sheet (+15 PPV by 2030)

Promoted by efficiency and weight reduction targets as well as product mix leaning toward larger vehicles, aluminum closure demand continues its growth

Source: Ducker

Key Growth Components (2022 to 2030)

1
+37 PPV between 2022 and 2030

Battery Housings

2
+34 PPV between 2022 and 2030

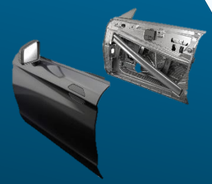
E-Motors / E-Drives Housings

EV components gain shares and naturally increase BEV aluminum content per vehicle thanks to EV specific components and additional aluminum components (chassis, BIW) to compensate the weight increase from the battery

Doors and sills/rockers demonstrate the continuous weight reduction effort from OEMs with more sheet and extrusions utilization in closures and BIW

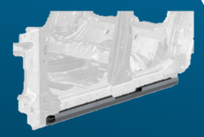
3
+8 PPV between 2022 and 2030

Doors



4
+4 PPV between 2022 and 2030

Sills/Rockers



Source: Ducker

Long Term Aluminum Adoption Drivers

EV SHIFT

- EV Incentives & IRA
  - Boost EV demand
  - Bring EV OEM and supply chain onshore
- New Components in Vehicles
  - Weight reduction requirements and EV specific components to increase aluminum content

MANUFACTURING

- Structural Castings
  - Further increase of AL application in BIW
- Megacasting Adoption
  - Increase aluminum content by displacing traditional steel solution

MARKET SHIFT

- Larger Vehicle Segment Mix
  - Trend toward larger vehicles that have more aluminum content per vehicle
- Steady Premium Share
  - Ensure aluminum demand due to above average aluminum content in premium models

SUSTAINABILITY

- Carbon Neutrality Targets
  - Strong trend toward low carbon aluminum
  - Rheocasting and other innovative solutions to increase ability to use more secondary aluminum
- CO_2 Tailpipe Policy
  - Increasing needs to improve efficiency in ICE due to more stringent CAFE standards

ALUMINUM AVAILABILITY

- New Capacity Additions
  - New production lines are likely to increase productivity (e.g., HPDC, extrusions, sheet, etc.)
- Material Costs Parity
  - Reduction in the gap between the cost of aluminum and competing materials

Source: Ducker

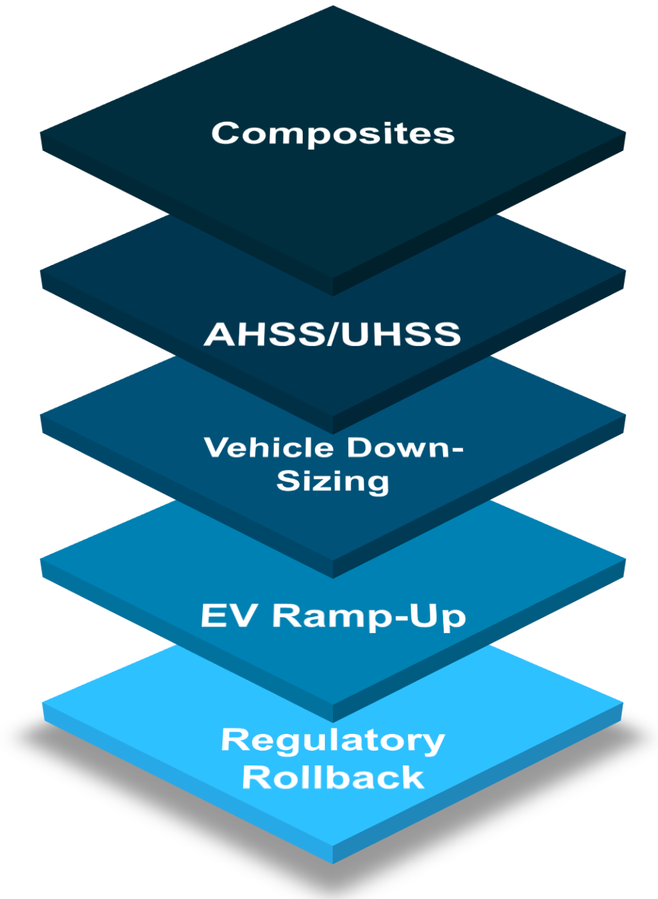
Long Term Aluminum Competitiveness

Although all Ducker scenarios point to YoY growth, there are risks to monitor that may impact the rate of growth for aluminum in the long term (2026 - 2030)

Proliferation of composites, for closures and battery housings

Affordability driving OEMs to shift production towards B & C segment vehicles (more cost sensitive)

Regulations that extend or rollback CO_2 and MPG goals



Breakthroughs in Gen 3 steel manufacturing and processing allowing for broader vehicle adoption in BIW and Chassis

Slower electrification ramp up due to higher material costs and lack of sufficient charging network

Source: Ducker

Conclusions

A. Continuous aluminum growth

- Aluminum content to continue growing
  - CAGR 1990-2000: 4.6%
  - CAGR 2000-2010: 2.8%
  - CAGR 2010-2020: 3.0%
  - CAGR 2020-2030: 1.9%
- Additional growth will come from new applications and innovation
- Overall content per vehicle is expected to hit 556 lbs. per vehicle by 2030

B. Electrification benefits to aluminum

- Electrification positively affects aluminum content and compensates the loss from powertrain components
- New components include e-drives, battery housings, and multiple high voltage devices
- HPDC benefits the most from electrification with more complex components
- Weight reduction is key to meet range expectations and to lower battery associated costs

C. Production mix impacts content

- Supply chain disruptions have led OEMs to lower production on smaller and less profitable models
- Aluminum content soared between 2020 and 2022 (4.5% CAGR) because of the combined effect of increased shares of aluminum intensive vehicles and electrification
- To improve affordability, OEMs may reintroduce smaller segment models (steel intensive)

D. Regulation drives growth

- Despite the benefits from EVs in the CAFE calculations, OEMs must continue working on weight reduction
- Vehicle weight may be further scrutinized leading to setting weight limits on EVs
- Carbon neutral strategies are pushing towards low carbon solutions including green aluminum and increases the need for recycling

E. OEMs to increase production

- IRA is driving more OEM production in North America to benefit from tax incentives leading to increased aluminum gross demand
- New factories to focus on EV production with higher aluminum content per vehicle
- Premium carmakers are expanding their North American footprint with aluminum intensive crossovers (e.g., BMW, Audi, Genesis, etc.)
- IRA push for more USMCA production is likely to increase North American exports

F. Increased competitive pressure

- Competing materials are innovating to gain shares
  - New high strength and Gen 3 steels to continue replacing mild and HSS steels as well as competing more with aluminum
  - Composites more actively targeting aluminum closures and battery housings
- Aluminum continues to increase its competitive innovation and dynamics

Source: Ducker

Study Insights

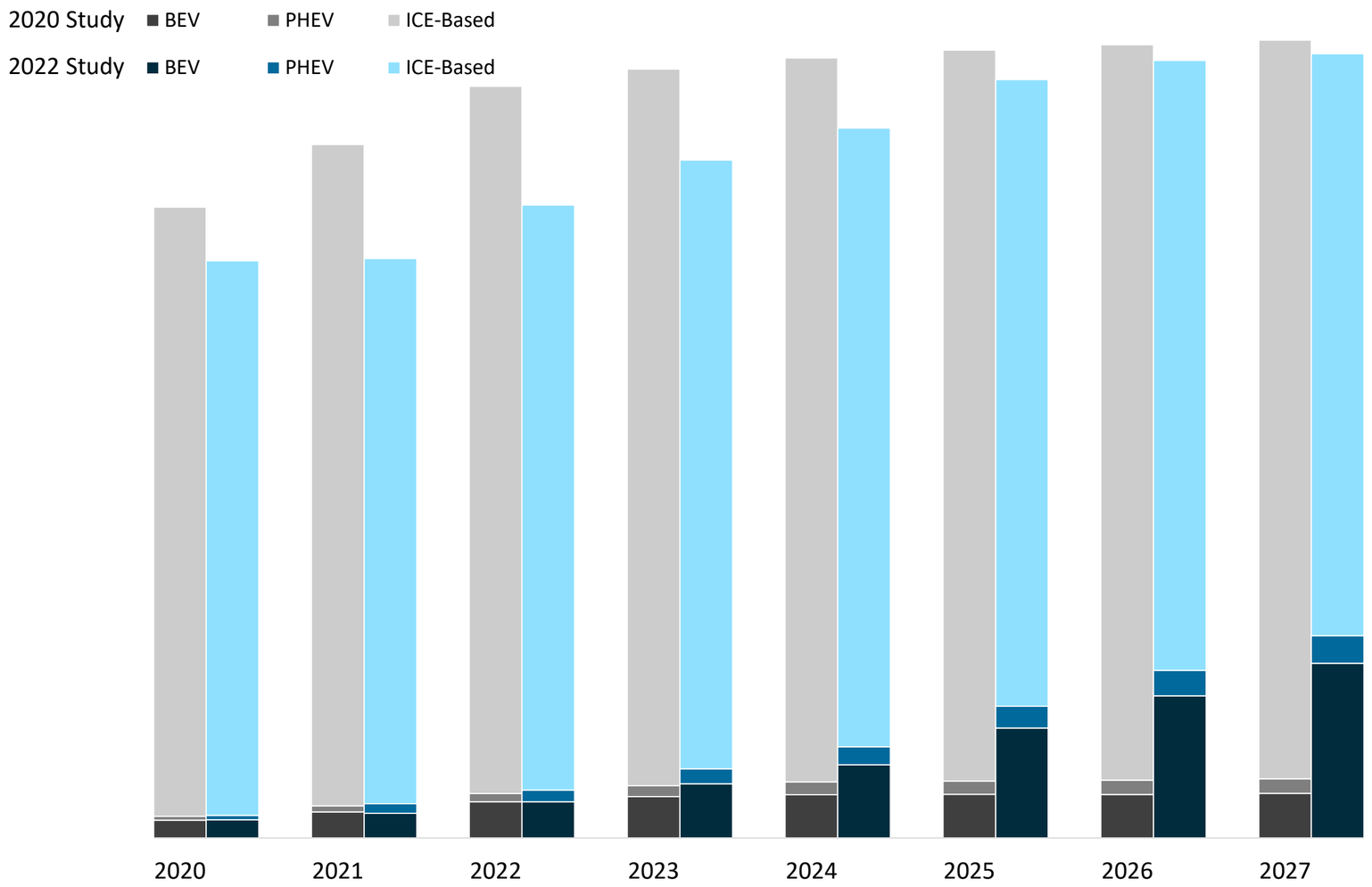
Production Forecast Comparison (2020 study vs. 2022)

Unexpected market conditions have propelled vehicles with higher aluminum content per vehicle (BEVs and D/E/F size segments) into the market for 2022, resulting in a strong growth in content per vehicle; however, this above average growth will ease, and the content increase will now continue at a slower pace

- Market volume has dropped due to COVID-19 lockdowns and the subsequent supply chain disruptions
- ICE (inc. MHEV) powertrains absorbed the entirety of the volume loss and, in the meantime, the volume of BEVs and hybrids increased more than originally forecasted
- As a result, the powertrain mix, along with the product mix (B and C segment contraction) increased share for vehicles with higher aluminum content, which has led the to the current market showing a distortion in shares increasing the content per vehicle more than expected in first place
- The strong content per vehicle increase between 2020 and 2022 will continue at a slower pace in the years to come

North America Light Vehicles Production Forecast

Share



Sources: Ducker, LMC Automotive April 2020 and Q4-2022

Long Term Aluminum Growth

Aluminum continues its unprecedented and uninterrupted growth through 2030 with 42 additional pounds per vehicle between 2020 and 2022, though, a multitude of external factors may slow its rate of growth in the next decade

