

A photograph of a hot stamping process in a factory. A glowing orange-red metal sheet is being formed by a large, yellow industrial machine. The machine has several rollers and a pressing arm. The background is dark and industrial.

Hot Stamping Experience and Tech Tour



November 29-30, 2022
Novi, MI

PRODUCED BY



MetalForming
Magazine

R&D Update: Recent Developments in Hot Forming of Steel and Aluminum

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MetalForming Magazine



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Research Engineer

Eren Billur

EREN@BILLUR.COM.TR

After studying in Baskent University and Virginia Commonwealth University, he received his PhD in mechanical engineering from Virginia Commonwealth University at the Center for Precision Forming, where he was responsible for research. His focus is set on comprehensive topics like material characterization, finite element simulations. Dr. Billur worked as an Assistant Professor at Virginia Commonwealth University, between 2014 and 2018. He is now technical manager at two companies, both located in Ankara, Turkey. He has authored several papers (including proceedings) and contributed to four books, "Hot Stamping Steels," published in late 2018.



Have been involved in sheet metal forming since 1989.

Moved to US in 2007 for MS and PhD in mechanical engineering

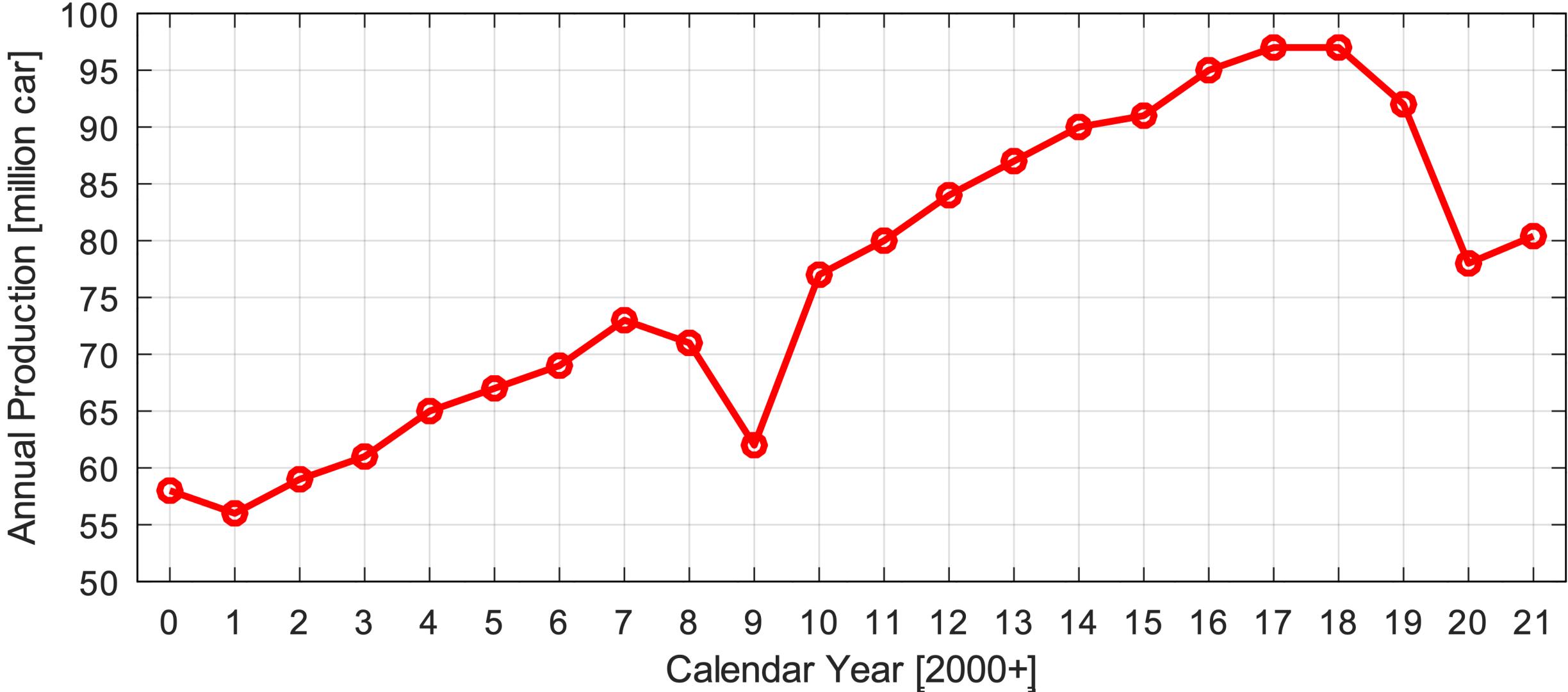
Completed PhD thesis on hot stamping in 2013 – which was later published as a book.

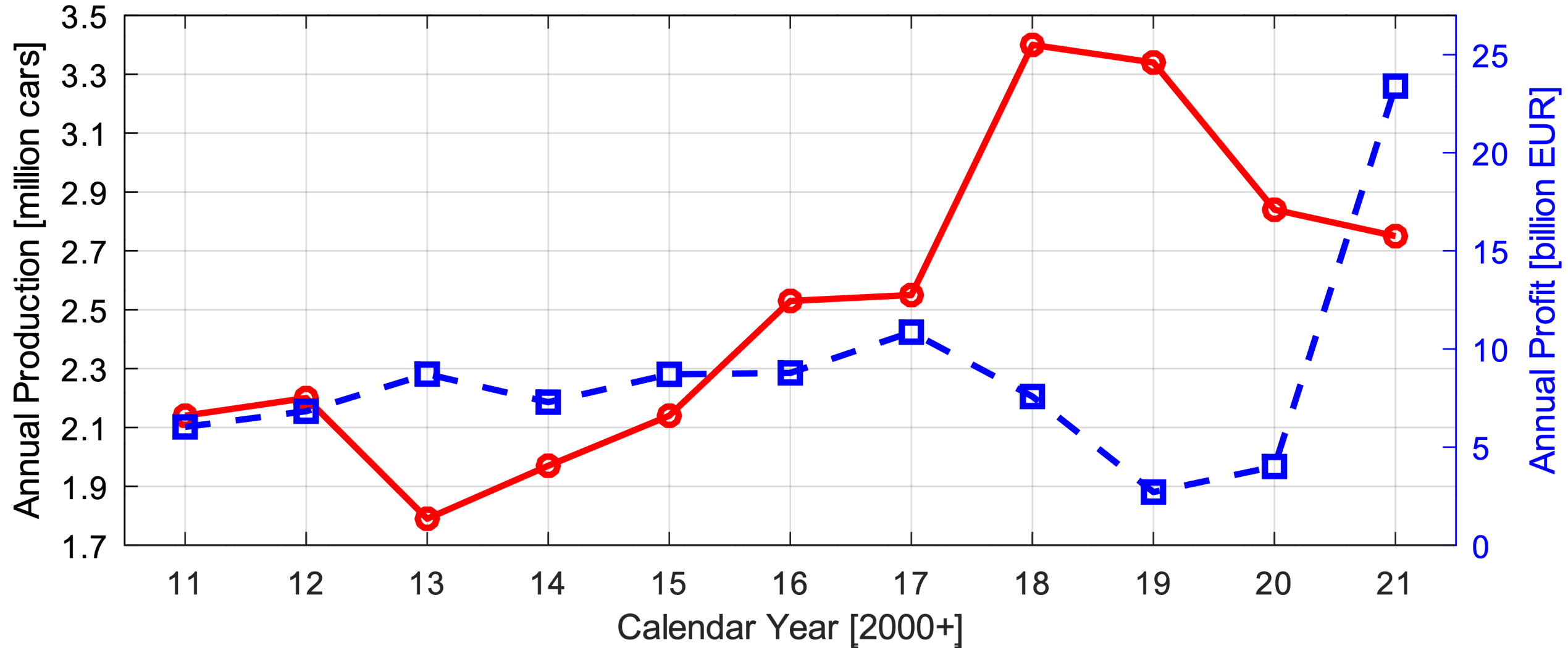
In 2015, established Billur Metal Form, which offers material characterization, simulation, training and consulting services.

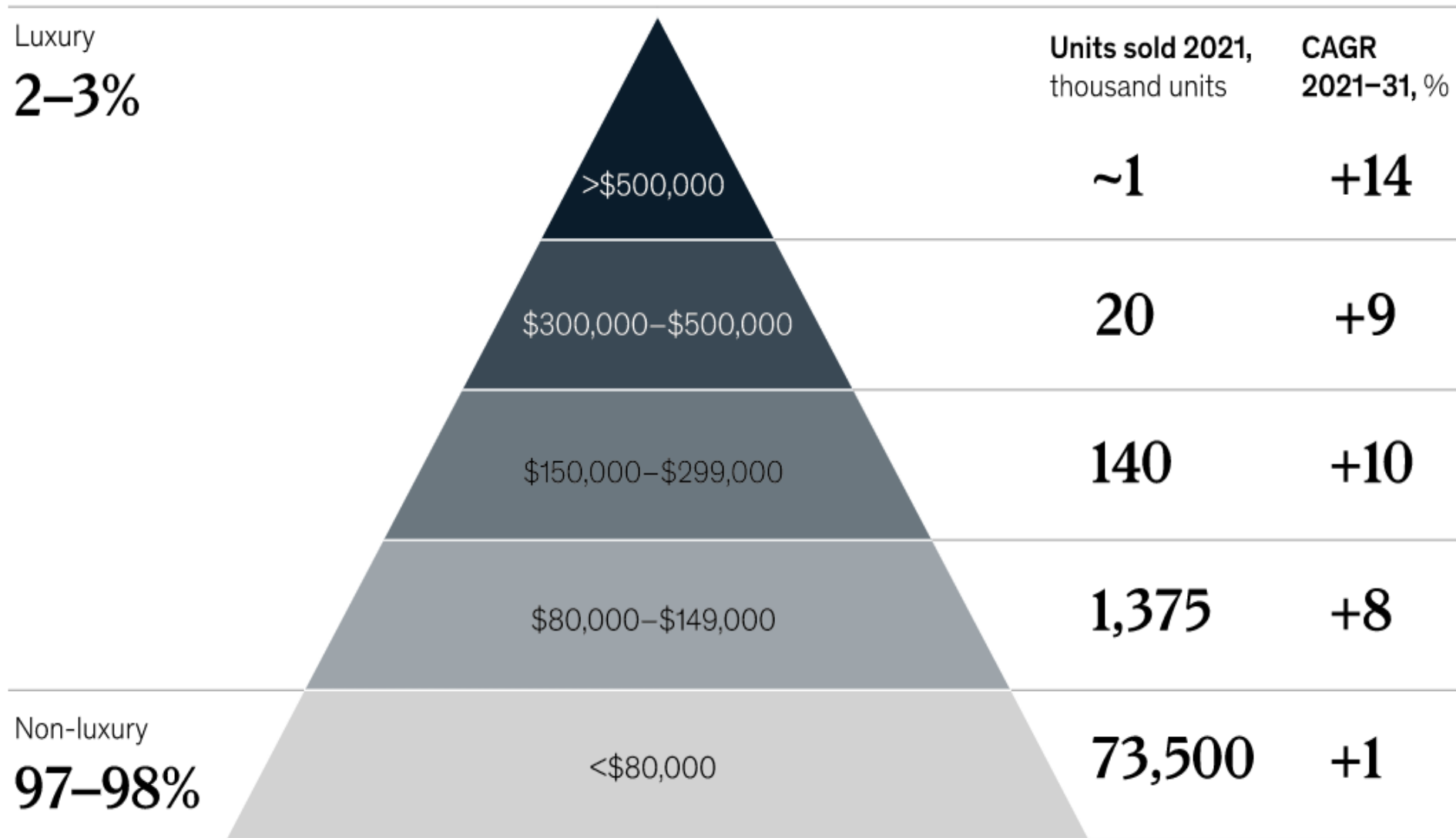
Since 2020, authoring “Cutting Edge” column in Metalforming Magazine.

- Automotive industry – the big revolution and new normal
- Electrification strategies
- New crash requirements
- PHS usage in conventional and modern architectures
- Recent PHS usage
- Competition to PHS
- Industry 4.0

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In 1970's only 5 VW models were offered globally

Billur

Maybe you and a Volkswagen were made for each other.



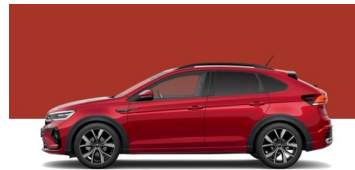
Today there are more than 35, only in Germany **Billur**



up!



Der Polo



Der Taigo



Der T-Cross



Der ID.3



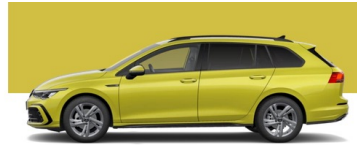
Der ID.4



Der neue ID.5



Der Golf



Der Golf Variant



Der T-Roc



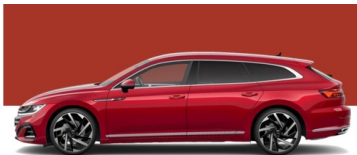
Das T-Roc Cabriolet



Der Touran



Der Arteon



Der Arteon Shooting Brake



Der Sharan



Der Tiguan



Der Tiguan Allspace



Der Passat Variant



Der Touareg



Der neue ID. Buzz



Der neue ID. Buzz
Cargo



Der Caddy



Der Caddy
California



Der Transporter
Kastenwagen 6.1



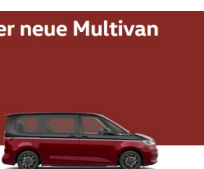
Der Transporter
Pritschenwagen 6.1



Das Crafter
Fahrgestell



Der Grand California



Der neue Multivan



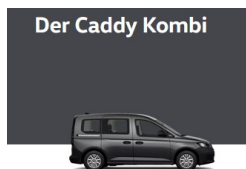
Der Multivan 6.1



Der California 6.1



Der Transporter
Kombi 6.1



Der Caddy Kombi



Der Caddy Cargo



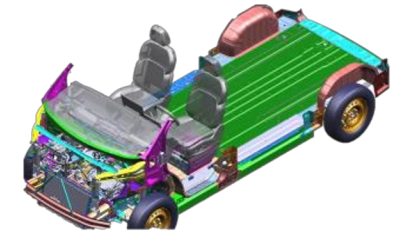
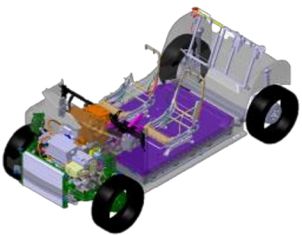
Taxi /
Funkmietwagen



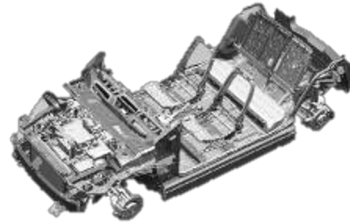
Der Caravelle 6.1

Modular (scalable) platforms since 2012

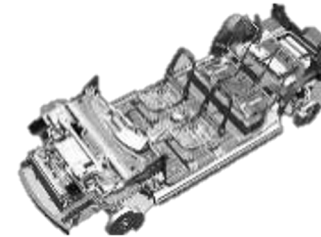
Modular platforms allow small city cars, compact and mid-size cars, people mover shuttles and crossover utility vehicles on single platform!