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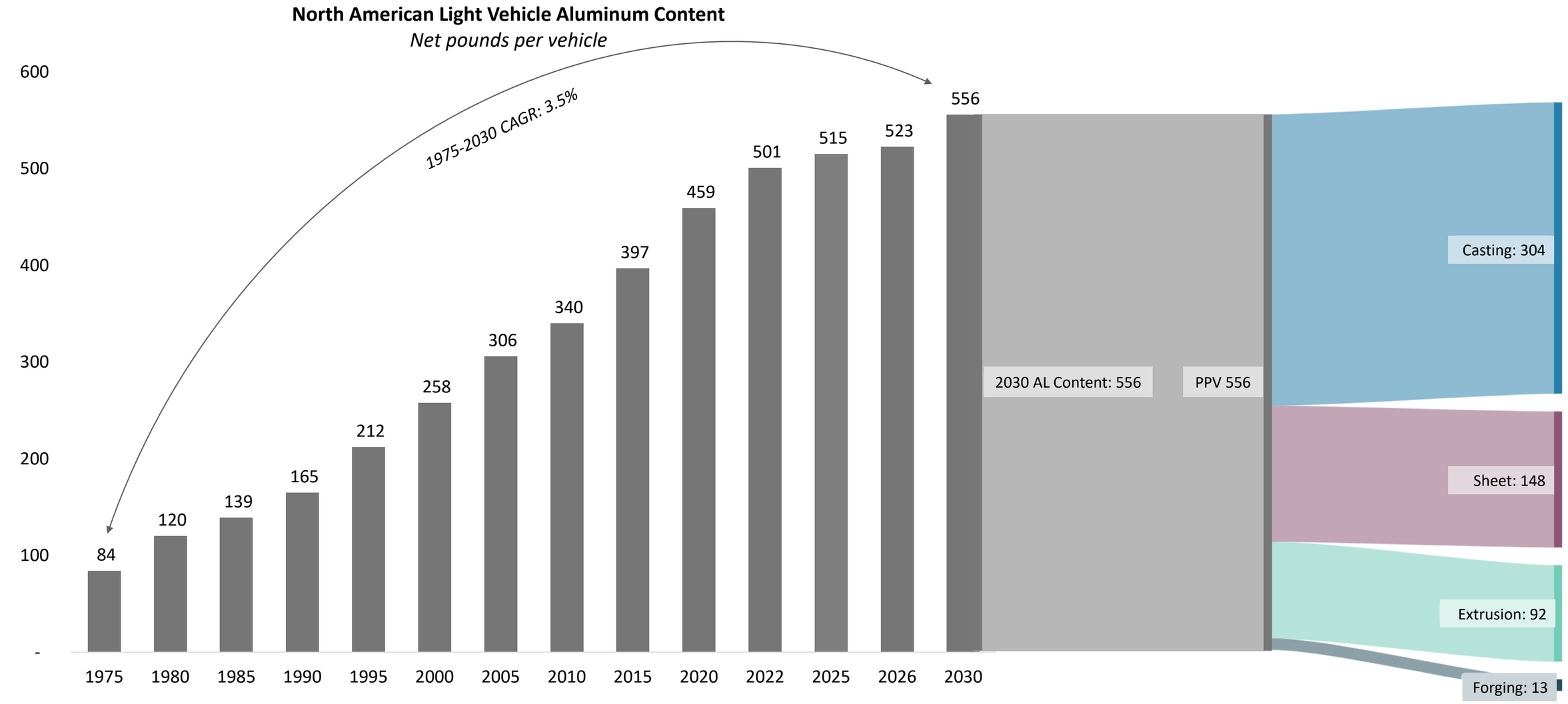

Source: Ducker Q1-2023

Forecast Bridge Analysis

Gross demand increases between 2020 and 2022 are the result of production volume increase and product mix evolutions with larger vehicles and stronger ramp-up of electrified vehicles

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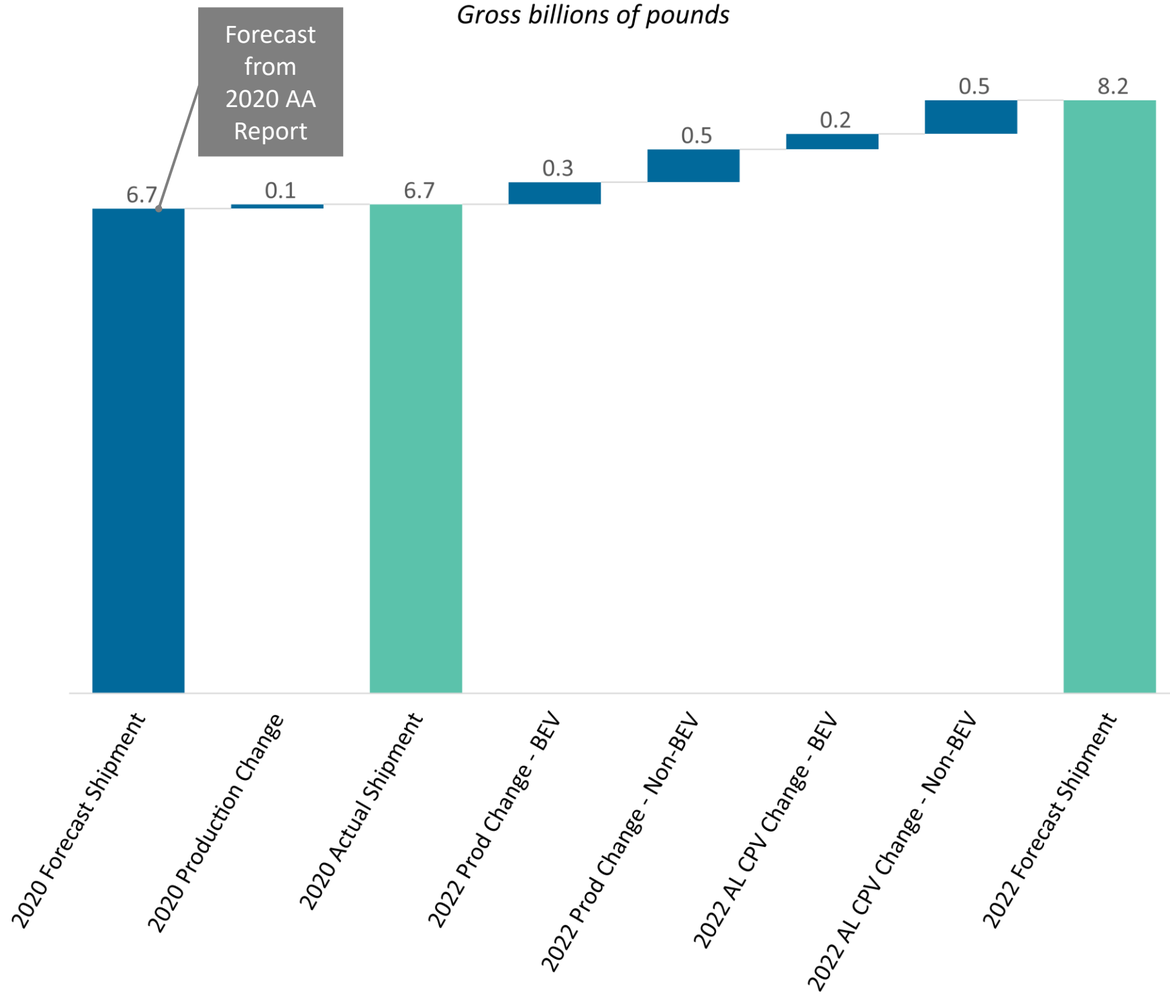
Variances in 2020 Gross Demand Compared to Today		
Vehicle Production	**2020 Adjustment**	LMC released 2020 final production in Q1 2021 with minor adjustment to Q4 2020 production volume, bringing total 2020 production from 12.8M to 12.9M, and resulting in 0.1B lbs. AL gross demand
	2022 Recovery	2022 production is forecasted to reach 14.2M, almost 1.3M units higher than 2020 when production was seriously disrupted by COVID, leading to ~0.8B lbs. AL organic growth (w/o CPV change)
BEV Growth	**BEV Share**	Based on 2020 BEV AL CPV, there will be additional 0.3B lbs. AL gross demand driven by the increasing volume of BEV production in NA (0.4M in 2020 vs. 0.8M in 2022)
	Non-BEV Share	The rest of 0.5B organic AL growth will be from non-BEV volume increase (12.5M in 2020 vs. 13.4M in 2022)
Design Changes	**BEV CPV**	BEV CPV has grown from 643 lbs. in 2020 to 885 lbs. in 2022, contributing to another 0.2B lbs. AL gross demand
	Non-BEV CPV	Non-BEV CPV, although not increasing as fast as BEV, still grows from 454 lbs. to 478 lbs. during 2020 to 2022, resulting in 0.5B lbs. AL gross demand

Source: Ducker Q1-2023

Total Automotive Aluminum Gross Demand

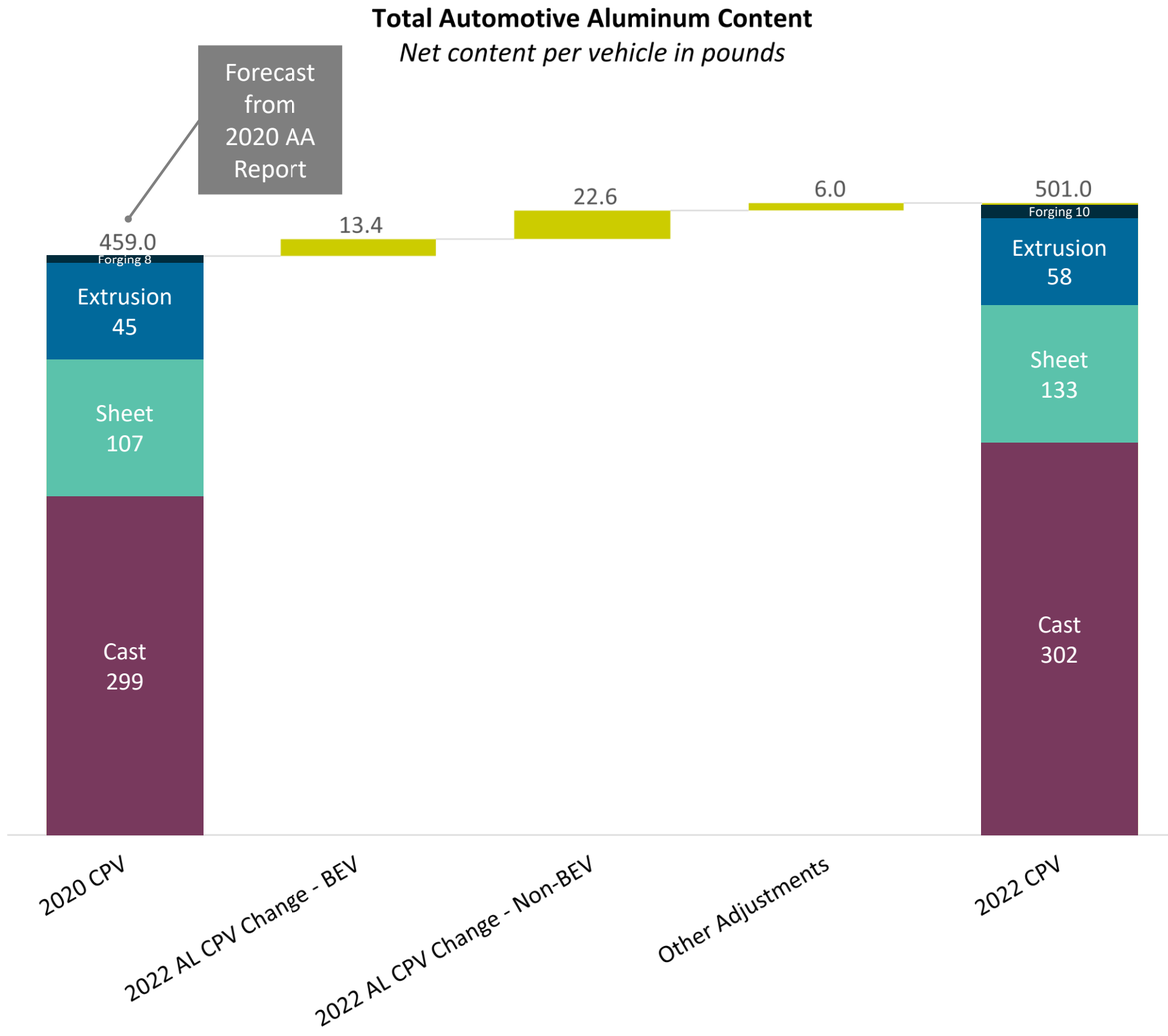
Gross billions of pounds



Forecast Bridge Analysis

Overall Aluminum CPV has increased by 42 lbs. from 2020 to 2022. AL CPV in BEV and non-BEV has contributed for around 14 lbs. and 23 lbs. respectively, and other adjustments have the impact of around 6 lbs. increase

Variances in 2020 CPV Compared to Today		
CPV Growth	**BEV CPV**	BEV CPV will grow from 643 lbs. in 2020 to 885 lbs. in 2022, driven by increasing share of aluminum intensive models
	Non-BEV CPV	Non-BEV CPV, although not increasing as fast as BEV, still grows from 454 lbs. to 478 lbs. during 2020 to 2022, driven by increasing penetration of AL in BIW, chassis, closures, etc., as well as vehicle mix change towards more aluminum intensive models
Other Adjustments	**AL Component Fitment**	Ducker has refreshed and revised aluminum component fitment for some new SOP models based on latest research for 2022 ATG study



Source: Ducker Q1-2023

Product Form Growth Details

Gross demand in 2022 is expected to reach 2016 levels despite a 3-million-unit gap in production. Aluminum content increases to 501 lbs. per vehicle, however, the distribution among the different product forms evolves due to a different product mix and a transition to BEV

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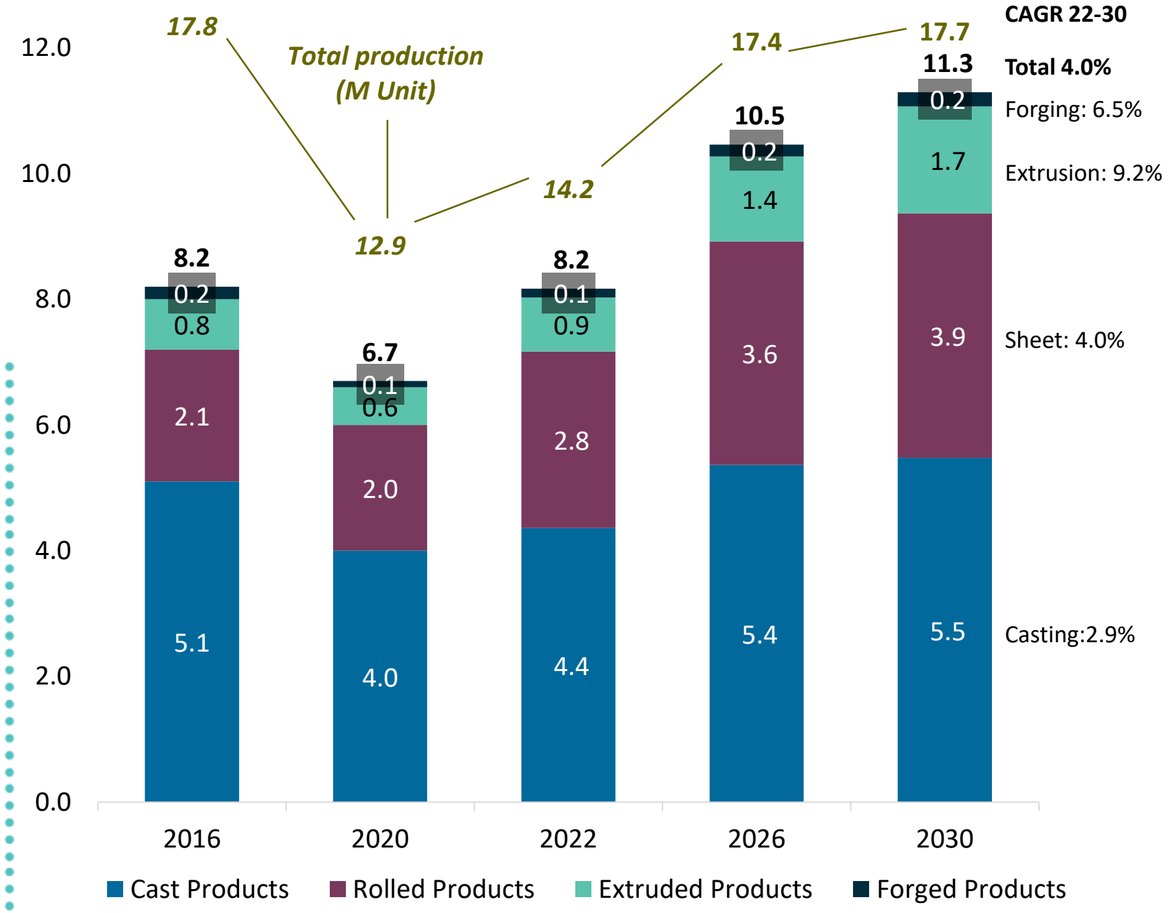
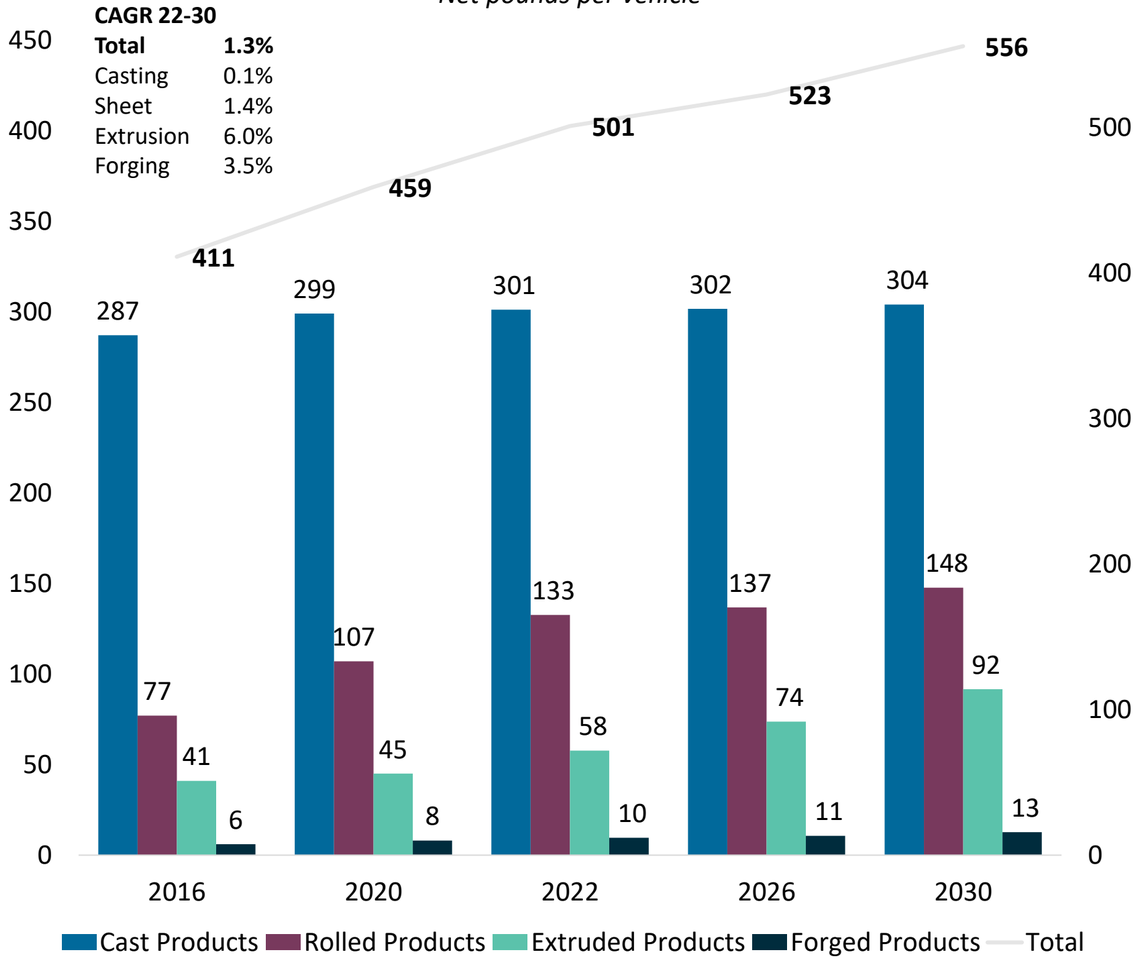
Light Vehicle Aluminum Gross Demand by Product Category

Gross billions of pounds



Light Vehicle Aluminum Net Content by Product Category

Net pounds per vehicle



Source: Ducker Q1-2023

Sheet and Casting Aluminum Overview

Sheet: OEMs continue adopting aluminum closures; ICE efficiency improvement and BEV weight increase keep requiring lightweighting solutions
Casting: downsizing along with the combined effect of lower market production and different product mix drive to lower powertrain and transmission CPV

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Sheet CPV	2016	2020	2022	2026	2030
Powertrain	<1	<1	<1	<1	<1
Transmission	1	1	1	<1	<1
Driveline	-	-	-	-	-
Wheel	-	-	-	-	-
Thermal Mgt.	20	19	31	30	28
BIW	12	23	32	30	29
Chassis	<1	<1	<1	<1	<1
Closures	41	59	65	67	79
EV Specific	<1	1	2	7	11
Steering	-	-	-	-	-
Brake	-	-	-	-	-
Trim	<1	<1	<1	<1	<1
Total	***77***	***107***	***133***	***137***	***148***

Casting CPV	2016	2020	2022	2026	2030
Powertrain	108	102	93	78	59
Transmission	68	69	57	49	38
Driveline	8	8	5	5	4
Wheel	63	70	82	83	86
Thermal Mgt.	4	4	5	5	5
BIW	8	10	12	15	21
Chassis	10	14	23	27	27
Closures	-	-	-	-	-
EV Specific	2	5	9	26	50
Steering	6	6	7	6	6
Brake	6	6	7	7	6
Trim	2	2	2	1	2
Total	***287***	***299***	***301***	***302***	***304***

Key Components

Door

Hood

Battery Housing

Key Components

EV Motor Housing

EV Inverter/ Converter

Megacasting

Wheel

Knuckle/Wheel Carrier

Shock Tower

Source: Ducker Q1-2023

Extrusion and Forging Aluminum Overview

Extrusion: strong interest for OEMs due to energy absorption properties leading to higher penetrations in EV batteries and crash related components
Forging: current market is driven by European OEMs; however, electrification offers an opportunity to grow content per vehicle

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Extrusion CPV	2016	2020	2022	2026	2030
Powertrain	1	1	1	1	<1
Transmission	<1	<1	<1	<1	<1
Driveline	3	3	2	2	2
Wheel	-	-	-	-	-
Thermal Mgt.	15	15	12	12	11
BIW	9	13	24	28	30
Chassis	6	6	9	9	9
Closures	-	-	-	-	-
EV Specific	<1	2	2	15	31
Steering	<1	<1	<1	<1	<1
Brake	2	2	2	3	4
Trim	3	3	4	4	4
Total	***41***	***45***	***58***	***74***	***92***