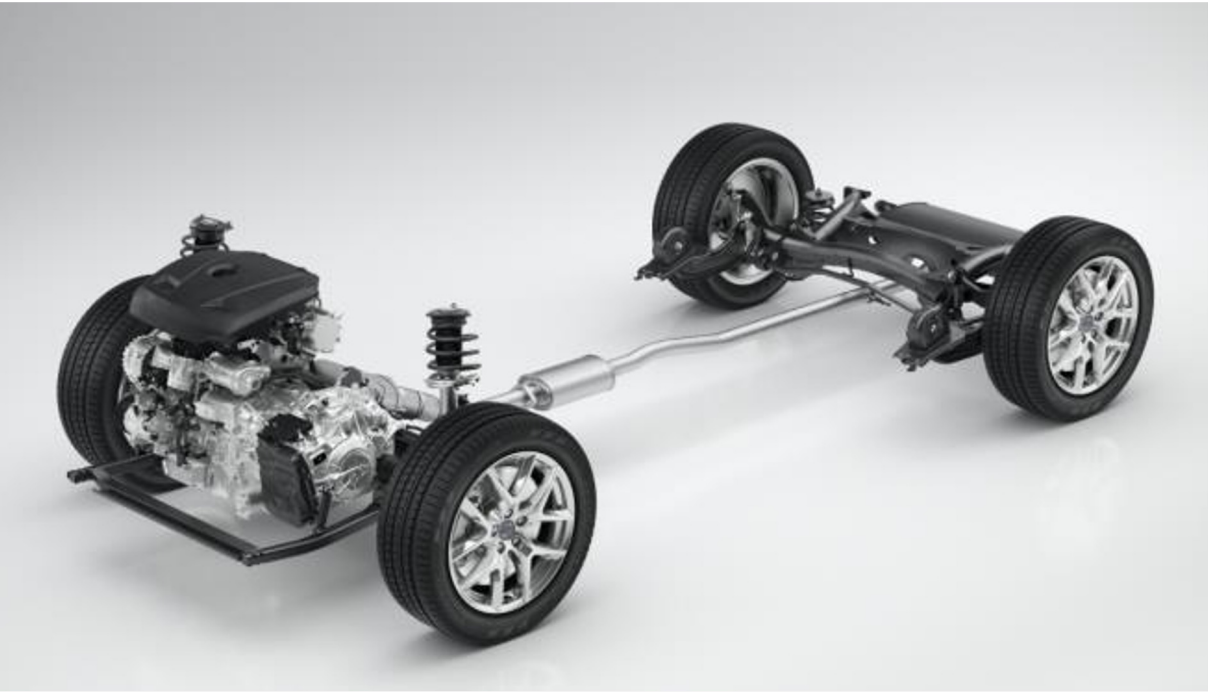
Van



Shuttle



- Automotive industry – the big revolution and new normal
- **Electrification strategies**
- New crash requirements
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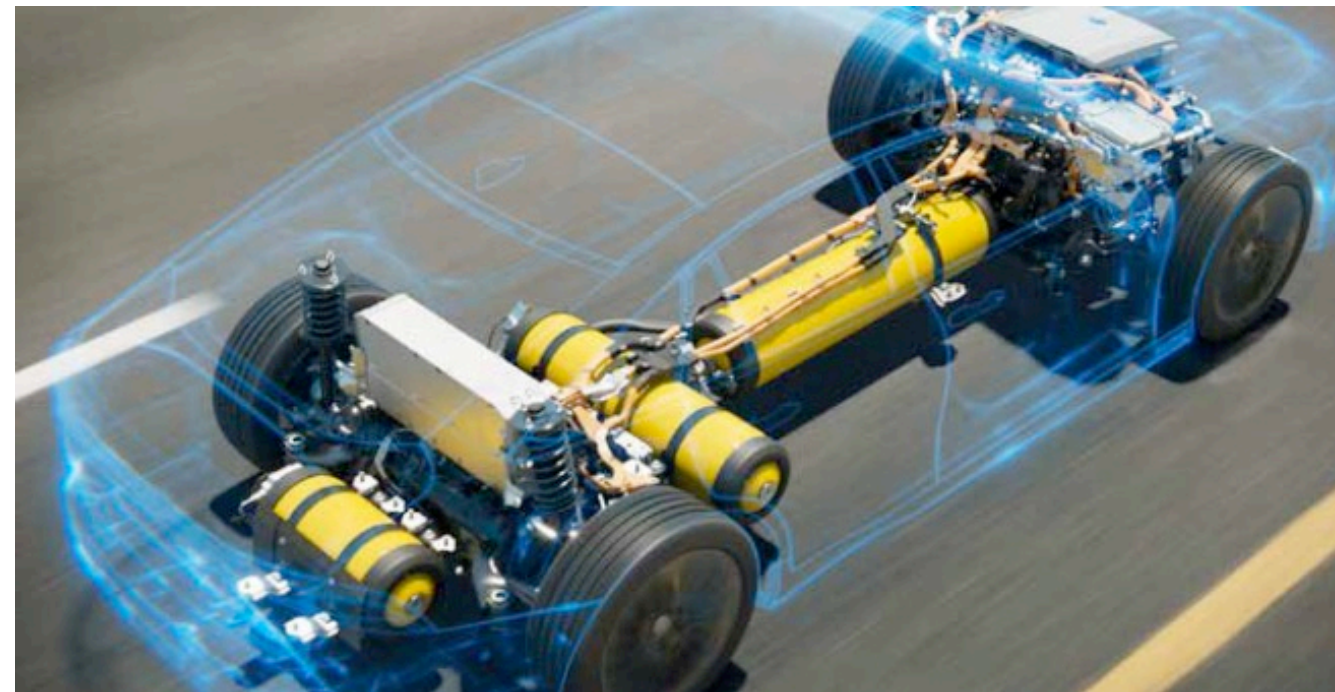
ICEV – Internal Combustion Engine (Petrol / Diesel). Currently the dominant one. Losing its dominance and share.



HEV or PHEV – (Plug-in) hybrid electric vehicle. Favored for longer range and higher efficiency. Requires both ICE and electric components, making them heavy and expensive.

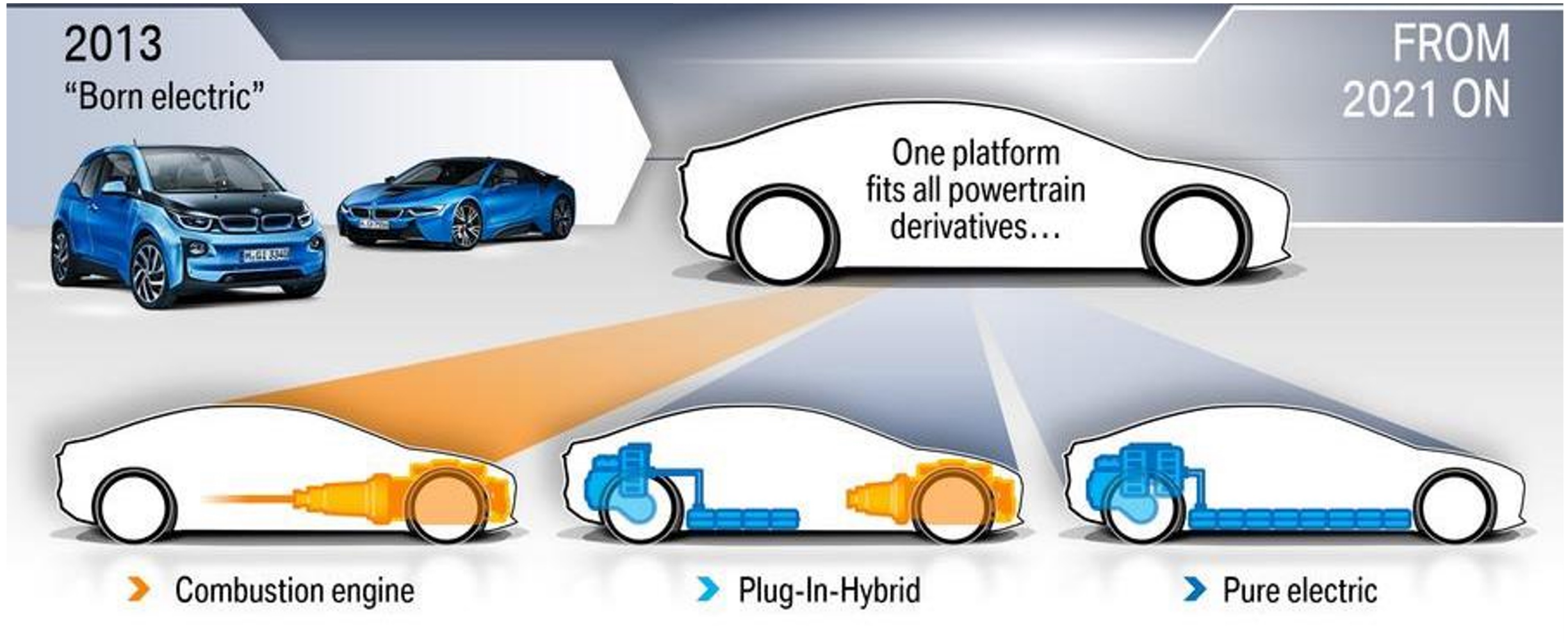


BEV – Battery electric vehicles. Currently the most efficient powertrain. Range, charging infrastructure, battery supply, high cost slow down their rapid increase. Range extenders were tried but did not become successful.



FCEV – Fuel Cell Electric Vehicles. Currently only 3 OEM's offer 1 model each. (Green) Hydrogen production, infrastructure and car packaging are problems.

Two electrification strategies



Separate EV Line-up

All Vehicles



In 2021, you had 16 ICE models to choose in BMW.
Your only PHEV option was i8,
Your only BEV option was i3.

In 2022, if you want to buy a compact VW:
Your ICE option is Golf
Your BEV option is ID.3

Choose your own powertrain



Volvo started XC40 production in 2017. This is a small SUV, available with 3- and 4-cylinder petrol and diesel engines.

1570 – 1770 kg
3460 – 3900 lbs



In 2019, the twin engine T5 recharge model is introduced. This is a Plug-in hybrid with 3-cylinder petrol engine and electric motor.

1810 kg (+240 kg on 3-cyl.)
3990 lbs (+530 lbs on 3-cyl.)



Since 2020, P8 Recharge is offered as a full electric car.

2030 – 2190 kg (FWD – AWD)
4475 – 4830 lbs

Choose your own powertrain



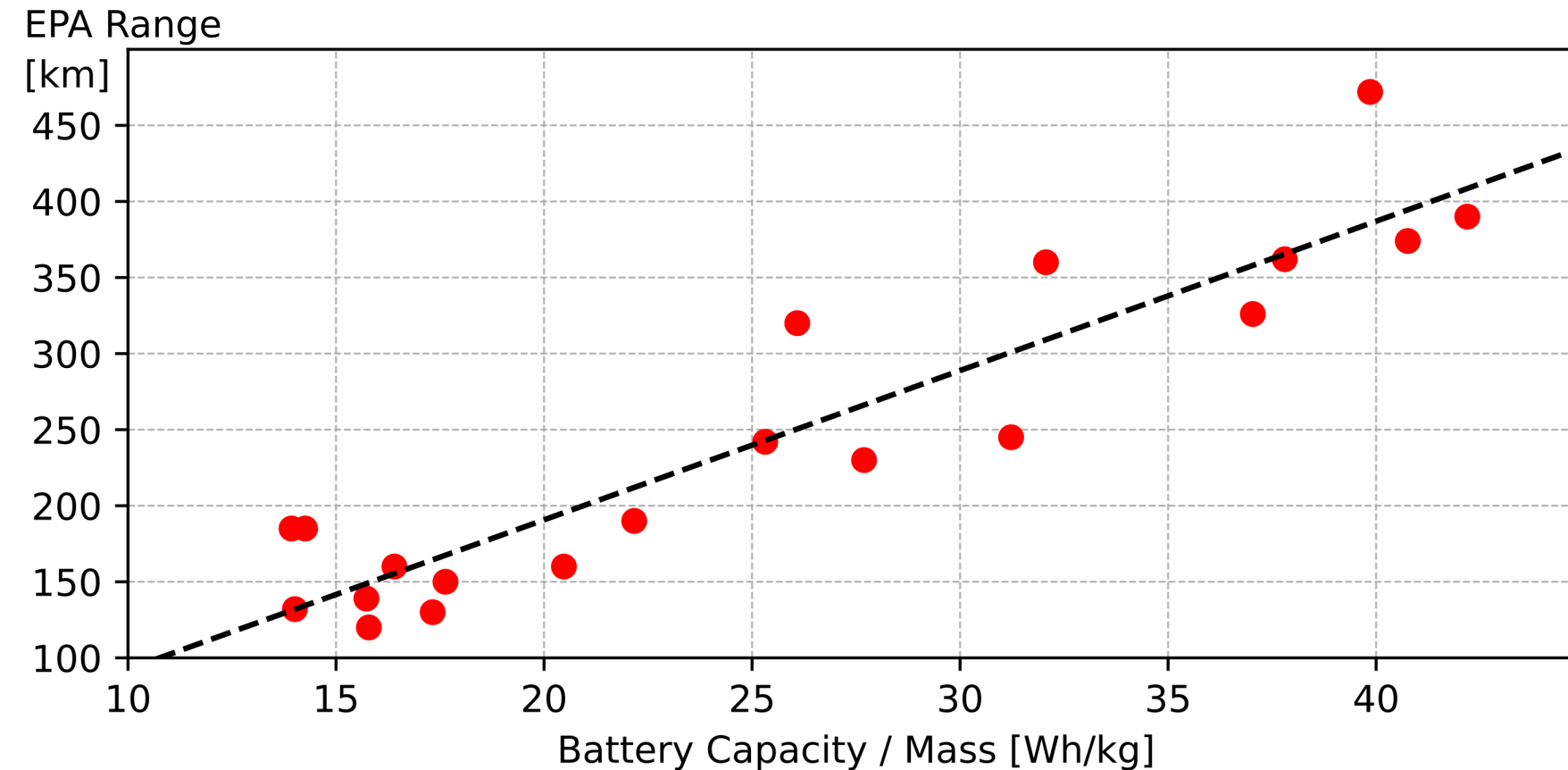
Billur

	735i ⁽¹⁾	740i ⁽¹⁾	760i xDrive ⁽¹⁾	740d xDrive	750e xDrive	M760e xDrive	i7 xDrive60
Bauzeitraum	ab 11/2022			ab 03/2023			ab 11/2022
Motorart	Ottomotor			Dieselmotor	Ottomotor + Elektromotor		2 Elektromotoren
Motorbauart	R6		V8	R6			—
Gemischaufbereitung	Benzindirekteinspritzung			Common-Rail-Einspritzung	Benzindirekteinspritzung		—
Aufladung	Twin-Scroll-Turbolader		zwei Twin-Scroll-Turbolader	Twin-Scroll-Turbolader			—
Motortyp	BMW B58		BMW S68	BMW B57	BMW B58		—
Hubraum	2998 cm³		4395 cm³	2993 cm³	2998 cm³		—
max. Leistung bei 1/min	210 kW (286 PS)/ 5000–6500	280 kW (380 PS)/ 5200–6250	400 kW (544 PS)/ 5500	220 kW (299 PS)/ 4000	360 kW (489 PS)/ 5000–6500	420 kW (571 PS)/ 5200–6250	400 kW (544 PS)
max. Drehmoment bei 1/min	425 Nm/ 1750–4500	540 Nm/ 1850–5000	750 Nm/ 1800–5000	670 Nm/ 1750–3000	700 Nm/ 1750–4700	800 Nm/ 5000	745 Nm
Getriebe, serienmäßig	8-Stufen-Automatikgetriebe ⁽²⁾						Zweistufiges Ein-Gang-Getriebe
Antrieb, serienmäßig	Hinterradantrieb		Allradantrieb xDrive				Elektrischer Allradantrieb xDrive
Leergewicht nach EU in kg	2150	2165	2345	2255	2455	2525	2715