Key Components

Battery Housing

Sill/Rocker

CMS

Door Beam

Forging CPV	2016	2020	2022	2026	2030
Powertrain	-	-	-	-	-
Transmission	-	-	-	-	-
Driveline	<1	<1	-	-	-
Wheel	1	1	<1	<1	<1
Thermal Mgt.	-	-	-	-	-
BIW	-	-	-	-	-
Chassis	4	5	8	9	11
Closures	-	-	-	-	-
EV Specific	-	-	-	-	-
Steering	1	1	1	1	1
Brake	-	-	-	-	-
Trim	-	-	-	-	-
Total	***6***	***8***	***10***	***11***	***13***

Key Components

Knuckle/Wheel Carrier

Control Arm

Source: Ducker Q1-2023

BEV & PHEV New Launches 2022-2029

BEV new model launches outnumber PHEV model launches by an approximate factor of 3 in the future; OEMs favor BEVs. Note that the ICE vehicle launches will all have some form of mild electrification in this period

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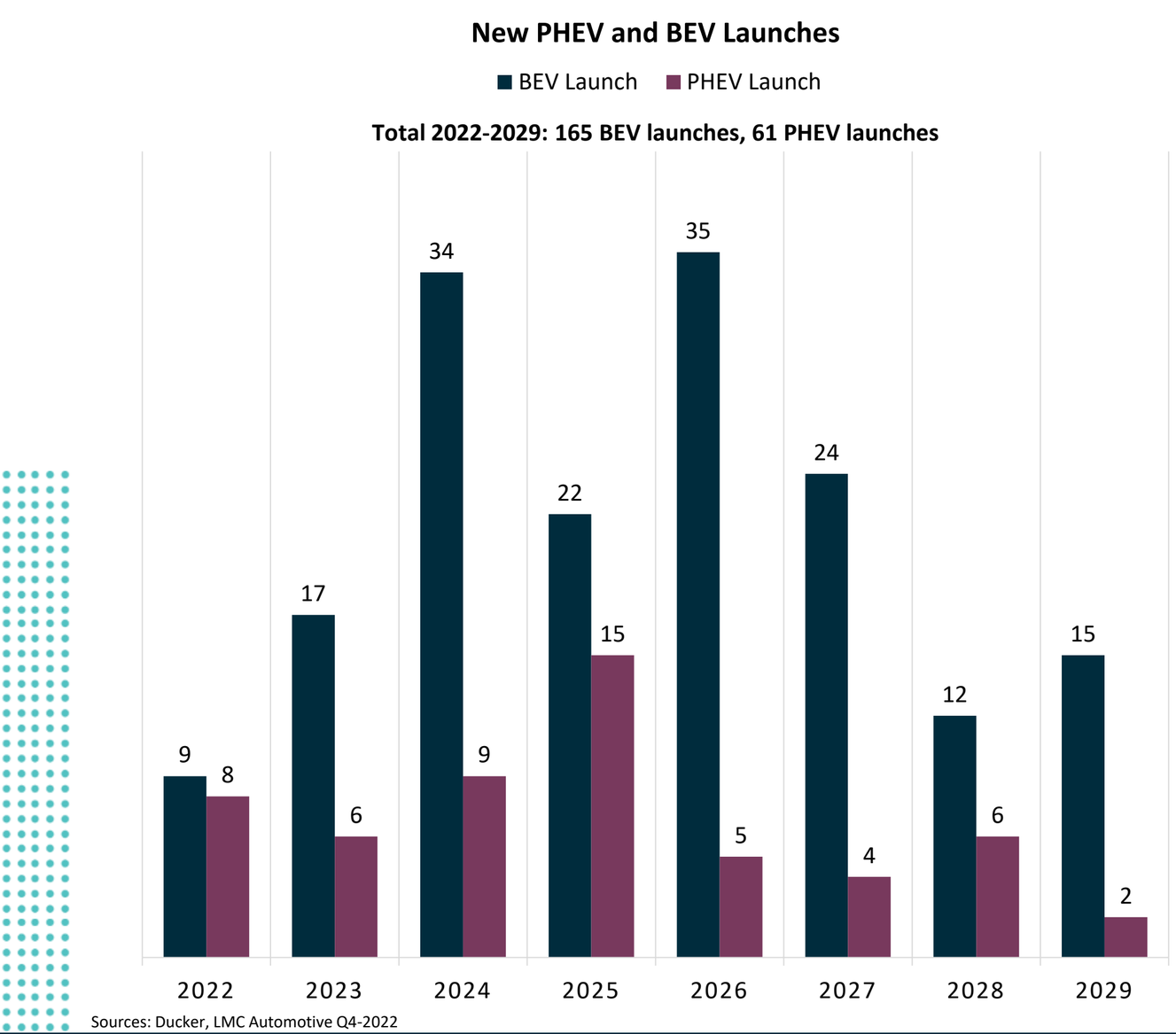
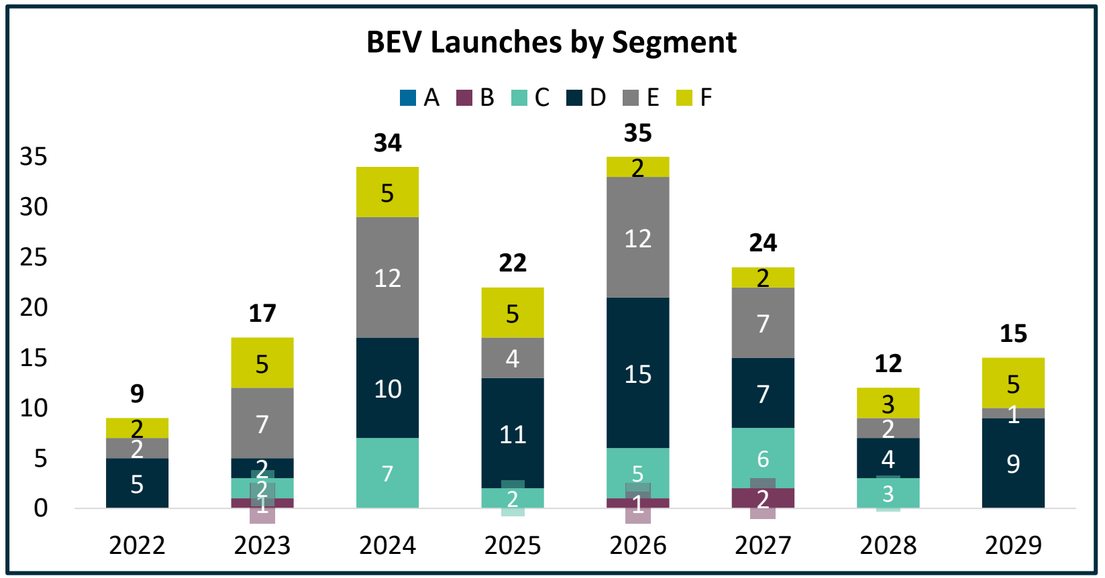
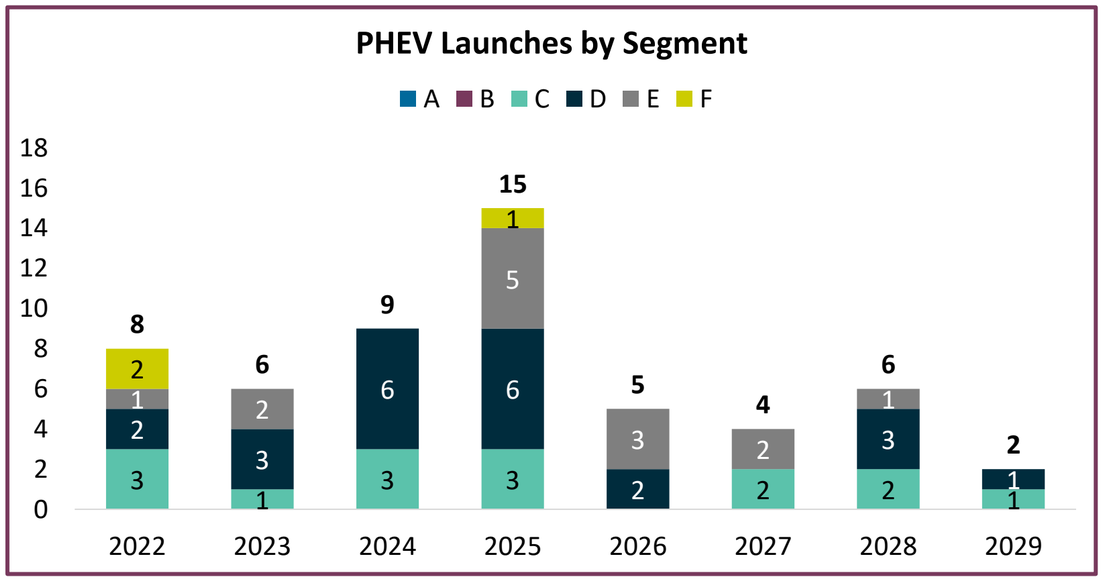


Sources: Ducker, LMC Automotive Q4-2022





OEM Car Launch on the Forecast Period

Despite of the discontinuation of several models, EV startups will launch several BEV sedans in the upcoming years (Lucid, Canoo, Mullen, Fisker)

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	2023	2024	2025	2026	2027	2028	2029
B-Segment Car	Mazda Mazda2 IC Only	Kia Rio IC Only					Mazda Mazda2 IC Only
C-Segment Car		BMW 2 Series MHEV	Nissan Sentra IC Only	Cadillac C-Sedan EV BEV	Honda Civic FHEV/IC Only		BMW 2 Series MHEV/IC Only
		Kia K3 IC Only	Nissan Versa IC Only/FHEV	Toyota Corolla IC Only/FHEV			
		Tesla Roadster BEV	Volkswagen Jetta IC Only/MHEV				
			Hyundai Elantra FHEV/IC Only				
D-Segment Car	Ford Mustang IC Only	Chevrolet Camaro BEV	BMW 3 Series IC Only/PHEV	Cadillac D-Sedan EV BEV	Tesla Model 3 BEV	BMW 3 Series BEV	Chevrolet Corvette (Zora) BEV
	Chevrolet Corvette (Zora) FHEV	Dodge Cuda BEV/IC Only	Chevrolet Corvette EV BEV	Acura TLX BEV/IC Only		Volvo S60 BEV	Lucid D-Sporty EV BEV
	Honda Accord FHEV/IC Only	Honda Accord PHEV	Hyundai IONIQ 6 BEV	Mullen DragonFLY BEV		Honda Accord FHEV/PHEV/IC Only	Subaru Legacy IC Only
	Kia K5 FHEV	Subaru Legacy IC Only	Lucid D-Conventional EV BEV	Infiniti D-Conventional EV BEV			
		Toyota Camry FHEV/IC Only	Canoo D-Sedan EV BEV				
			Nissan D-Conventional EV BEV				
E-Segment Car	Cadillac CELESTIQ BEV	Dodge Charger BEV/IC Only		Acura NSX BEV			
		Fisker Ronin BEV		Tesla Model S BEV			

Sources: Ducker, LMC Automotive Q4-2022

BEV(FCEV) Dedicated

BEV(FCEV)/ICE Variants

ICE-based Only

OEM Light Truck Launch on the Forecast Period (1/2)

Over 130 light truck models will be launched from 2023 to 2025. Around half of them are BEVs, and most of the rest are hybrids

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	2023		2024		2025	
B-Segment LTR	Nissan Kicks IC Only	Canoo B-MPV EV BEV				
C-Segment LTR	Ford Bronco Sport BEV	Mazda CX-50 FHEV	Ford Bronco Sport FCEV	Honda CR-V PFCEV	Jeep Compass PHEV/IC Only	Volkswagen Tayron PHEV
	Chevrolet Equinox EV BEV	Infiniti QX50 FHEV	Chevrolet Equinox IC Only	Kia Sportage LWB FHEV	Toyota RAV4 IC Only/FHEV/PHEV	VinFast VF 7 BEV
	Honda HR-V (ZR-V) FHEV	Subaru Crosstrek IC Only	GMC Terrain IC Only	Genesis GV60 BEV	Cadillac OPTIQ BEV	Subaru Forester IC Only
	Mazda CX-30 MHEV	Toyota Corolla Cross PHEV	Jeep Recon BEV	Fisker PEAR BEV		
			Jeep Wagoneer S BEV	Faraday Future FF 81BEV		
			Volkswagen Tayron IC Only/MHEV	Canoo C-Pickup EV BEV		
			Ford Escape PHEV/FHEV/IC Only	Subaru Crosstrek PHEV		
			Lincoln Corsair PHEV/IC Only	Toyota C-Pickup FHEV		
D-Segment LTR	Chrysler Voyager PHEV	Cruise Origin BEV	Honda Prologue BEV	Acura RDX IC Only	Chrysler Pacifica BEV/PHEV/IC Only	Honda Passport IC Only/PHEV
	Mitsubishi Triton IC Only	Honda Pilot PHEV	Nissan Frontier IC Only	Hyundai Santa Fe IC Only/FHEV/PHEV	Chrysler Voyager PHEV/IC Only	Hyundai IONIQ 5 BEV
	Toyota Tacoma IC Only/FHEV	Workhorse C650 BEV	Jeep Cherokee BEV/IC Only	VinFast VF 8 BEV	Jeep Cherokee PHEV	Kia EV6 BEV
	Audi Q5 PHEV/MHEV	Nissan Murano IC Only	Toyota 4Runner FHEV/IC Only	Mullen FIVE BEV	BMW X3 BEV/FCEV/IC Only	Jeep Grand Cherokee BEV
	Ford Bronco FHEV		Audi Q5 Sportback PHEV/MHEV	Canoo Lifestyle BEV	BMW X4 MHEV/IC Only	Chrysler Airflow BEV
			BMW X3 MHEV/PHEV	Nissan Pathfinder FHEV	Honda Odyssey PHEV	Subaru Ascent IC Only
			MINI Traveller MHEV/PHEV/IC Only	Jeep Grand Cherokee MHEV/IC Only/PHEV		
			Volvo EX80 BEV	Subaru Outback IC Only		
			Cadillac SYMBOLIQ BEV	Volkswagen ID.8 BEV		
E-Segment LTR	BrightDrop Zevo 400 BEV	GMC Canyon IC Only	Ford Explorer EV BEV	GMC Acadia IC Only	Ford Explorer PHEV/FHEV/IC Only	Tesla E-Pickup EV BEV
	Lexus RX PHEV	Mercedes-Benz eSprinter BEV	Lincoln Aviator EV BEV	Acura ZDX BEV	Lincoln Aviator IC Only/PHEV	Toyota Highlander IC Only/FHEV
	Chevrolet Blazer EV BEV	Arrival E-Van EV BEV	GMC Acadia EV BEV	Honda Ridgeline IC Only/FHEV	Ford Ranger PHEV/FHEV	Toyota Grand Highlander PHEV
	Ford Ranger IC Only	LMC E-Van EV BEV	Chevrolet Traverse EV BEV	Kia EV9 BEV	Hyundai IONIQ 7 BEV	Lexus TX PHEV
	Volvo EX90 BEV	Jeep Gladiator PHEV	Buick Enclave Electra BEV	Lucid Gravity BEV	Mullen One BEV	Volkswagen ID.Buzz BEV
	Chevrolet Traverse IC Only	Toyota Grand Highlander IC Only/FHEV	Polestar 3 P519 BEV	VinFast VF 9 BEV		
	Chevrolet Colorado IC Only	Lexus TX IC Only/FHEV	Buick Enclave IC Only	Jeep Wagoneer IC Only/MHEV/EREV		
F-Segment LTR	Ford F-250/F-350 IC Only	Oshkosh NGDV IC Only	Ram 2500/3500 IC Only	Cadillac Escalade IQ BEV	Ram 2500/3500 FCEV	Cadillac Escalade IQL BEV
	GMC HUMMER EV SUV BEV	Oshkosh NGDV BEV	Ford Expedition FHEV/IC Only	GMC Sierra EV BEV	BMW X7 EV BEV	Edison Future EF1-T BEV
	Chevrolet Silverado EV BEV	Tesla Cybertruck BEV	Lincoln Navigator BEV/IC Only	Ram 1500 REPB-EV BEV/EREV	BMW X7 MHEV/PHEV	Edison Future EF1-V BEV
	Bollinger DELIVER-E BEV		Volvo EX100 BEV		Ford F-250/F-350 Lightning EV BEV	

BEV(FCEV) Dedicated

BEV(FCEV)/ICE Variants

ICE-based Only

Sources: Ducker, LMC Automotive Q4-2022

OEM Light Truck Launch on the Forecast Period (2/2)

Among the new models between 2026 and 2029, BEV share will continuously increase, including BEV dedicated platforms and shared platforms by both BEV and ICE-based variants

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	2026		2027		2028		2029	
B-Segment LTR	VinFast VF 6 BEV		Chevrolet B-SUV EV BEV	Honda B-SUV EV BEV				
C-Segment LTR	Jeep Compass BEV	Mazda CX-30 IC Only/MHEV	Ford Escape EV BEV	Genesis GV60 BEV	Toyota RAV4 BEV	Kia Sportage LWB IC Only/FHEV/PHEV	Subaru Crosstrek IC Only/PHEV	
	Ford Bronco Sport BEV/IC Only/FCEV/FHEV	Honda CR-V EV BEV	Lincoln Corsair EV BEV	Hyundai Santa Cruz IC Only	Ford Maverick BEV	Mazda CX-50 FHEV/MHEV		
	Honda HR-V (ZR-V) BEV	Nissan Rogue IC Only	Honda CR-V FHEV	Nissan C-SUV EV BEV	Honda HR-V (ZR-V) FHEV/BEV/IC Only	Jeep Wrangler MHEV/IC Only/PHEV		
			Ford Maverick FHEV/IC Only	Nissan C-Pickup EV BEV	Volkswagen Taos IC Only/MHEV			
			Honda CR-V IC Only/PFCEV	Tesla C-SUV EV BEV				
			Hyundai Tucson LWB IC Only/FHEV/PHEV	Toyota Corolla Cross IC Only/FHEV/PHEV				
D-Segment LTR	Dodge D-SUV EV BEV	Rivian R2S BEV	Genesis GV70 BEV	Nissan Pathfinder IC Only/BEV/FHEV	Lexus RZ BEV	Nissan Frontier IC Only	Ford Bronco BEV/IC Only/FHEV	Honda Pilot BEV
	Ford Mustang Mach-E BEV	Rivian R2T BEV	Lucid D-SUV EV BEV	Infiniti D-SUV EV BEV	Honda Odyssey PHEV/IC Only	Volkswagen ID.4 BEV	Cadillac LYRIQ BEV	Jeep Grand Cherokee BEV/MHEV/IC Only/PHEV
	Kia D-Pickup EV BEV	Nissan Murano FHEV	Nissan D-SUV EV BEV	Infiniti QX60 IC Only/MHEV/BEV	Honda Pilot IC Only/PHEV		Chevrolet Corvette EUV BEV	Subaru Outback IC Only
	Toyota Tacoma BEV	Toyota bZ4X BEV					Honda Odyssey BEV	Toyota bZ4X BEV
	BMW X4 BEV	Volkswagen Atlas PHEV/IC Only						
	Honda Vision S BEV	Volkswagen Atlas Cross Sport IC Only/PHEV						
	Kia EV7 BEV	Scout D-SUV EV BEV						
E-Segment LTR	BMW X5 BEV/MHEV/PHEV/IC Only/FCEV	Mercedes-Benz Sprinter BEV	Ram ProMaster BEV/FCEV/IC Only	Rivian R3S 1 BEV	GMC Yukon BEV	Jeep Gladiator BEV/IC Only/PHEV	Lexus E-SUV EV BEV	
	Ford Transit BEV/IC Only	Rivian EDV BEV	BMW X6 BEV/IC Only/PHEV	Rivian R3T 1 BEV				
	Ford E-Transit BEV	Jeep Wagoneer BEV	Acura MDX BEV/IC Only	Jeep Wagoneer BEV/MHEV/EREV				
	Kia Telluride IC Only/PHEV	Tesla Model X BEV	Mercedes-Benz GLE Coupe MHEV/PHEV/IC Only					
	Kia E-Pickup EV BEV	Tesla E-Van EV BEV						
	Mercedes-Benz GLE MHE/PHEV/IC Only	Scout E-Pickup EV BEV						
F-Segment LTR	Chevrolet Silverado IC Only	Ford F-150 Lightning EV BEV	Chevrolet Silverado HD IC Only	Chevrolet Silverado HD FCEV	Chevrolet Tahoe BEV	Chevrolet Silverado FCEV	Ford Expedition EV BEV	
	GMC Sierra IC Only	Mercedes-Benz GLS MHEV	Ram 2500/3500 EREV	GMC Sierra HD IC Only/FCEV	Chevrolet Suburban BEV	Ram 1500 FCEV	Lincoln Navigator EV BEV	
	Ford F-150 IC Only/FHEV	Edison Future EF1-S BEV	Ford F-150 BEV	Ram 1500 BEV/IC Only/MHEV/EREV	GMC Yukon XL BEV		Ford F-250/F-350 IC Only	

BEV(FCEV) Dedicated

BEV(FCEV)/ICE Variants

ICE-based Only

Sources: Ducker, LMC Automotive Q4-2022

Aluminum Content By Vehicle Segment

Light trucks are expected to have 564 pounds of average aluminum content in 2030, a comparable level to that of D-segment cars. E-segment passenger cars boast over 900 lbs. of aluminum per vehicle, thanks to new EV brand models such as the Tesla Model S and Lucid Air

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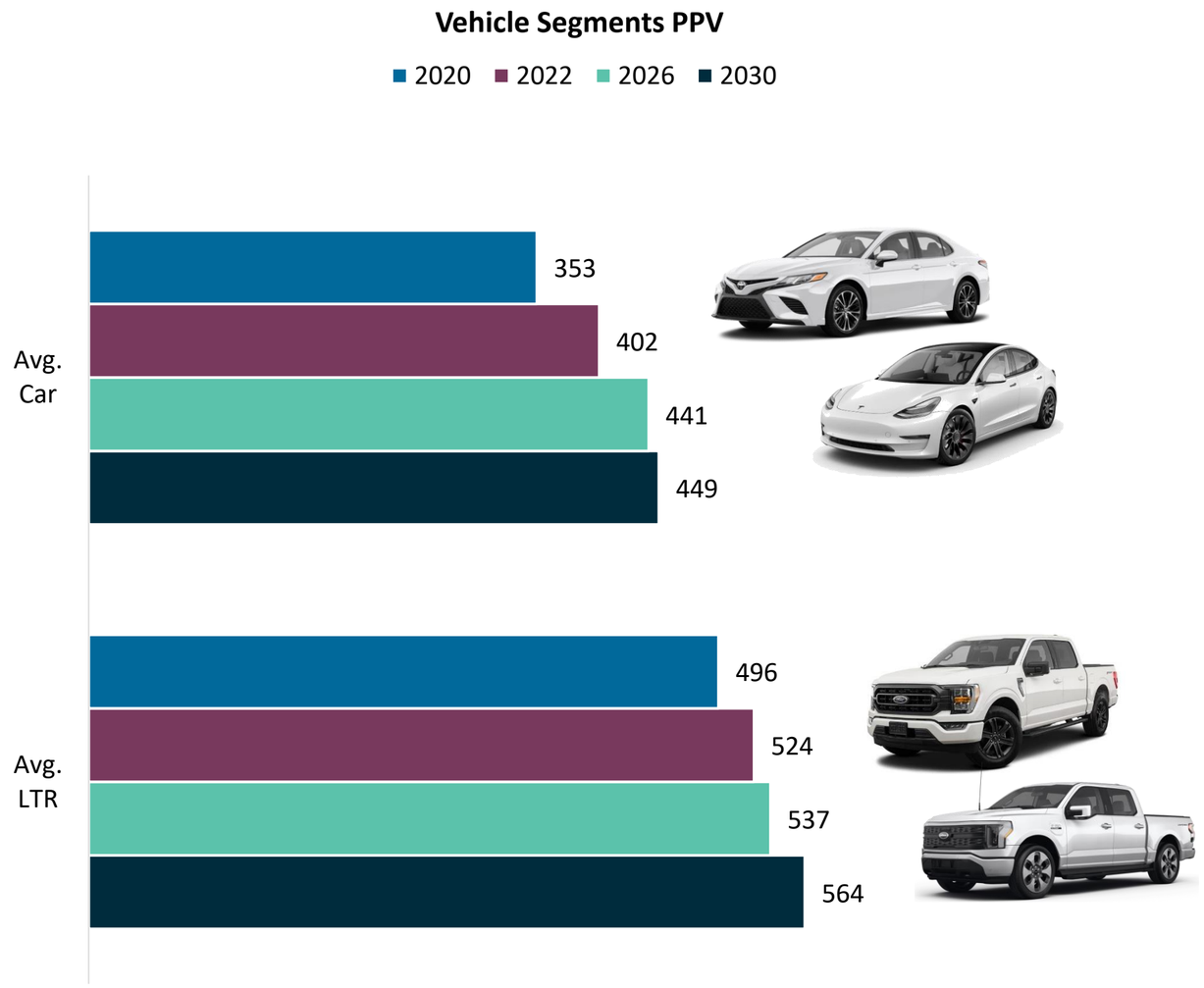