EV Weight Spiral



More PHS or Hot Formed AI Required



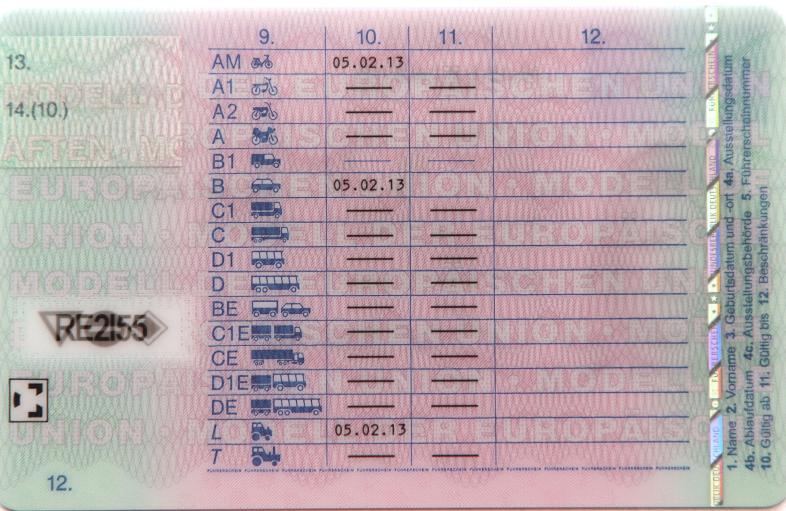
Longer range requires larger capacity battery

Larger capacity batteries weigh more

Chassis, brakes and the body have to be modified

More mass introduced reduces the range

Several EV Weight Problems in EU



Without a commercial license you can only drive:
8 passengers + 1 driver
3,500 kg (7,700 lbs) GVW

Since 2019 the limit is revised to 4,250 kg (9,400 lbs)
only for Alternative Fuel Vehicles.



Mercedes-Benz eSprinter has two versions:

Battery [kWh]	Range	Payload
41	120 km / 75 mi	1,045 kg / 2,300 lbs
55	168 km / 105 mi	891 kg / 1,960 lbs

Similar options can be found in Fiat e-Ducato,
Opel Vivaro-e, Toyota Proace Electric.
Arrival will have 4 different battery/payload options.

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Heavier cars – IIHS Roof Strength



Peak Force = 19,949 lbs (9,057 kgf)

Weight = 3,811 lbs (1730 kg)

SWR = 5.23 > 4.00 **Good**

Summary:
17% higher peak force
7% less SWR



Peak Force = 23,312 lbs (10,583 kgf)

Weight = 4,787 lbs (2170 kg)

SWR = 4.87 > 4.00 **Good**

Heavier cars – EuroNCAP Full Frontal



2020 ★★★★★

Honda JAZZ

Small Family Car



2020 ★★★★★ ☆

Honda e

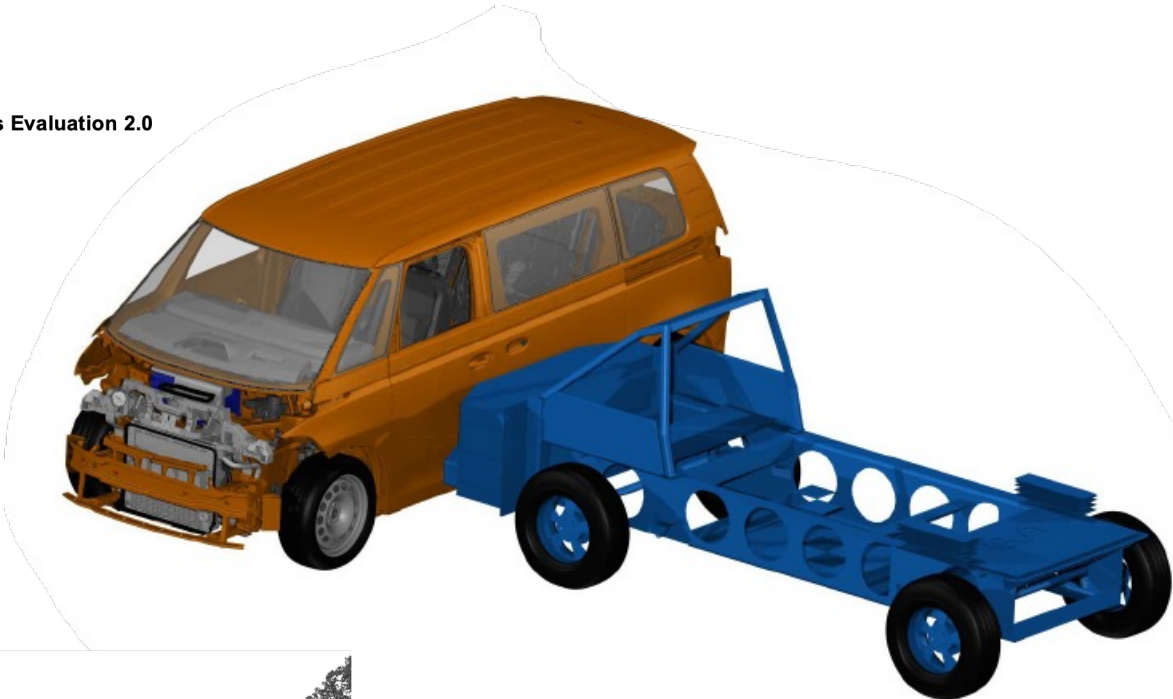
Small Family Car

More PHS or Hot Formed AI Required

New crash requirements



Side Impact Crashworthiness Evaluation 2.0
Crash Test Protocol
Version II
October 2022



Years	Pre-2020	Post-2020	
Speed	50	60	km/h
	31.3	37.5	MPH
Mass	1,300	1,400	kg
	2,860	3,080	lbs
Energy	125	194	kJ
	100%	155%	

IIHS

Insurance Institute for Highway Safety
988 Dairy Road
Ruckersville, VA 22968
researchpapers@ihs.org
+1 434 985 4600
ihs.org



More PHS or Hot
Formed AI Required

Years	Pre-2021	Post-2021	
Speed	50	60	km/h
	31.3	37.5	MPH
Mass	1,500	1,900	kg
	3,300	4,185	lbs
Energy	145	264	kJ
	100%	182%	

New crash requirements



A small EV in Europe
(Similar size of Honda Fit or Ford Fiesta HB in US)



2013 ★ ★ ★ ★ ★

Renault ZOE

Supermini

✗ Rating Expired



2021 ☆ ☆ ☆ ☆ ☆

Renault Zoe

Supermini



More PHS or Hot
Formed AI Required

New crash requirements

2022 Chevrolet Malibu

MIDSIZE CAR / 4-DOOR SEDAN



Crashworthiness

Small overlap front: driver-side

G

Moderate overlap front

G

Side: original test

G

Side: updated test

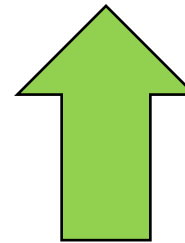
P

Roof strength

G

Head restraints & seats

G



More PHS or Hot
Formed AI Required

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Unibody

Longitudinal front engine

Transverse front engine

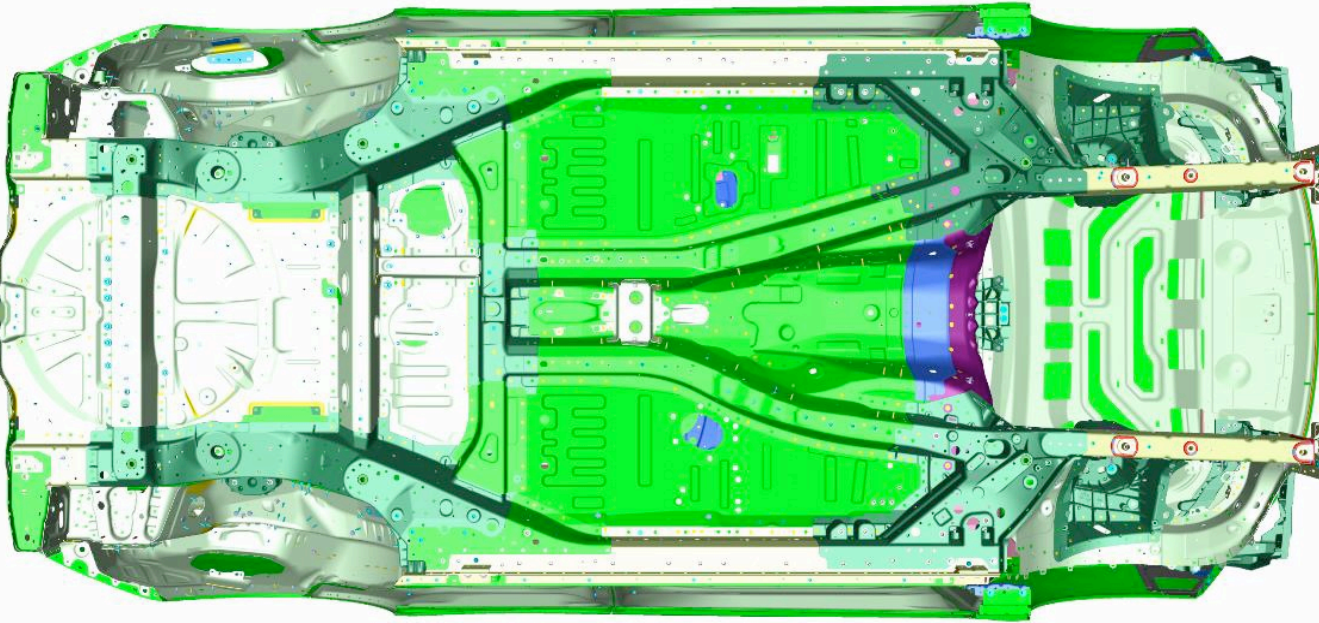
Rear engine

Body-on-frame

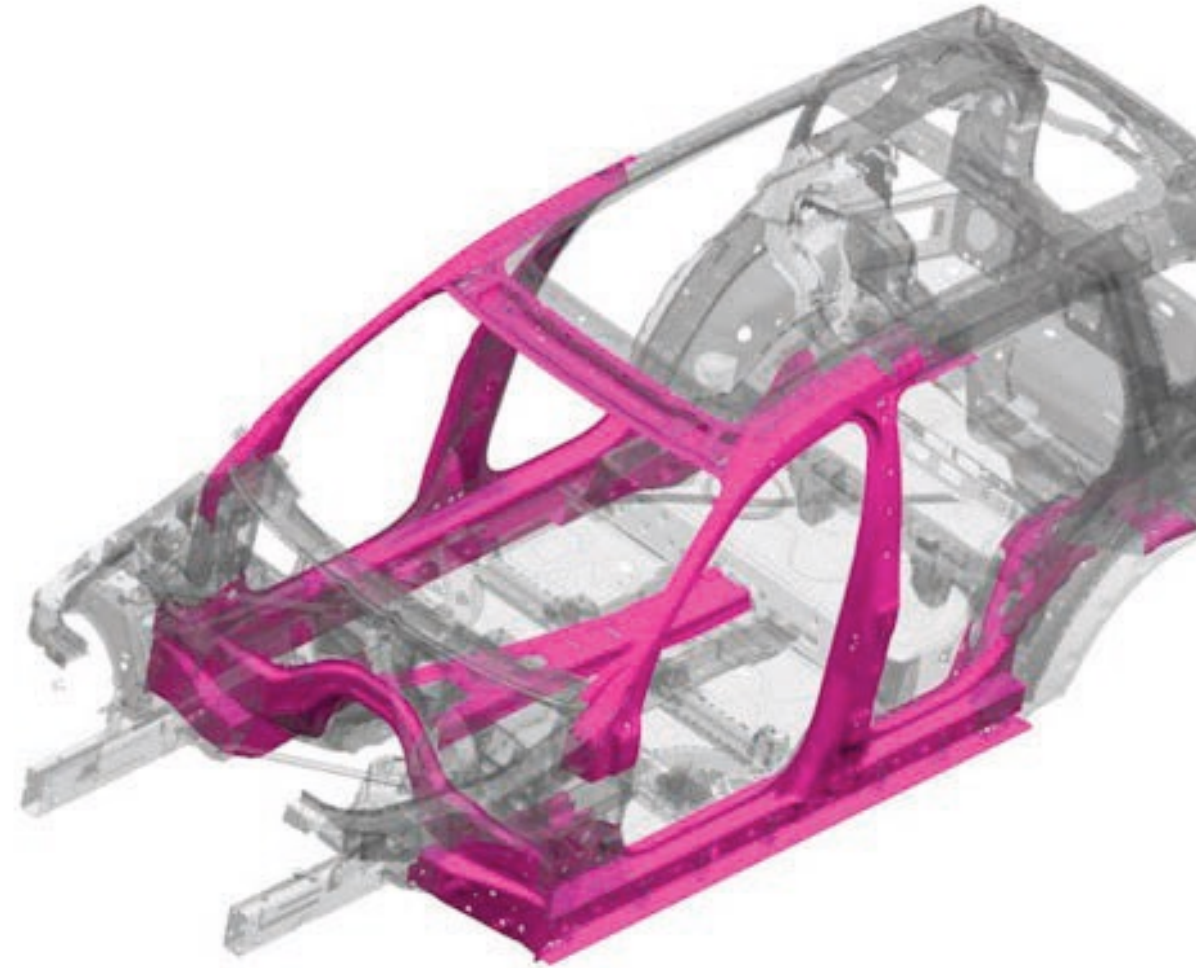
Pick-up truck

SUV

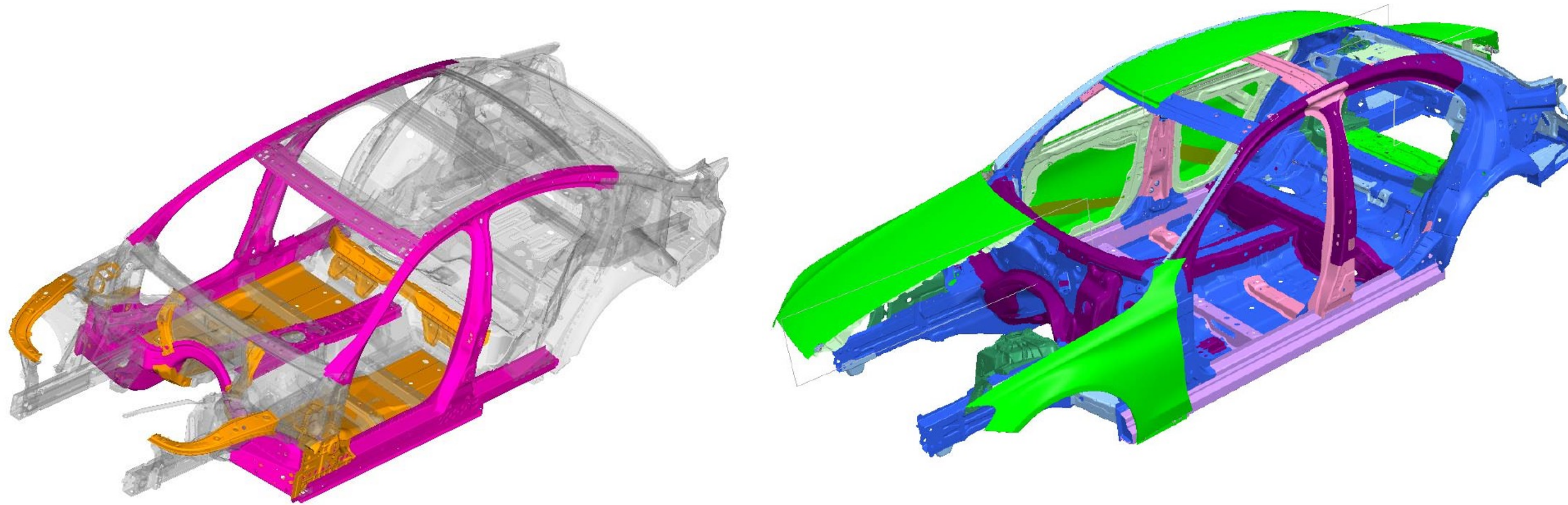
Longitudinal front engine



Longitudinal engine can move inside the passenger cabin and must be stopped.
Significant PHS is used in the firewall area.

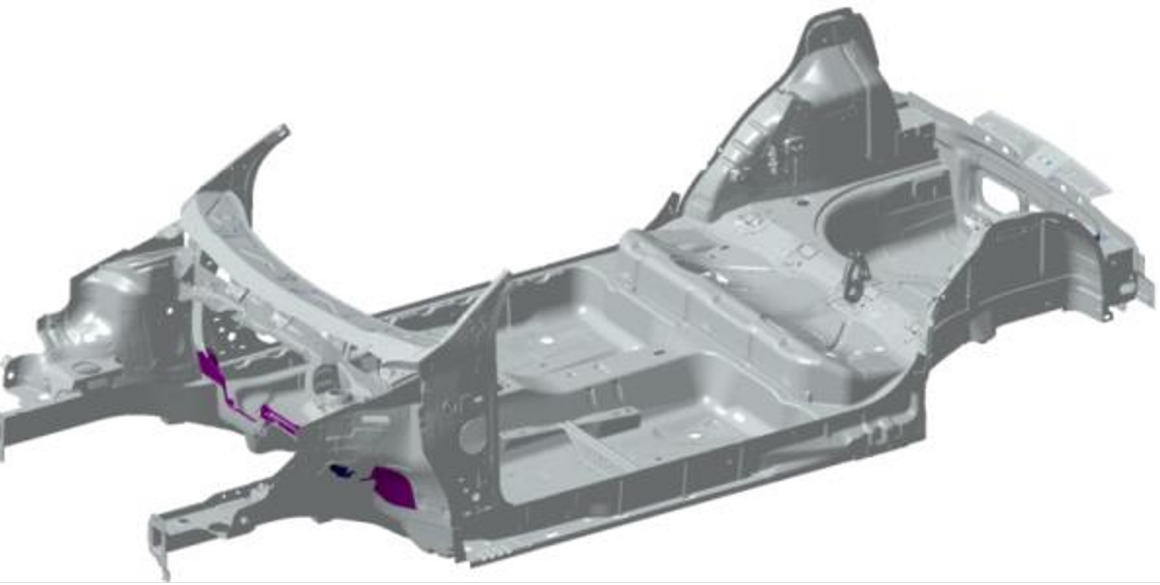


Longitudinal front engine

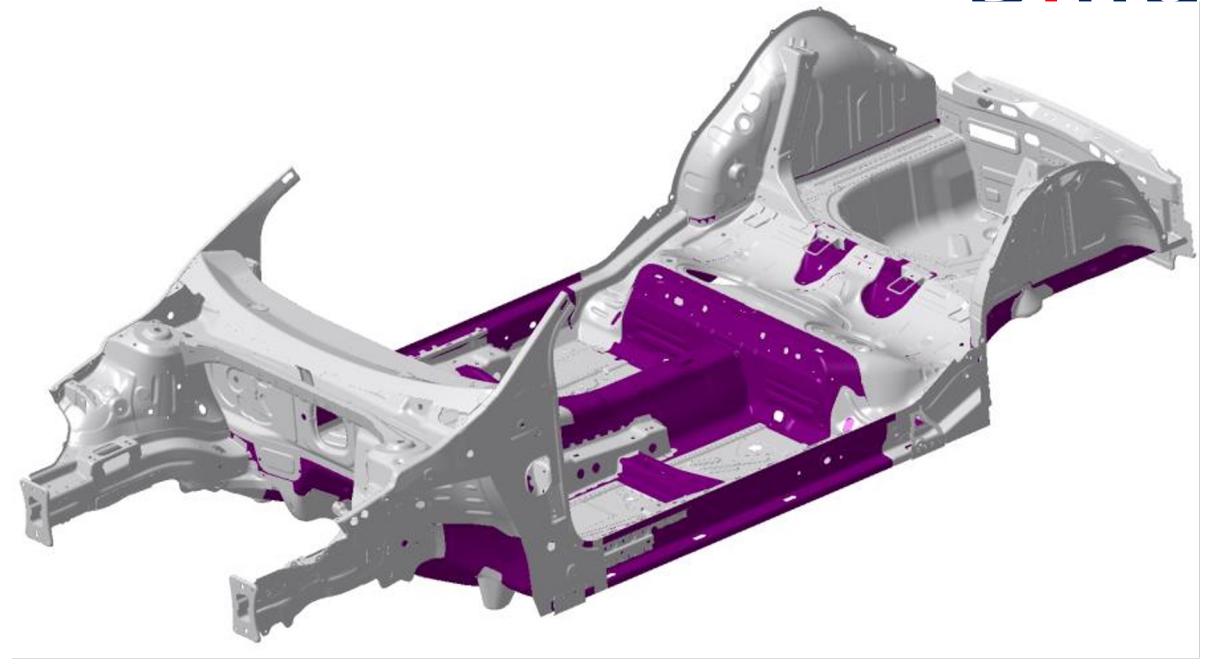


In addition to front; rear and side impact paths are also strengthened with PHS.
Most cars have 8-23% PHS by weight.

Transverse front engine

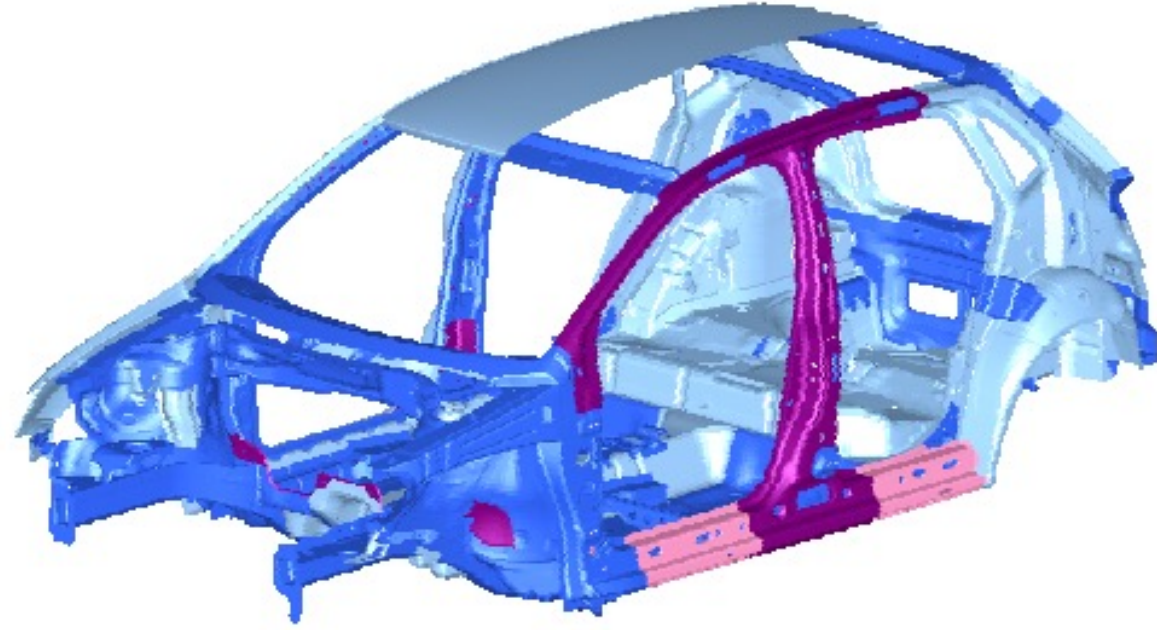


Platform used in VW Polo V (2010-2017)
Only had 2% PHS in the entire underbody.

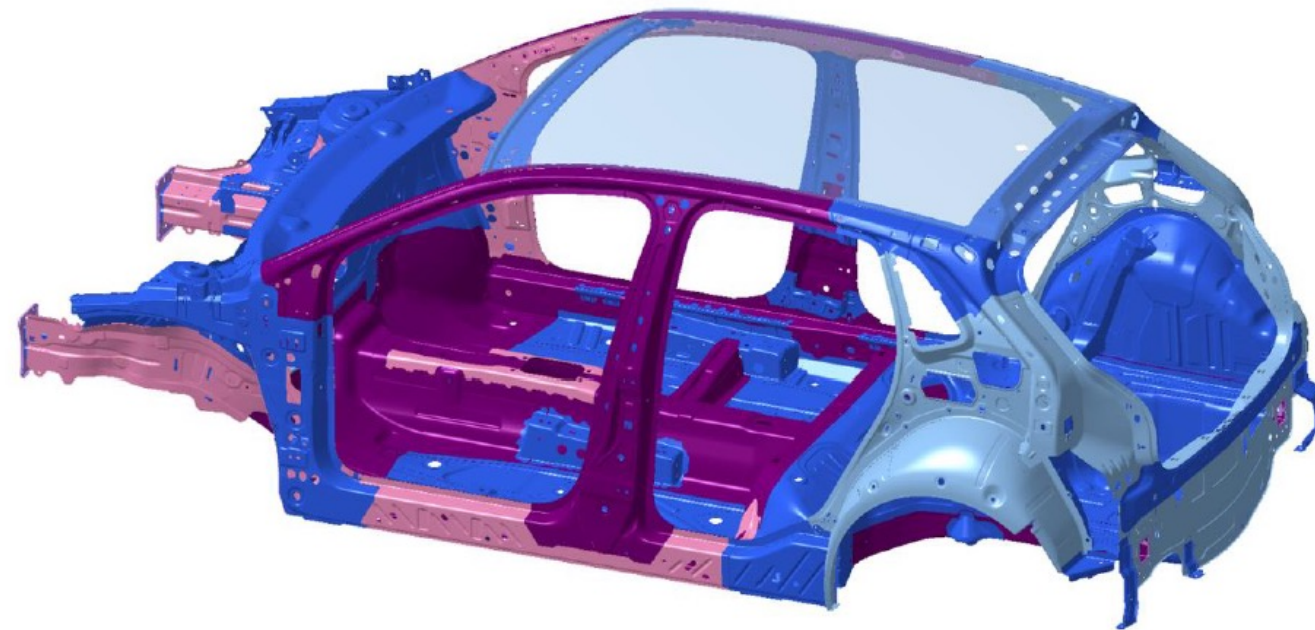
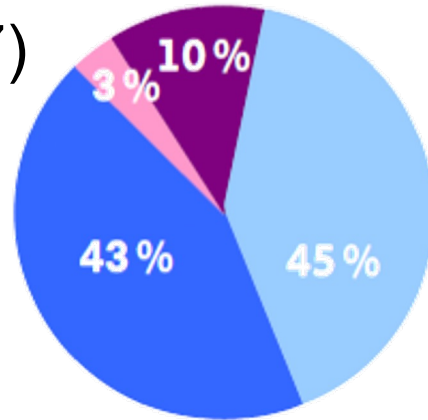


The first mega-platform MQB has 34% PHS
in underbody (seen here is 2017 Polo VI)