Segment	2020 PPV	2022 PPV	2026 PPV	2030 PPV
A-Segment Car	304	-	-	-
B-Segment Car	258	218	208	209
C-Segment Car	270	268	273	281
D-Segment Car	423	475	552	569
E-Segment Car*	519	608	828	924
F-Segment Car*		-	-	-
Average Car	***353***	***402***	***441***	***449***
Segment	**2020 PPV**	**2022 PPV**	**2026 PPV**	**2030 PPV**
A-Segment LTR	-	-	-	-
B-Segment LTR	241	216	232	241
C-Segment LTR	357	341	353	392
D-Segment LTR	410	488	511	549
E-Segment LTR*	654	542	595	651
F-Segment LTR*		726	755	734
Average LTR	***496***	**524**	**537**	**564**
Segment	**2020 PPV**	**2022 PPV**	**2026 PPV**	**2030 PPV**
Total Average	***459***	***501***	***523***	**556**

**E/F segments were combined in 2020 study*

Source: Ducker Q1-2023

Material Content Evolution in North America

Aluminum share will continue to grow through 2026. As BEVs gain more share towards the end of the decade, the average vehicle curb weight is expected to continue rising, largely due to EV batteries

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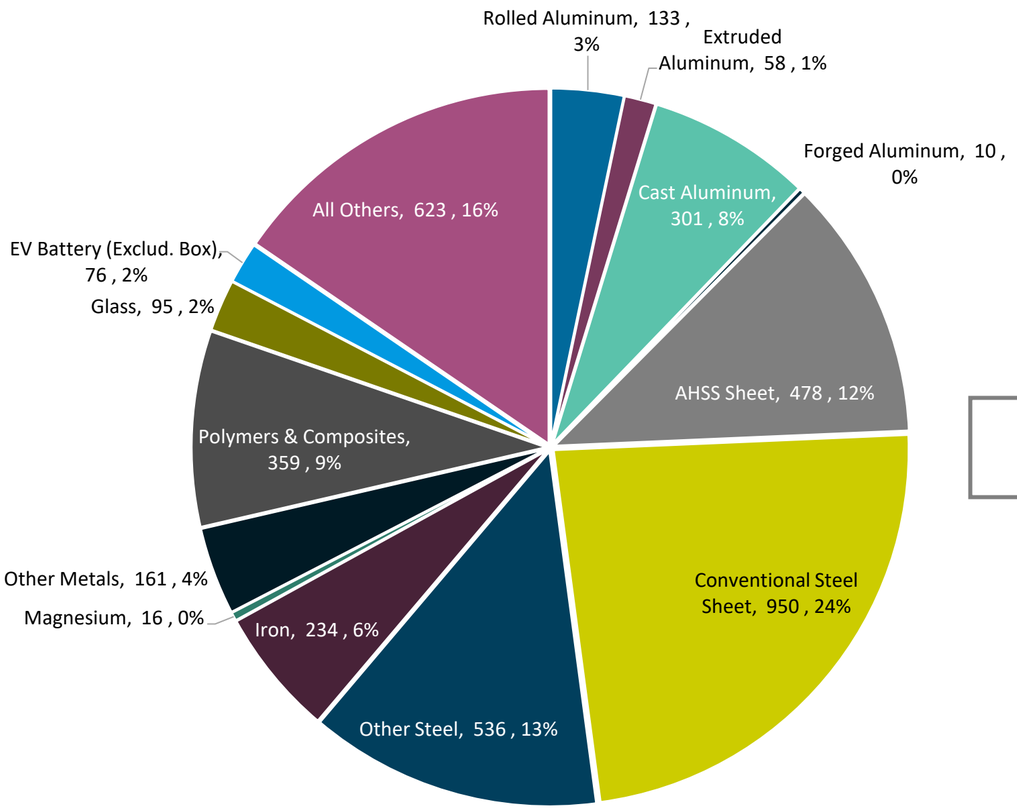
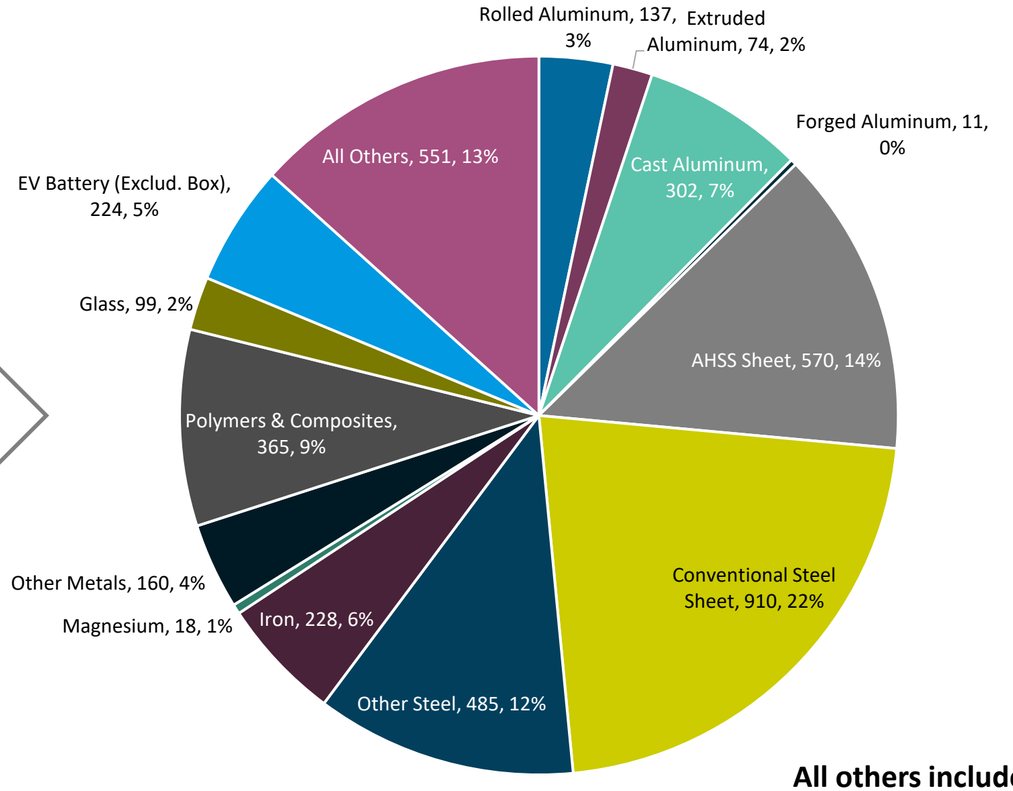
2022 Average Vehicle Material Weight: 4,029 lbs.



2026 Average Vehicle Material Weight: 4,134 lbs.



All others include:
Rubber, coatings, textiles, fluids and lubricants and all other miscellaneous materials

Sources: Ducker, American Chemistry Council

Market Perspectives

NA Light Vehicles Production

Production has been negatively impacted by the COVID-19 lockdowns and the semiconductor disruptions; a slow recovery is ongoing, but it is still lingering as supply chain disruptions are multiplying and hurting production capacity; no volume correction is expected to recover from lost volumes

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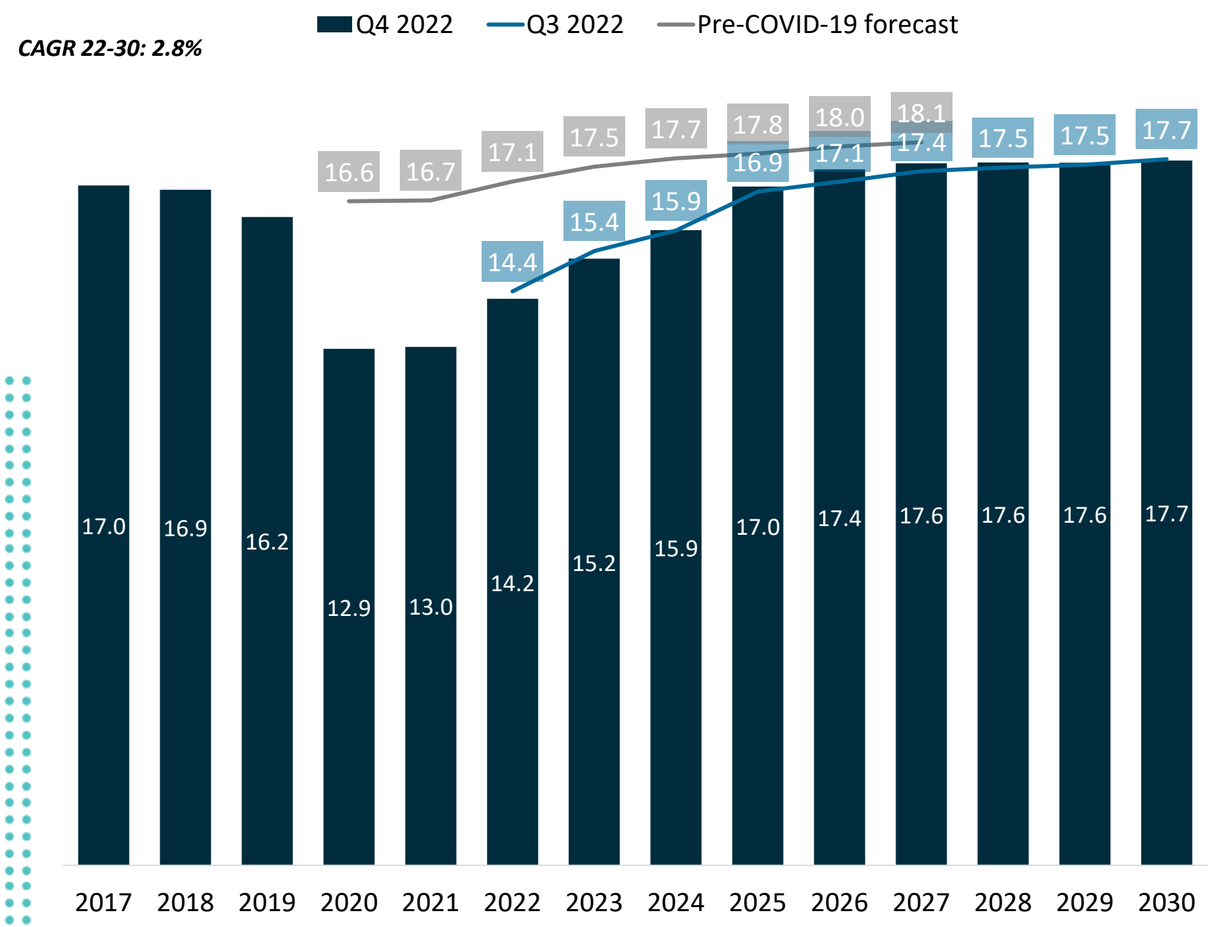
North America Light Vehicles Production Forecast