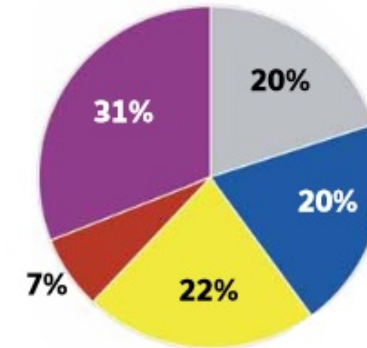
Transverse front engine



VW Polo V (2010-2017)
had 10% PHS



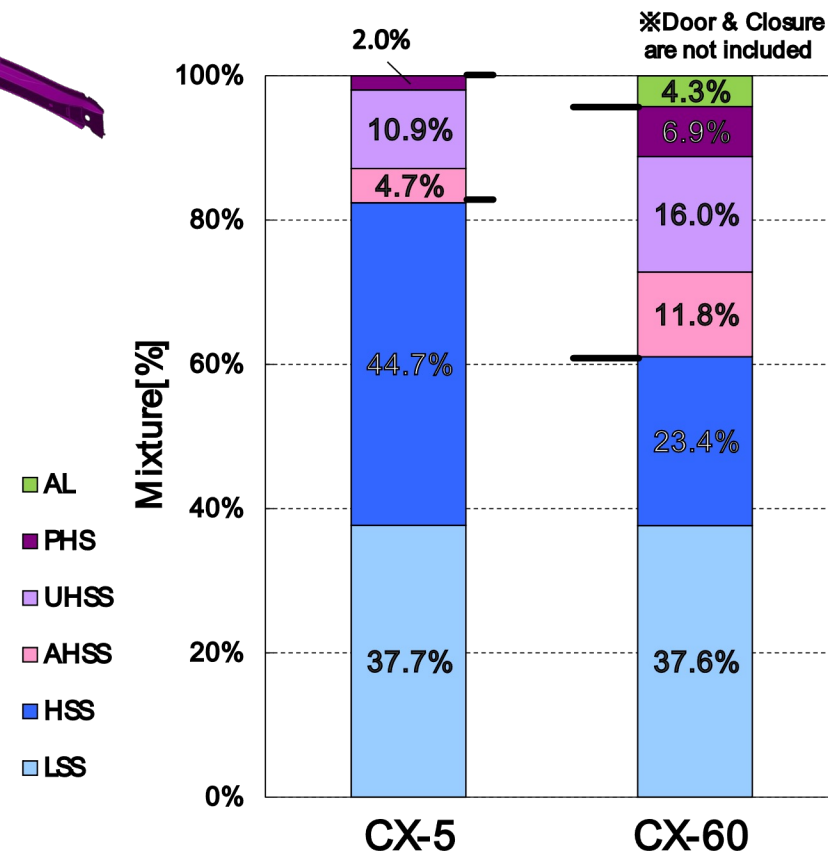
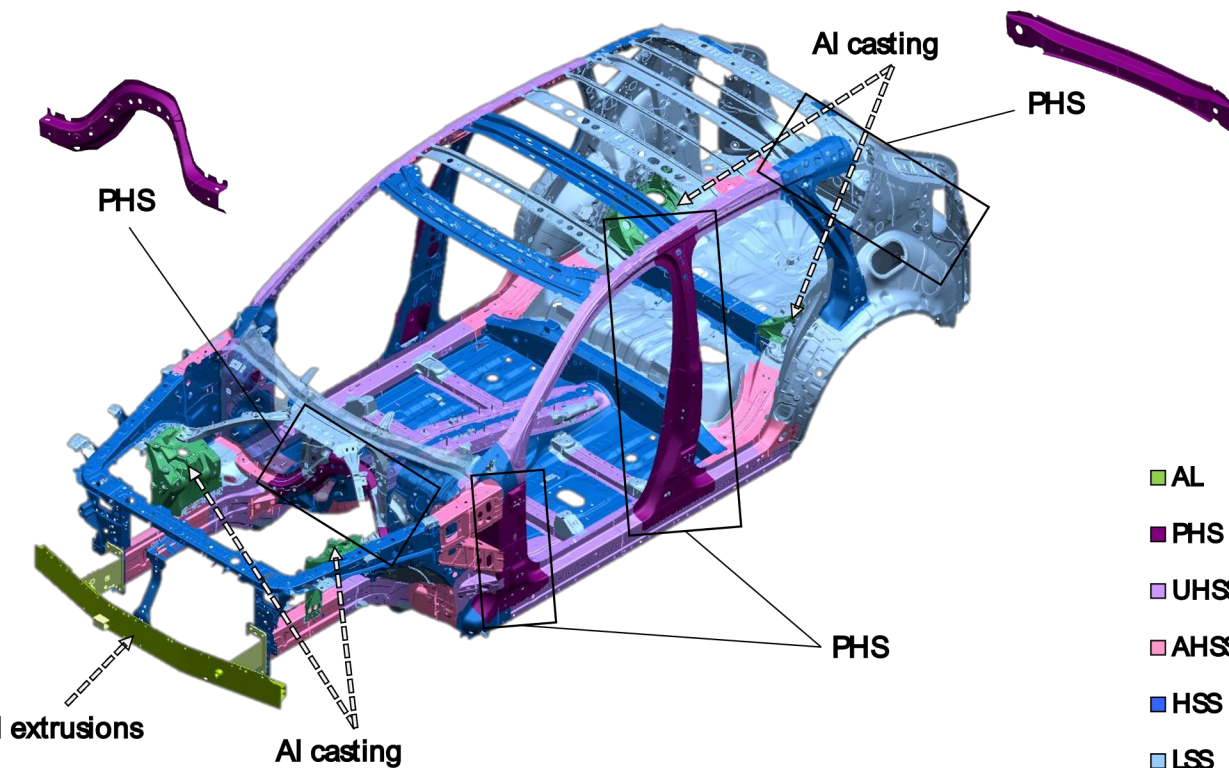
VW Polo VI has over 30% PHS by weight



Transverse front engine

There are still some transverse front engine cars that have very low PHS content. These are typically:

- 1) Budget oriented cars, or
- 2) Instead of PHS, high use of AHSS is realized (especially in Japan)



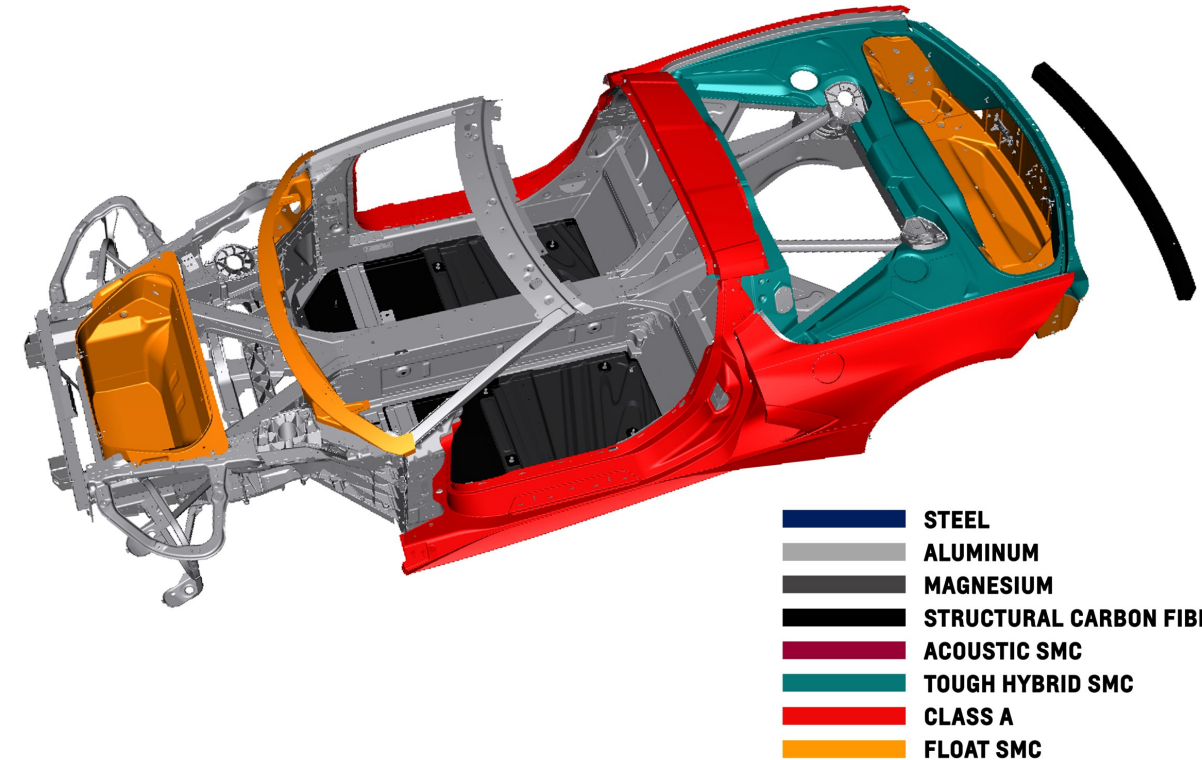
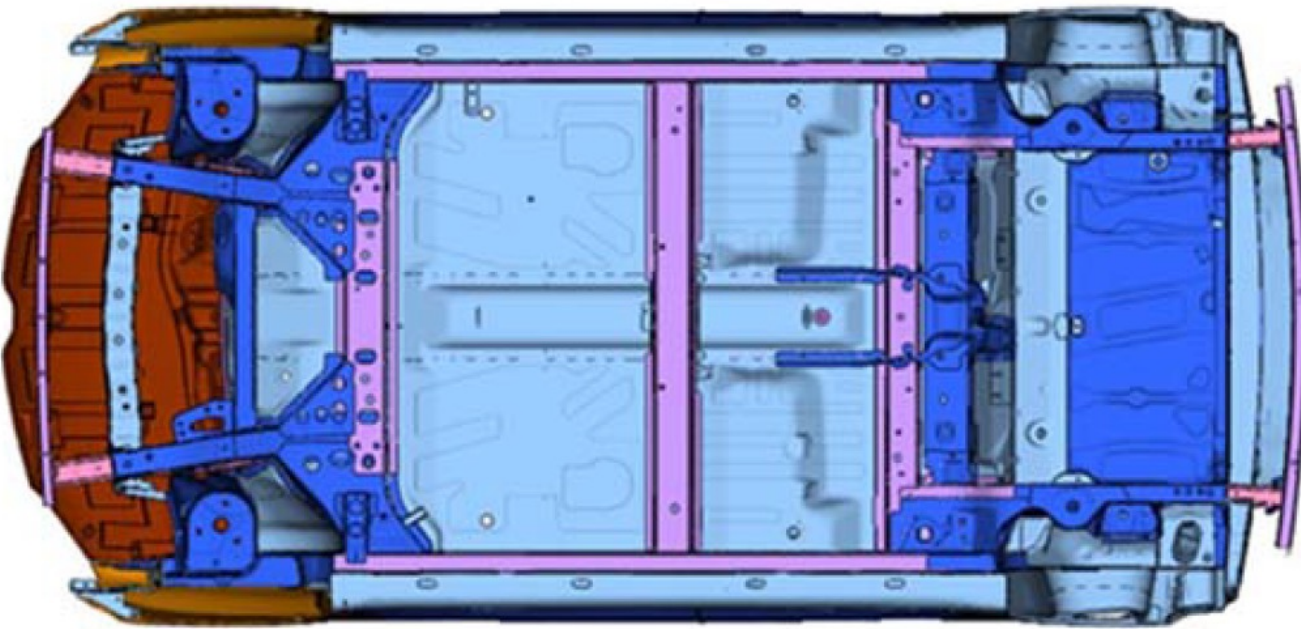
Transverse front engine



Still one of the highest PHS+PQS usage is at 2nd Gen. Volvo XC90 (2014-Present)

33% PHS1500
5% PQS500
(not shown here)

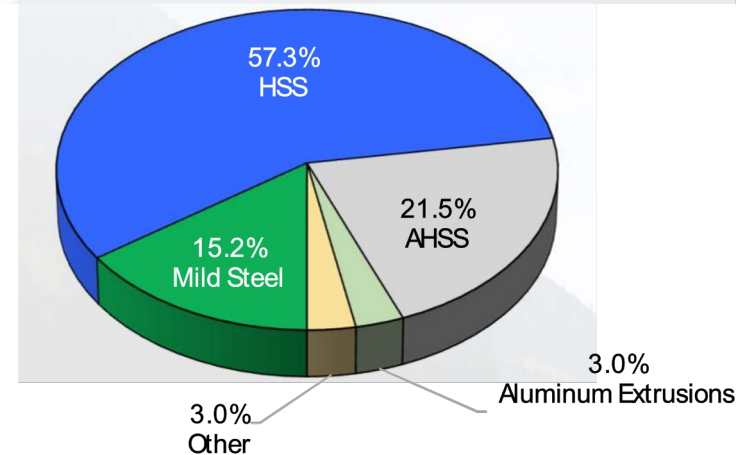
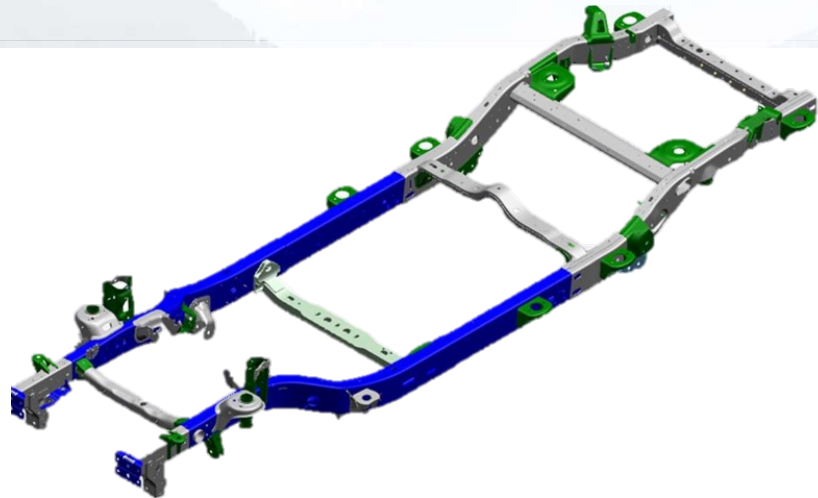
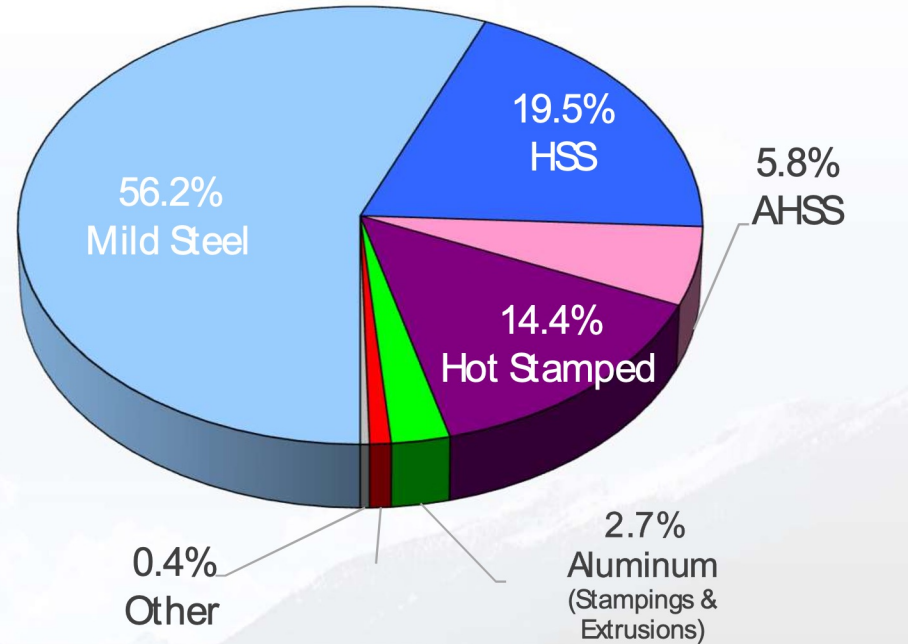
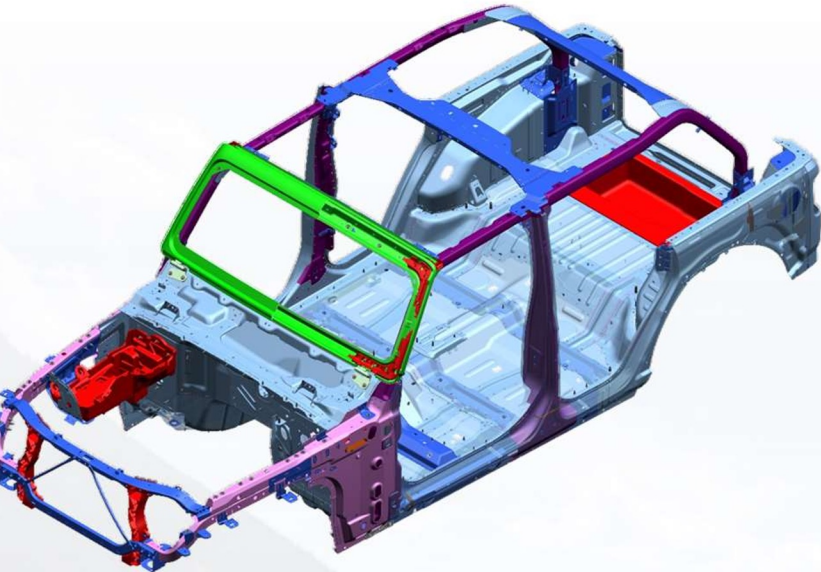
Rear engine



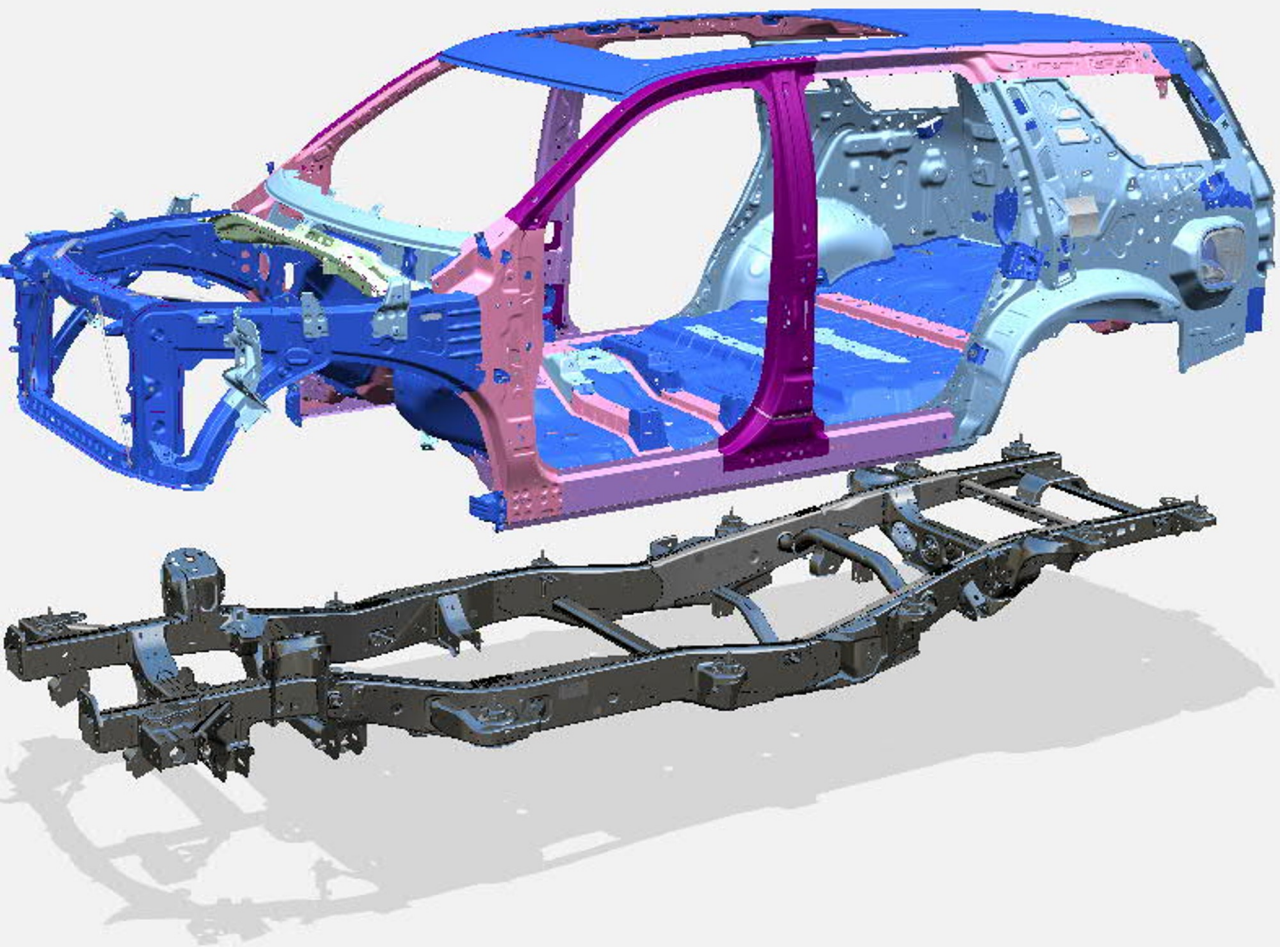
2 Uses:

- 1) Budget oriented city cars (i.e., Smart ForTwo), or
- 2) High performance cars (i.e., Chevrolet Corvette). Neither of them has high usage of PHS.

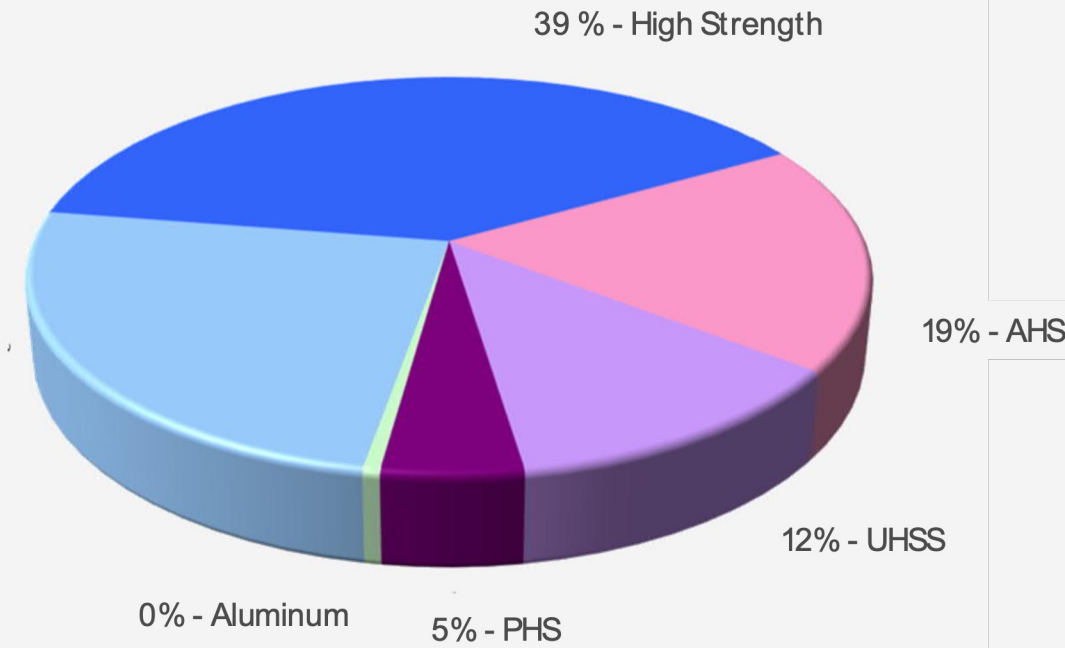
Body-on-frame SUV



Body-on-frame SUV

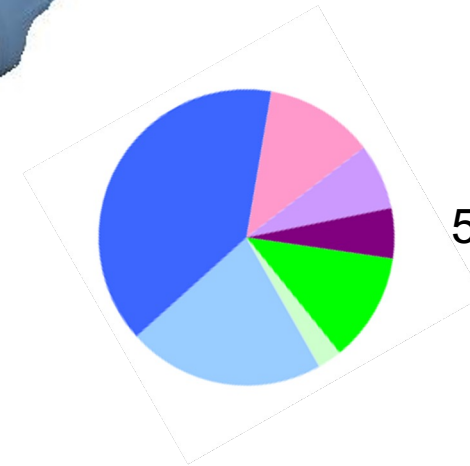


25% - Mild



Body-on-frame pick-up

2018 Chevy Silverado



Unibody

Body-on-frame

Exo-Skeleton?

Exo-Skeleton Body Design



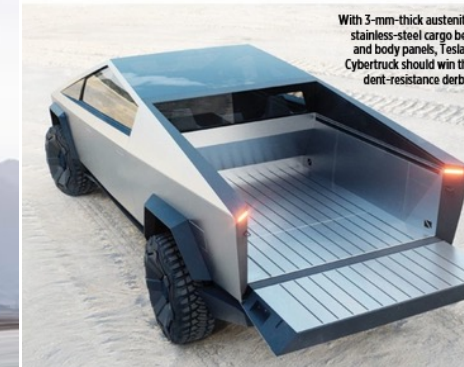
May end the use of PHS?

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LIGHTWEIGHT METALS

Tesla's Cybertruck is audaciously austenitic

STAINLESS STEEL | MATERIALS FEATURE



With 3-mm-thick austenitic stainless-steel cargo bed and body panels, Tesla's Cybertruck should win the dent-resistance derby.

A proprietary 301-series stainless steel gives Tesla's first pickup truck unique sales attributes while saving tooling cost.

by Lindsay Brooke



In the 1960s, Edgcomb Steel contracted Autocar Trucks to build 17 road tractors in bright stainless to promote its primary product line. The 302-alloy sheet was sourced from Armco Steel. The nine stainless Autocars surviving today are prized by collectors, including this one owned by the Iowa-80 Truck Museum.

Not since Ford's epic switch to aluminum for its F-Series body structures has an automaker's materials strategy created such a buzz. Tesla's decision to use stainless steel for its upcoming Cybertruck, as part of what CEO Elon Musk calls an "exoskeletal" architecture, aims to give the new electric pickup strength and durability beyond that of its competitors. The vehicle is slated to enter production in late 2021.

Musk described the corrosion-resistant, 3-mm-thick (.118-in) sheet specified for Cybertruck as "ultra-hard 30X cold-rolled stainless-steel," indicating an alloy variant developed from 300-series stainless steel. This popular class was used by DeLorean (304 alloy) in its roughly 10,000 DMC-12 sports cars, and by heavy-truck maker Autocar (302 alloy) in a small-volume run in the 1960s. During the same period Ford also experimented with a few stainless-bodied Thunderbirds and Lincolns, also in 302 alloy. Today's exhaust pipes typically use ferritic stainless tube.

"Tesla's strategy with this truck is very interesting," observed Dr. David Matlock, professor emeritus at the Colorado School of Mines' Advanced Steel Processing and Products Research Center. Reviewing Musk's public comments on Cybertruck online, Matlock surmises that the material is "very likely a modified version of the lean-alloyed 301 austenitic 301 alloy." When this alloy system is deformed or cold-worked, it transforms into a microstructure that includes austenite and martensite, primary constituents for a strong and tough metal.

"The more you deform it, such as cold rolling, the more martensite you get. And that contributes to a significant increase in strength," he explained. Martensitic high-strength (non-stainless) steels are increasingly used in vehicle structures to increase strength, but they achieve their hardness through heating and quenching as is done in press hardened steel used in automobiles today. By comparison, the lean austenitic stainless alloys can create martensites by cold-roll-induced transformation at room temperature, Matlock noted.

But while Tesla's proprietary 30X-alloy stainless skin may endow

Cybertruck with industry-leading dent resistance, the material spec and the exoskeleton design force tradeoffs. "Cold rolling makes this material very strong but sacrifices ductility and formability. That means a minimum subsequent metal forming is possible and dictates mostly flat panels and straight character lines," Matlock said. The truck's faceted outer body contributes to the strength of the vehicle structure, unlike a conventional body-in-white whose strength comes from controlling the A- and B-pillar geometries and using combinations of press-hardened steels.

As a result, the Tesla truck's polarizing "planar" styling is either Blade Runner-cool or high-school-metal-shop crude, depending on your aesthetic sense.

The material characteristics and robust 3-mil sheet thickness (typical steel door panels are on the order of 0.7mm to 1mm) spurred Musk to claim that the "ultra-hard 30X" can break a stamping press. Hyperbolic or not, Tesla has engineered a material and manufacturing solution that requires minimal forming operations, enabling huge potential savings in presses, dies and related operations for its radical new pickup. ■

FROM LEFT: TESLA; IOWA-80 TRUCK MUSEUM

AUTOMOTIVE ENGINEERING

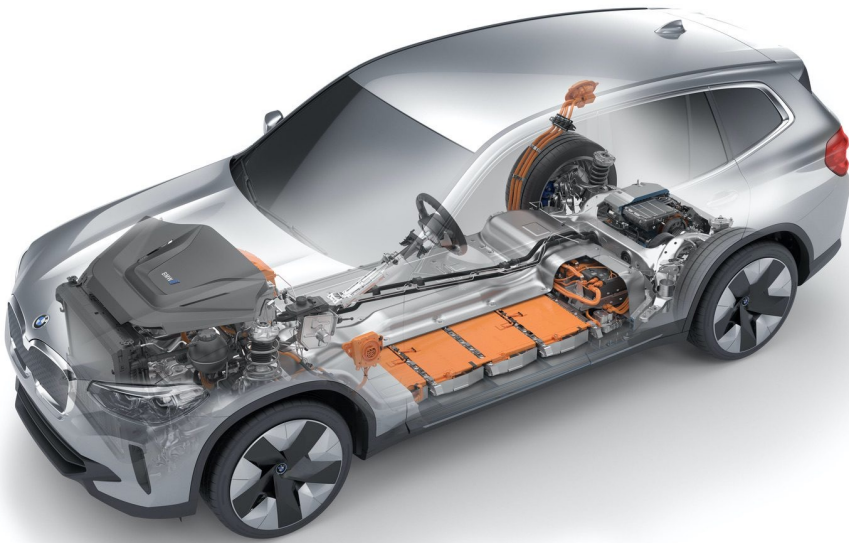
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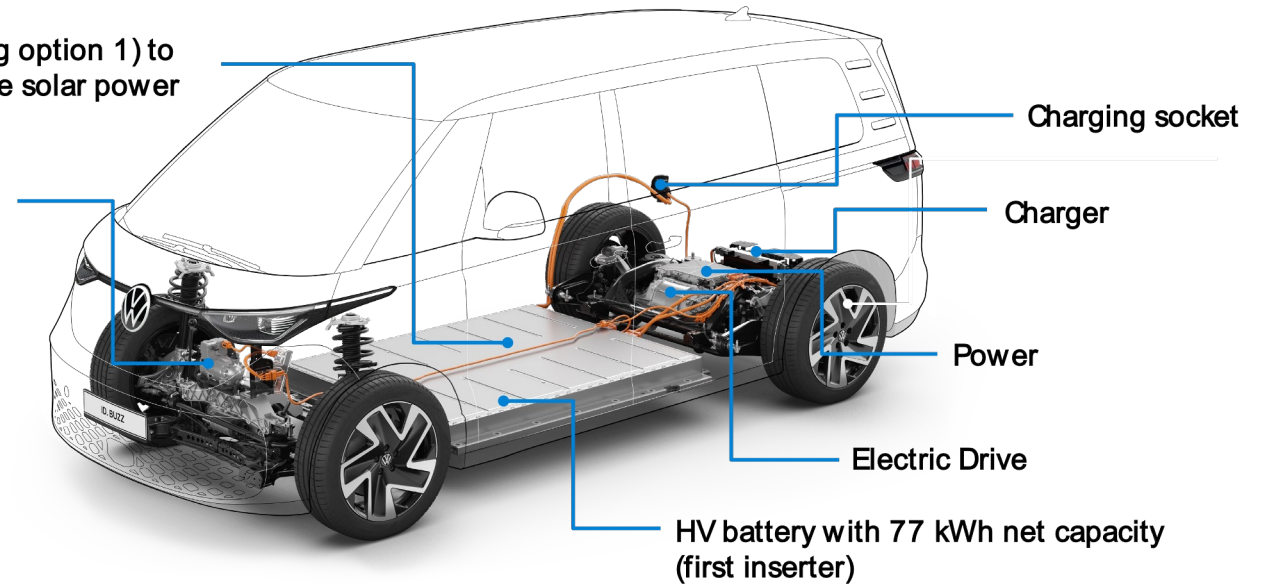
November 29-30, 2022 | Novi, MI