Million Units (light vehicles)

CAGR 22-30: 2.8%



Sources: Ducker, LMC Automotive Q4-2022, World Semiconductor Trade Statistics

- Industry stalled due to COVID-19 in 2020 following lockdowns and low mobility needs
- Market is unlikely to fully return to normal production levels before 2025 in the best-case scenario
- Supply chain issues are not likely to resolve soon due to economic warfare with China and the Russian invasion of Ukraine
- The European natural gas supply situation is impacting the cost of energy on a worldwide perspective, leading to a slowdown in some energy intensive component productions
- There is a possibility that the market will not recover the lost volumes due to high prices
- To secure volumes, carmakers may have to invest into lower segment vehicles to reduce price entry for new vehicles
- Most volume loss is absorbed by ICE-based powertrain as carmakers are ramping up EV production, creating a distortion in the market share of EVs
- The economy remains strong in North America, but consumers are dominated by a fear of recession leading to an easing demand for new vehicles

NA Light Vehicle Production Share by Status/Size/Body Type

Due to a fundamental shift by the Detroit 3 in production mix by body type to favor larger SUVs and pickup trucks, the outlook over the next seven years is stable. BEVs, although currently aligning with larger D and E segments, will shift to C segment (inflation reduction act and price ceilings for rebates)

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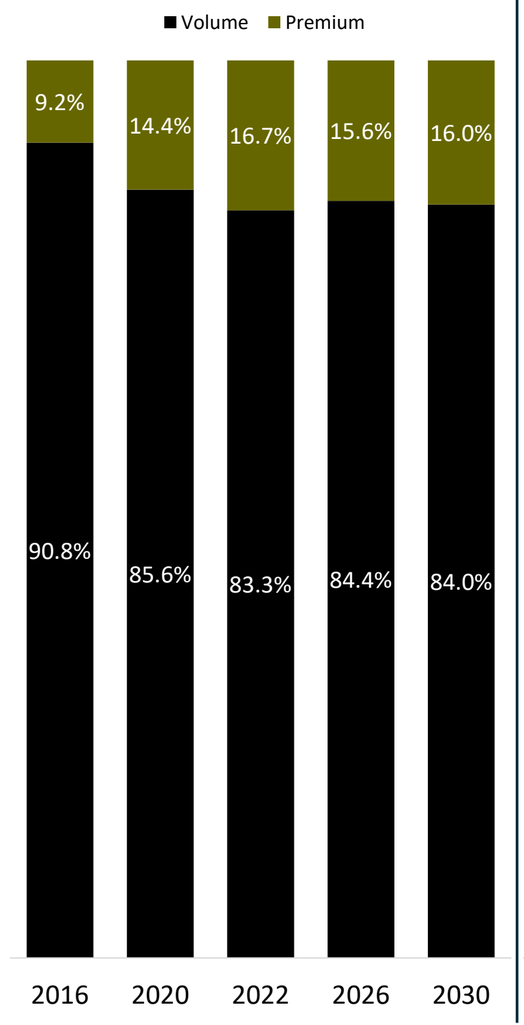
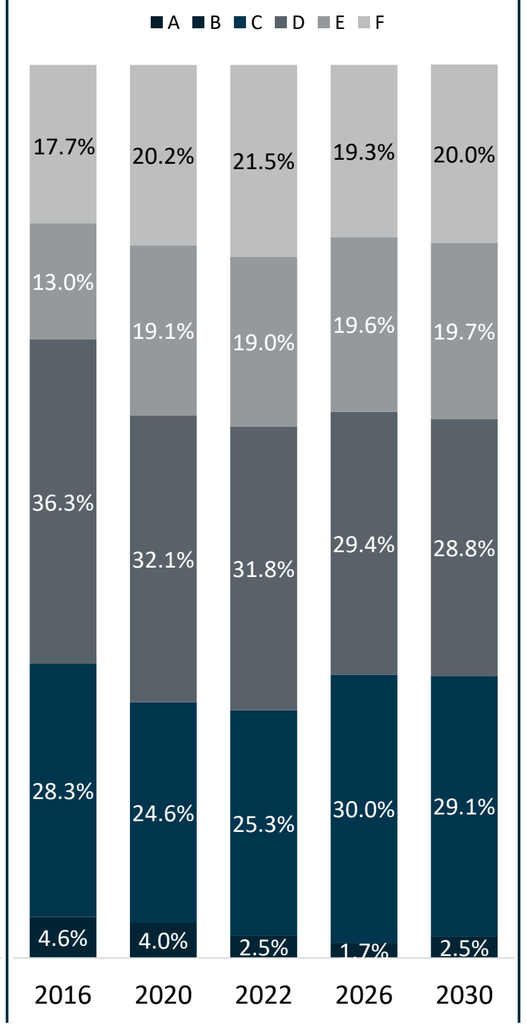
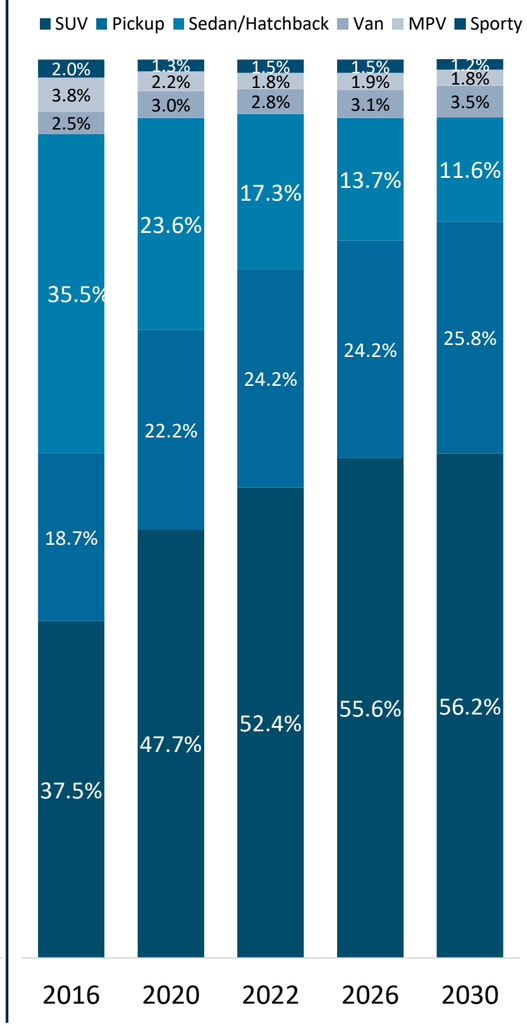
NA LV Production by Status



NA LV Production by Size



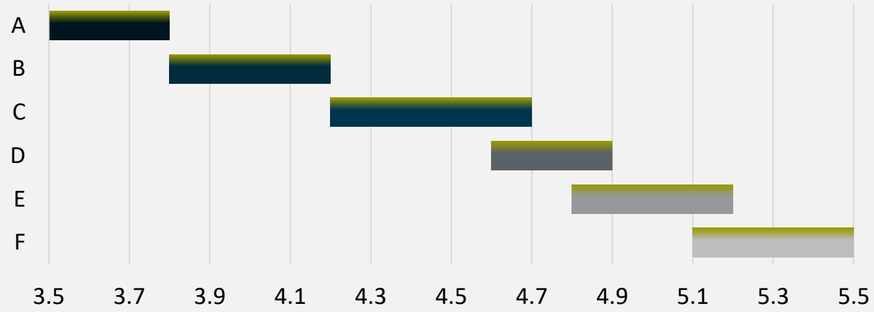
NA LV Production by Body Type

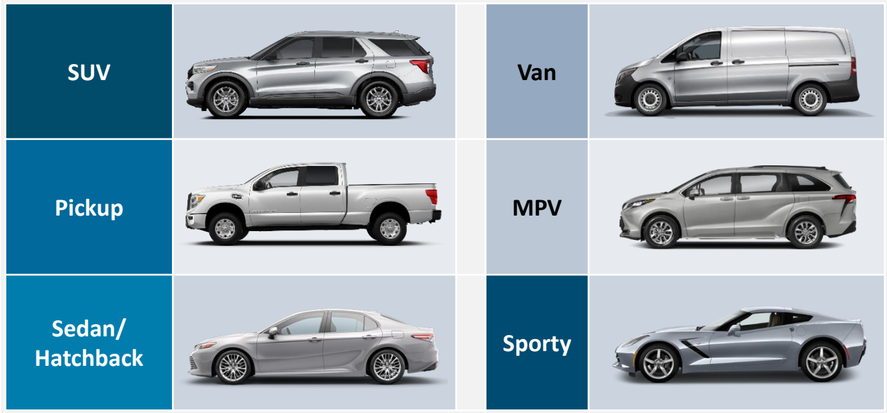


Definitions

Premium brands: Acura, Alfa Romeo, Audi, BMW, Cadillac, Fisker, Genesis, Infiniti, Karma, Lexus, Lincoln, Lucid, Maserati, Mercedes-Benz, MINI, Mullen, Polestar, Porsche, Rivian, Tesla, Volvo and **specialty luxury and sportscar brands** (e.g., Bentley, Ferrari, Lamborghini, McLaren, Rolls Royce)

Size Segment Indicative Vehicle Lengths (m)





Sources: Ducker, LMC Automotive Q4-2022

A-segment < 0.1%

BEV – NA Light Vehicle Production Share by Status/Size/Body Type

The BEV market has been shaped by the low number of models in the past several years, creating major changes and distortions in the market structure; as OEMs are introducing more models in a diversity of size, status, and body type, the market is evolving accordingly