The common architecture is now challenged



BiDi DC charging option 1) to temporarily store solar power

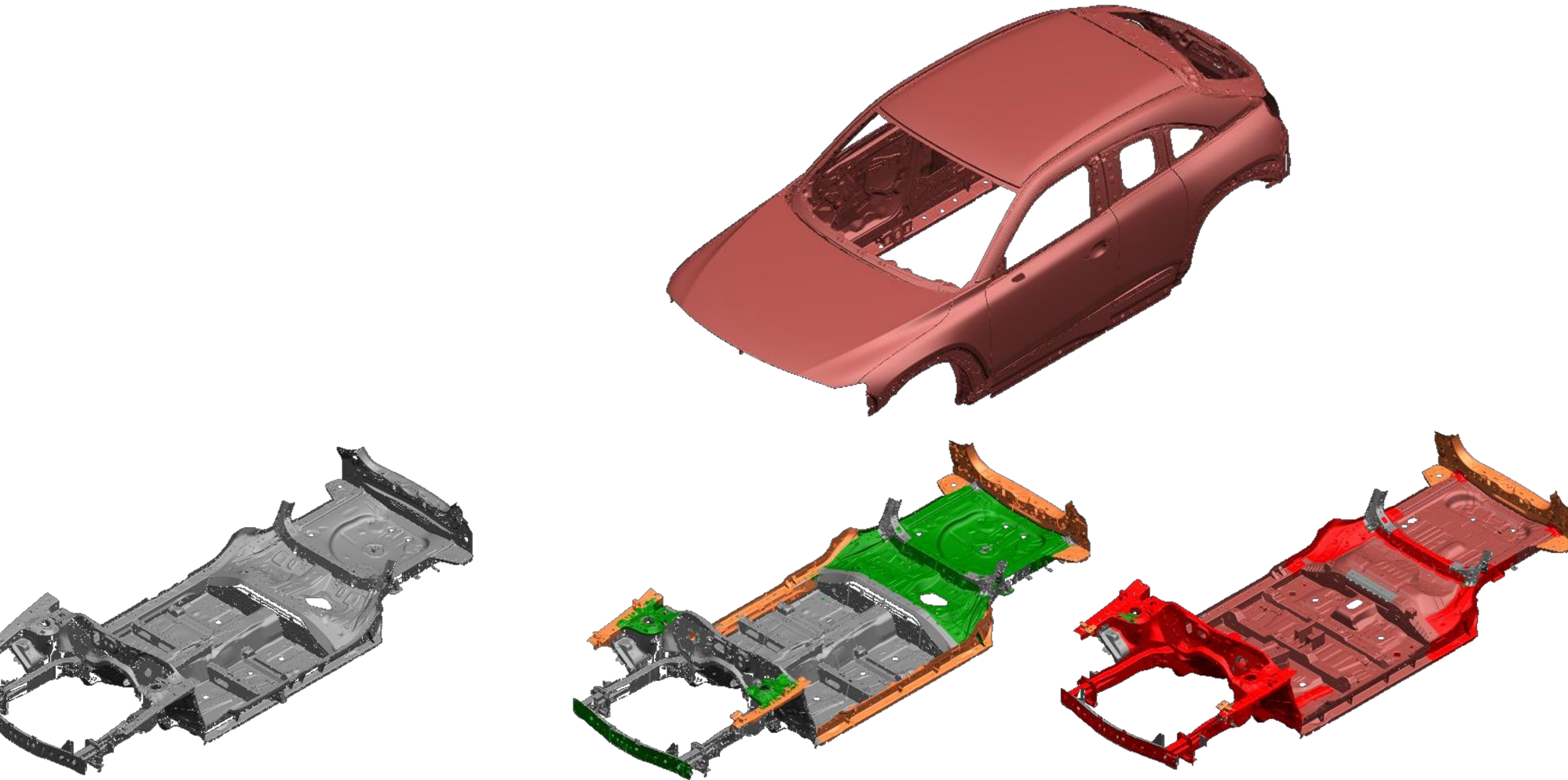
Electric HV-Air conditioning compressor



Rear Engine – Rear Wheel Drive
Skateboard battery platform

The common architecture is now challenged

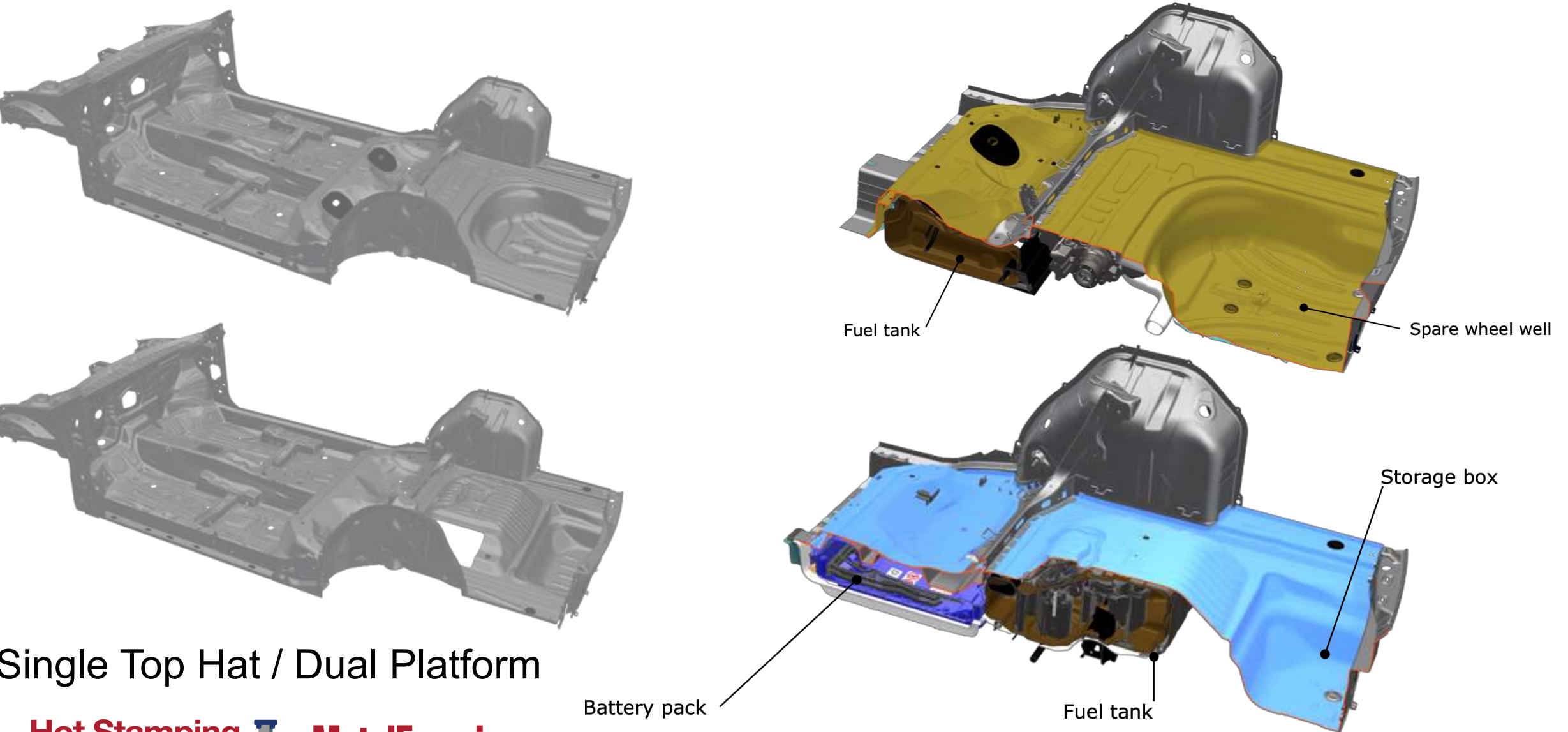
Billur



Single Top Hat / Dual Platform

The common architecture is now challenged

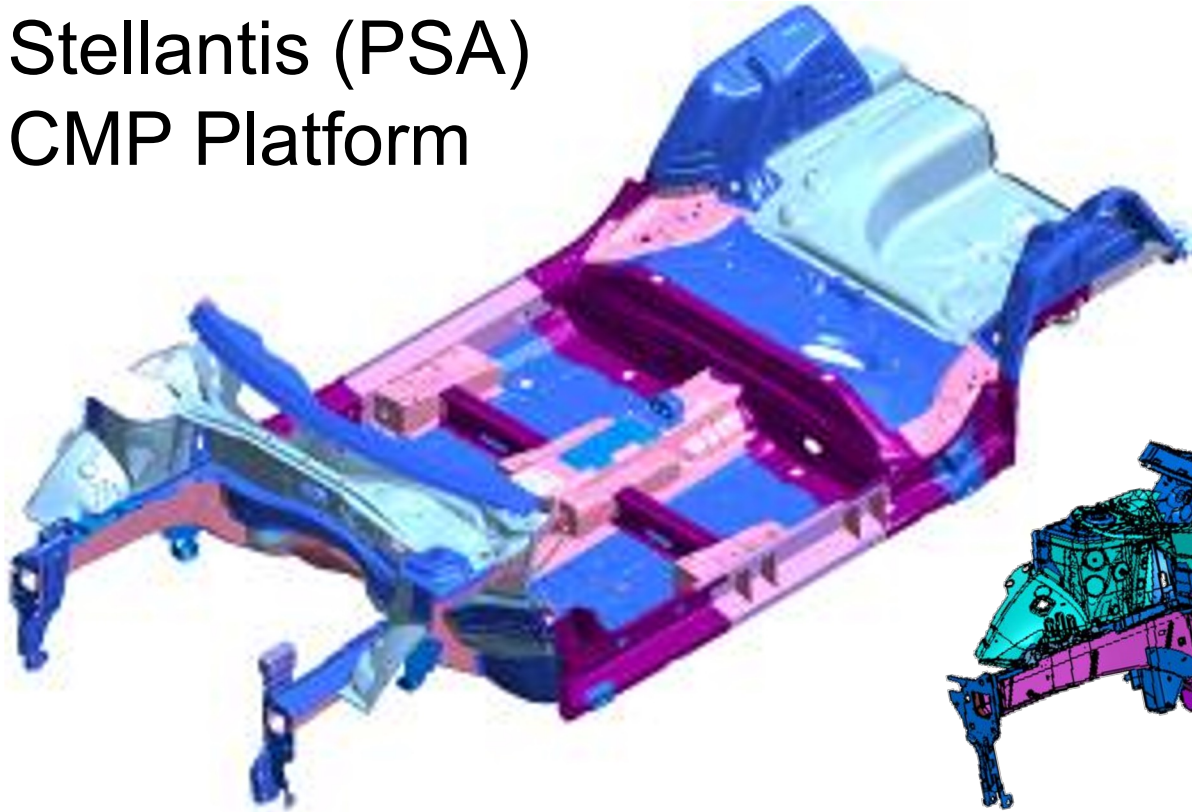
Billur



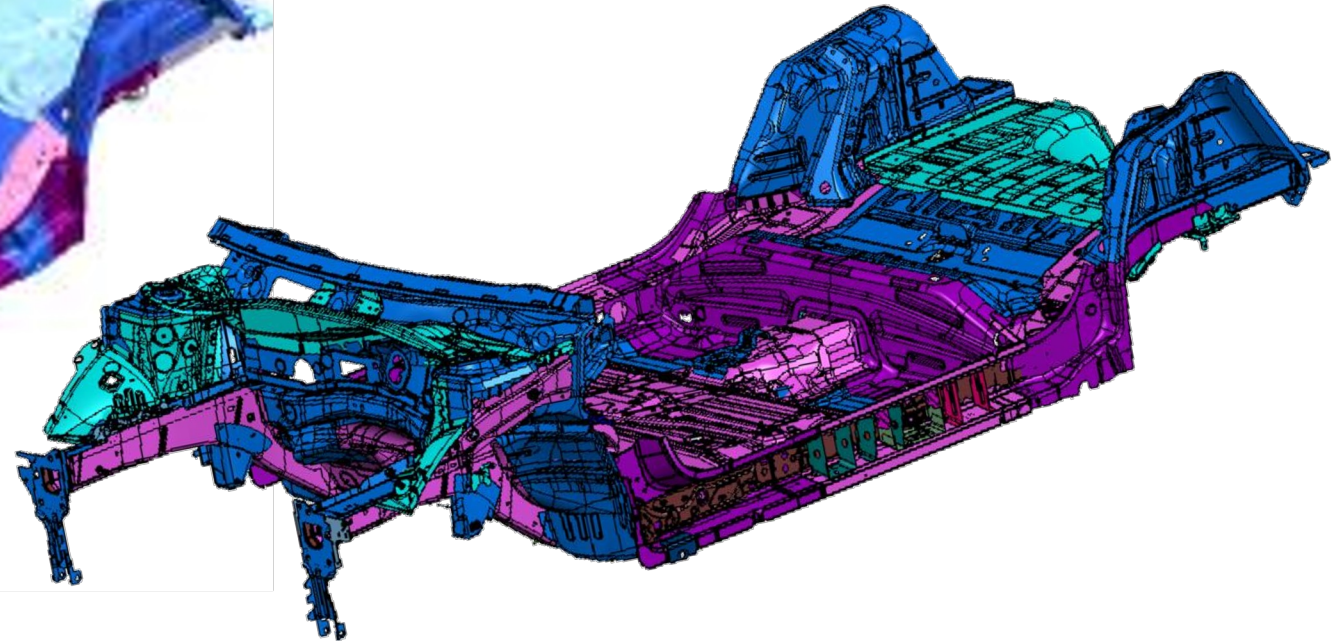
Single Top Hat / Dual Platform

The common architecture is now challenged

Stellantis (PSA)
CMP Platform



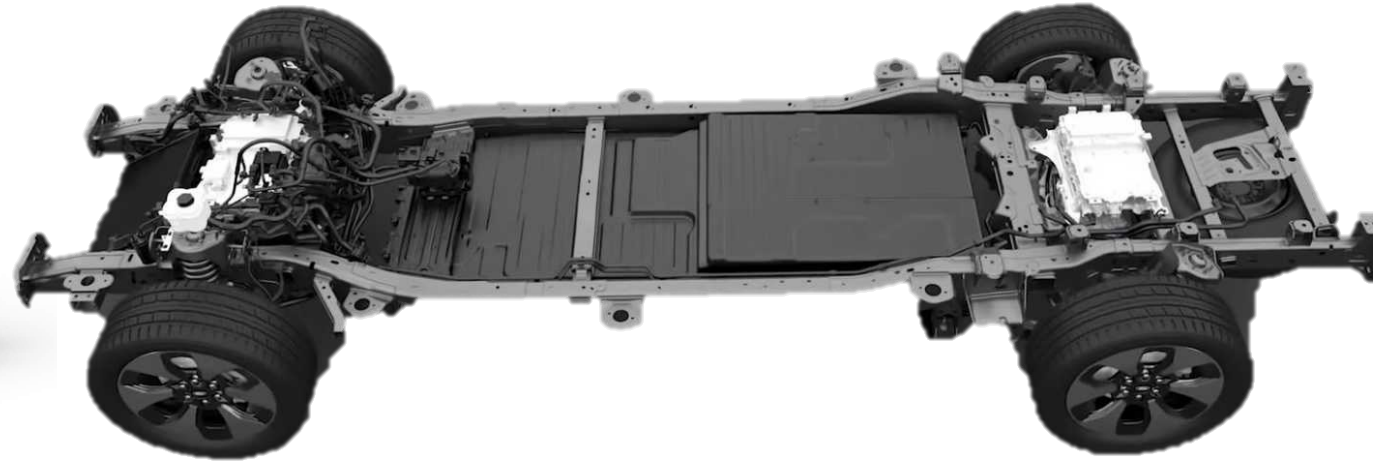
Stellantis (PSA)
e-CMP Platform



Single Top Hat / Dual Platform

The common architecture is now challenged

Billur



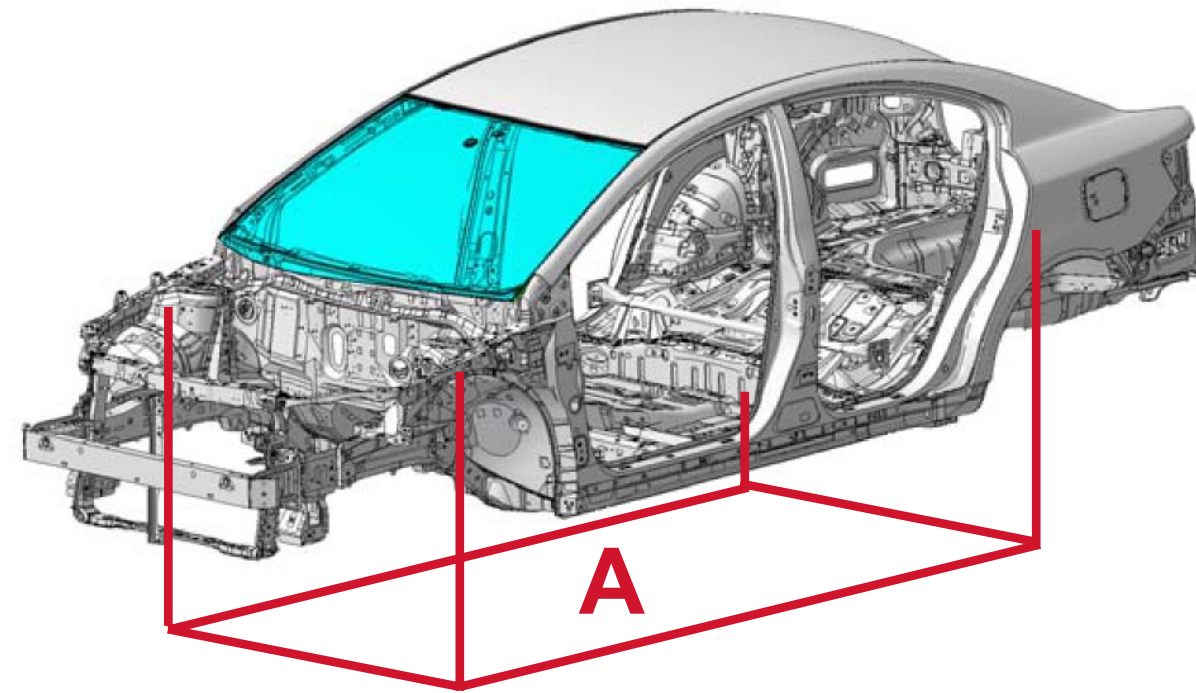
Lightweight efficiency as we know it

$$L = \frac{m_{BIW}}{K_t A}$$

m_{BIW} = mass of the body-in-white in kg