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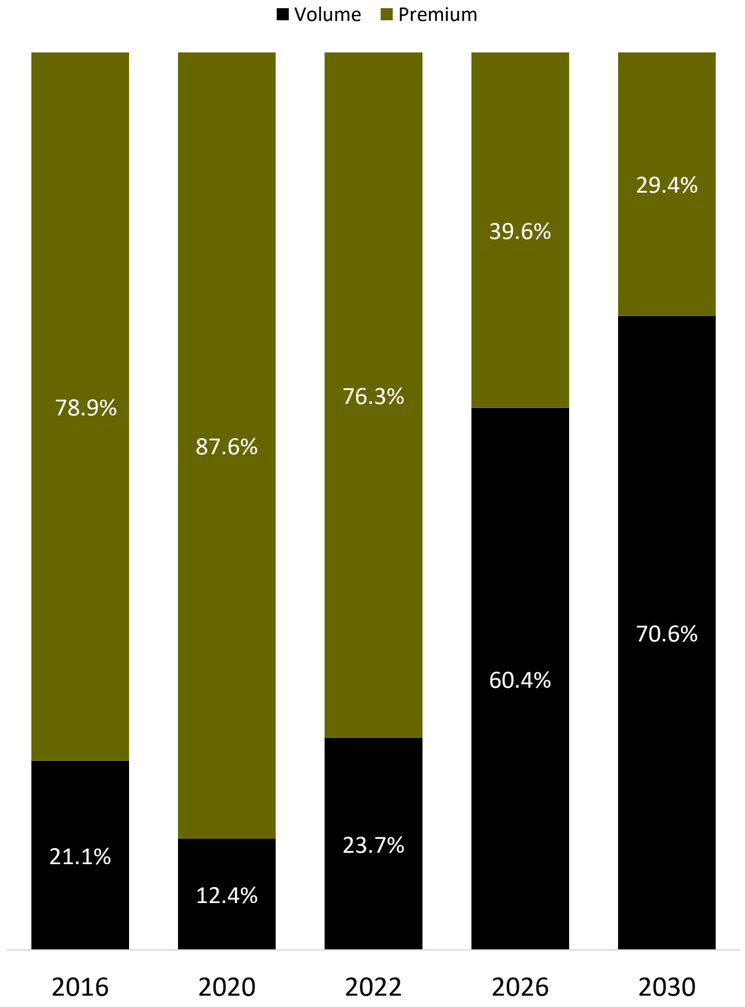
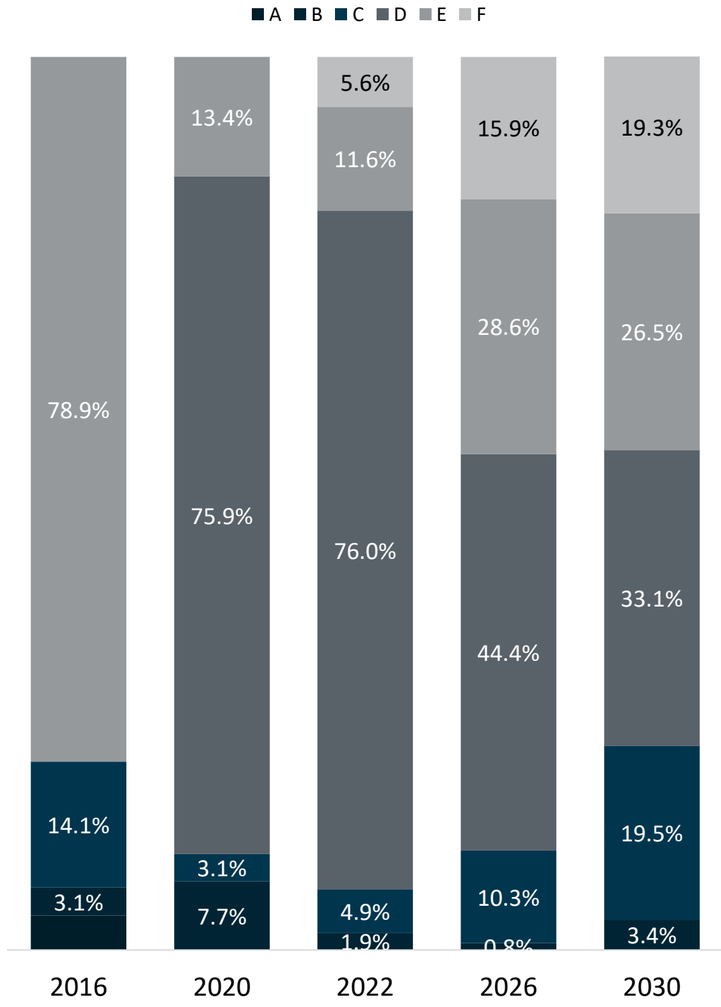
NA BEV LV Production by Status

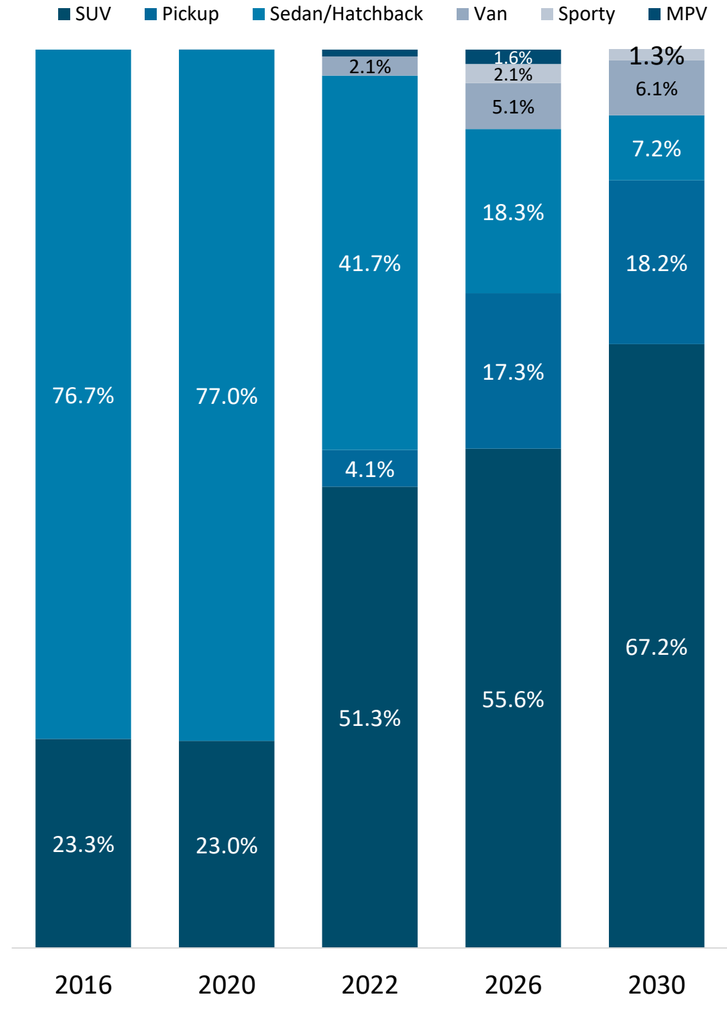


NA BEV LV Production by Size



A-segment < 0.1%

NA BEV LV Production by Body Type



Sources: Ducker, LMC Automotive Q4-2022

The Road to Sustainability

OEMs are asking suppliers by to establish the carbon footprint for the material supplied

- No restriction has yet been implemented
- BMW and Volvo have announced CO2 targets from components as part of the carbon neutrality strategy
- VW Group is expected to follow the same path, nothing yet has been announced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September 23, 2020 01:57 PM

California plans to ban sale of new gasoline-powered passenger vehicles in 2035

DAVID SHEPARDSON and NICHOLA GROOM

Reuters

2050

- Audi: Carbon neutrality
- Ford: Carbon neutrality
- RNM: Carbon neutrality
- Toyota: 90% less CO2 emissions compared to 2010
- VW: Carbon neutrality

2040

- GM: Carbon neutrality
- Honda: 100% BEV
- JLR: CO2 neutrality (incl. supply chain)
- Mercedes-Benz: CO2 neutrality
- Hyundai: 100% BEV

2035

- GM 100% Electrified
- Ford: Cut 50% GHG
- RNM: 100% EV

2035 Hydrogen Fuel Cell

- Fuel Cell EVs
- Based on low-carbon hydrogen

2030

- Audi: 100% BEV by 2033
- BMW: 50% BEV global
- Cadillac: 100% BEV
- Honda: 40% BEV
- Volvo: 100% BEV
- VW: 50% BEV

2025

- BMW: launch of new fully electric platform
- GM: 30 new EVs
- Jaguar: 100% BEV
- Hyundai-Kia: 20% BEV
- Mercedes-Benz: 50% EV
- Porsche: 50% EV
- Stellantis: EV variants for all new models
- Toyota: 70 new EVs
- Volvo: 100% EV (incl. 50% BEV)

2023

- BMW: 90% of models with at least one BEV version

2025? e-fuels

- CCU synthetic fuels
- Drop-in solutions (ICE-based)
- Virtuous carbon cycle

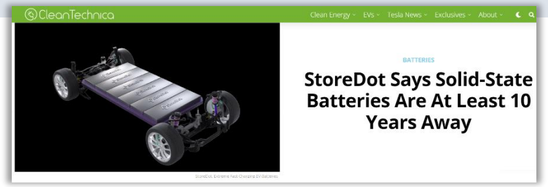
Influencers

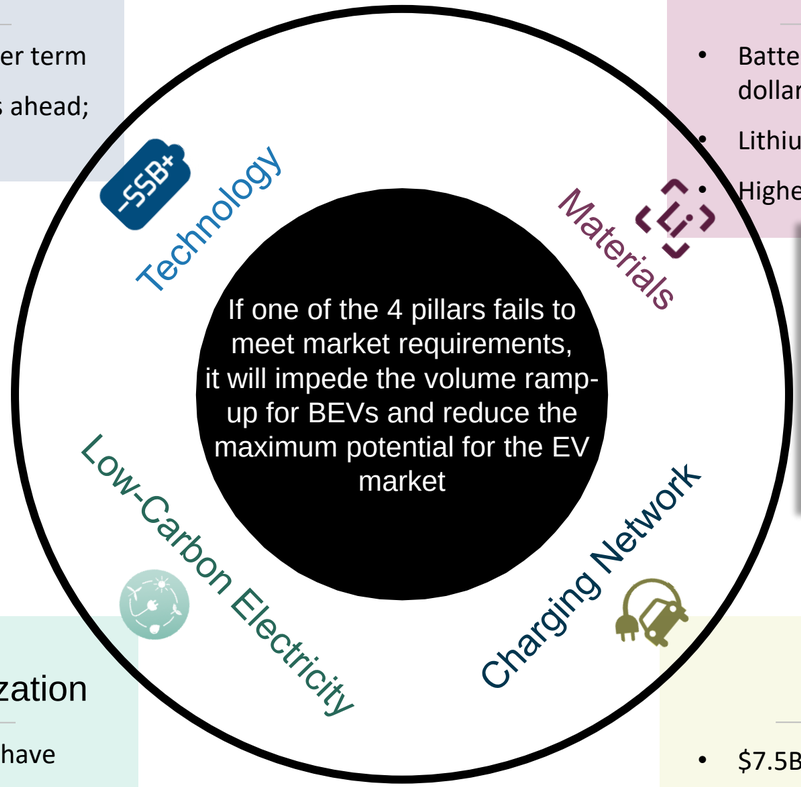
Source: Ducker

Steering BEVs Towards Success

A breakthrough is required to reduce the need for materials and implement ultra fast charging

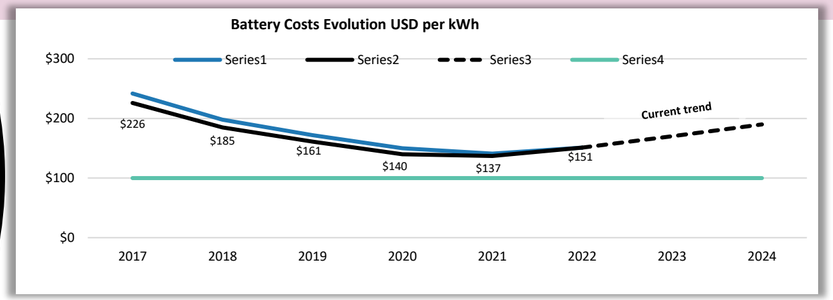
- Target is to reach over 300Wh/kg and up to 600Wh/kg on a longer term
- In the best-case scenario, first solid-state applications are 5 years ahead; most industry participants expect industrialization in 10+ years





Strong demand pushes costs up, decrease is not expected before 2026 due to strong demand

- Battery costs went down to $137/kWh in 2021 ($151 in 2022 constant dollars), but are now rising as 2022 they increased back to 2019 levels
- Lithium costs increased by 7x since 2020 (CNY38,500/T => CNY250,000/T)
- Higher battery material costs likely to have a positive impact on al demand

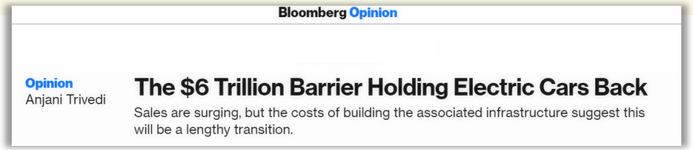


The current grid capacity is insufficient to support charging needs at peak time and requires modernization

- The US must increase electricity production by 22% (900TWh) to have enough energy to shift 25% of the US VIO to EVs
- Low carbon electricity is critical to reduce efficiently mobility emissions

Charging networks lead to range anxiety with only 53,000 stations and 140,000 connectors in the US

- $7.5B invested in EV charging infrastructure (500,000 stations by 2030)
- Charging infrastructure required investments and materials to support Level 3 charging capability



Source: Ducker Q1-2023

THIS CONCLUDES OUR PRESENTATION.
THANK YOU.

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