K_t = torsional stiffness in kNm/deg

A = projected area (wheelbase x track width) in m²



EV's are stiff – very stiff

2013-2020 Ford Fusion



19,450 Nm/°

2020 Ford Explorer



23,800 Nm/°

2021 Ford Mustang Mach-E



22,200 Nm/°

Without battery frame

31,600 Nm/°

With battery frame

Now the top hat can be changed



Volvo XC40 ICEV

27,300 Nm/°



Volvo XC40 Recharge (BEV)

31,300 Nm/°

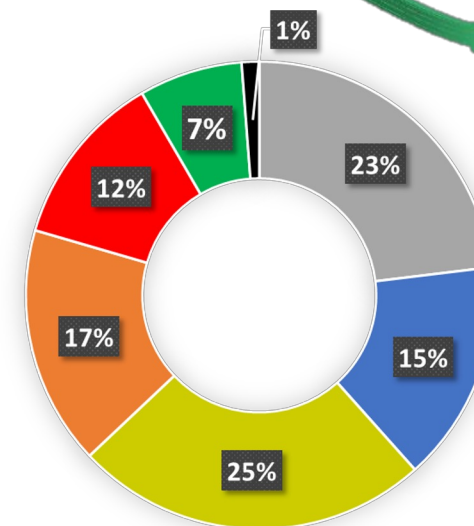
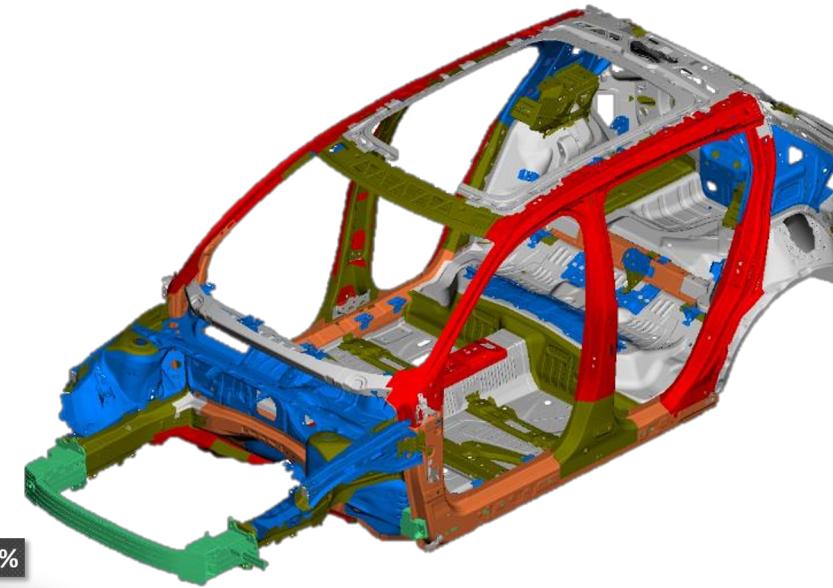
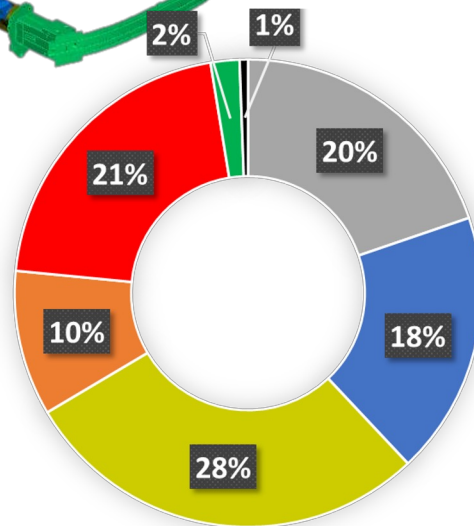
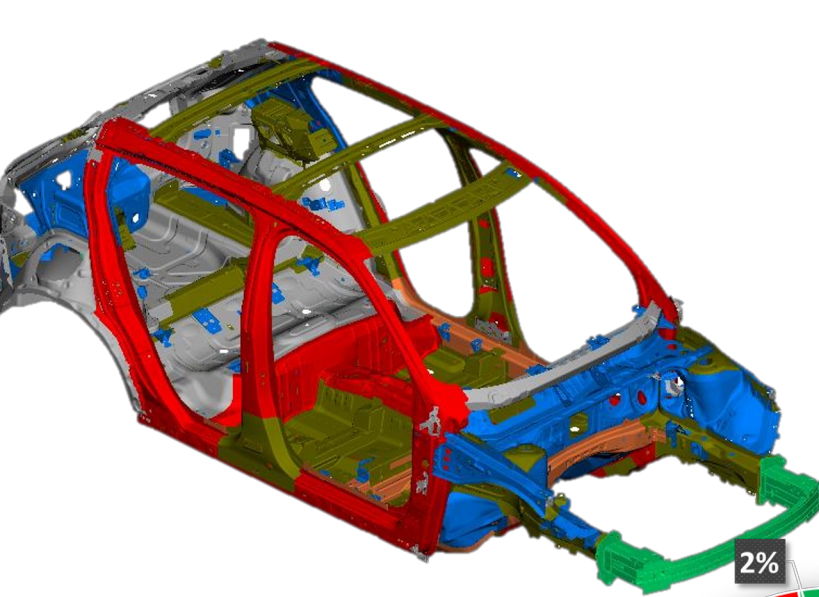
With battery frame

21,100 Nm/°

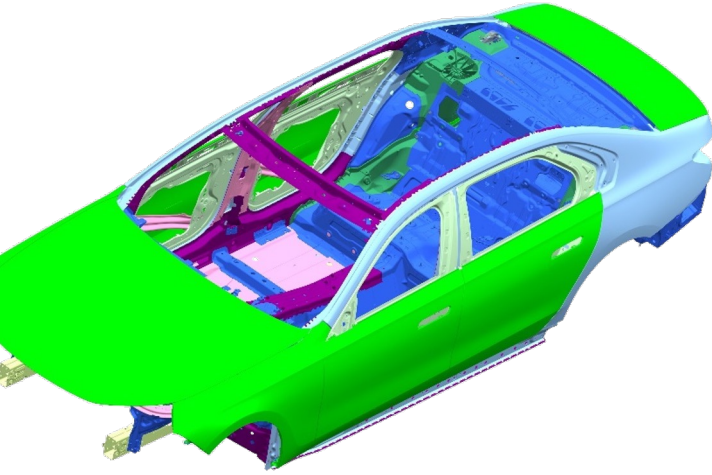
Without battery frame

XC40 BEV has less PHS than ICEV

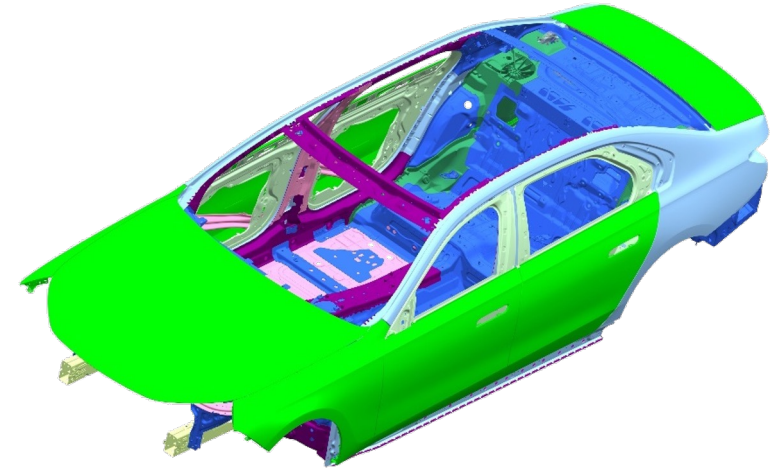
Billur



BMW 7 vs i7 has same amount of PHS

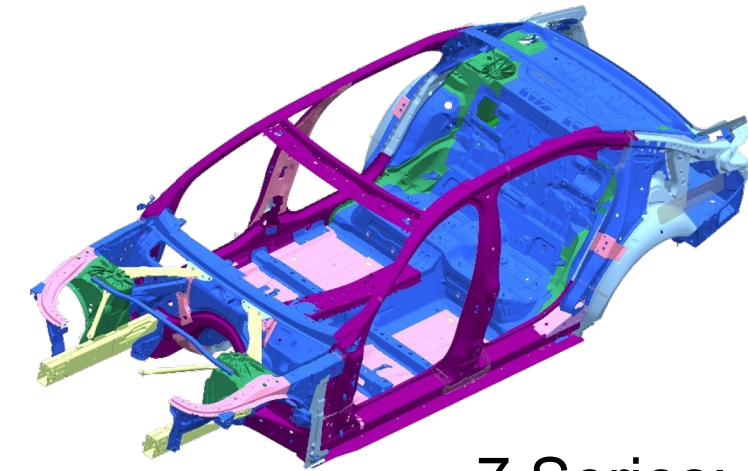


i7: 20% PHS
(including BIW+D/C)

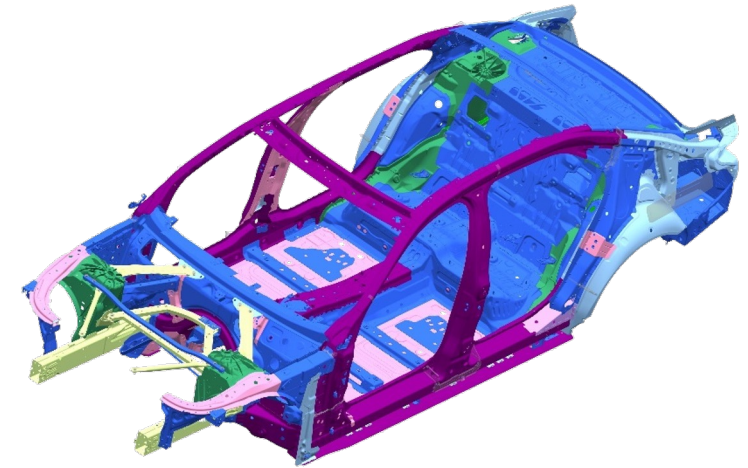


43,600 Nm/°

62,600 Nm/°



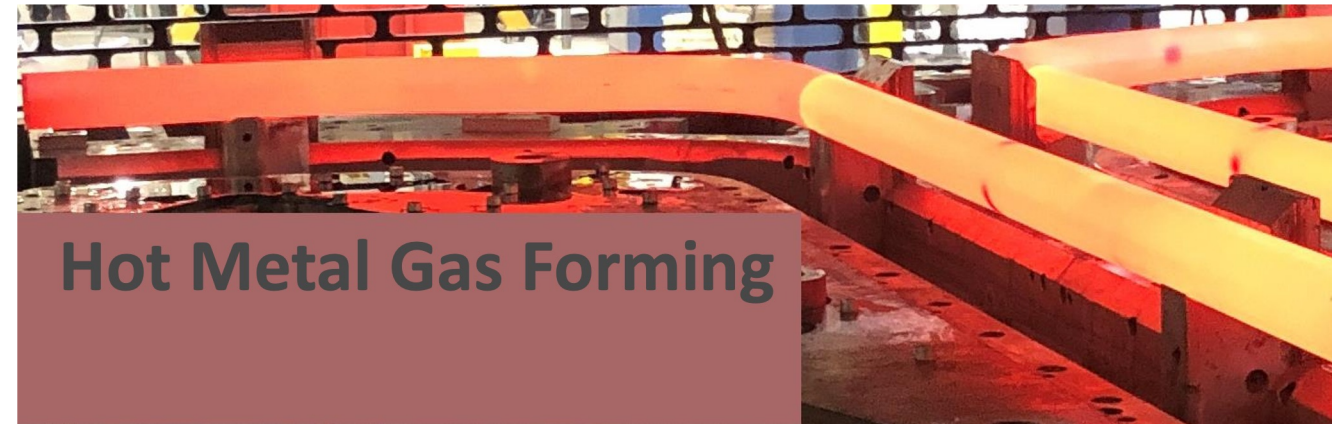
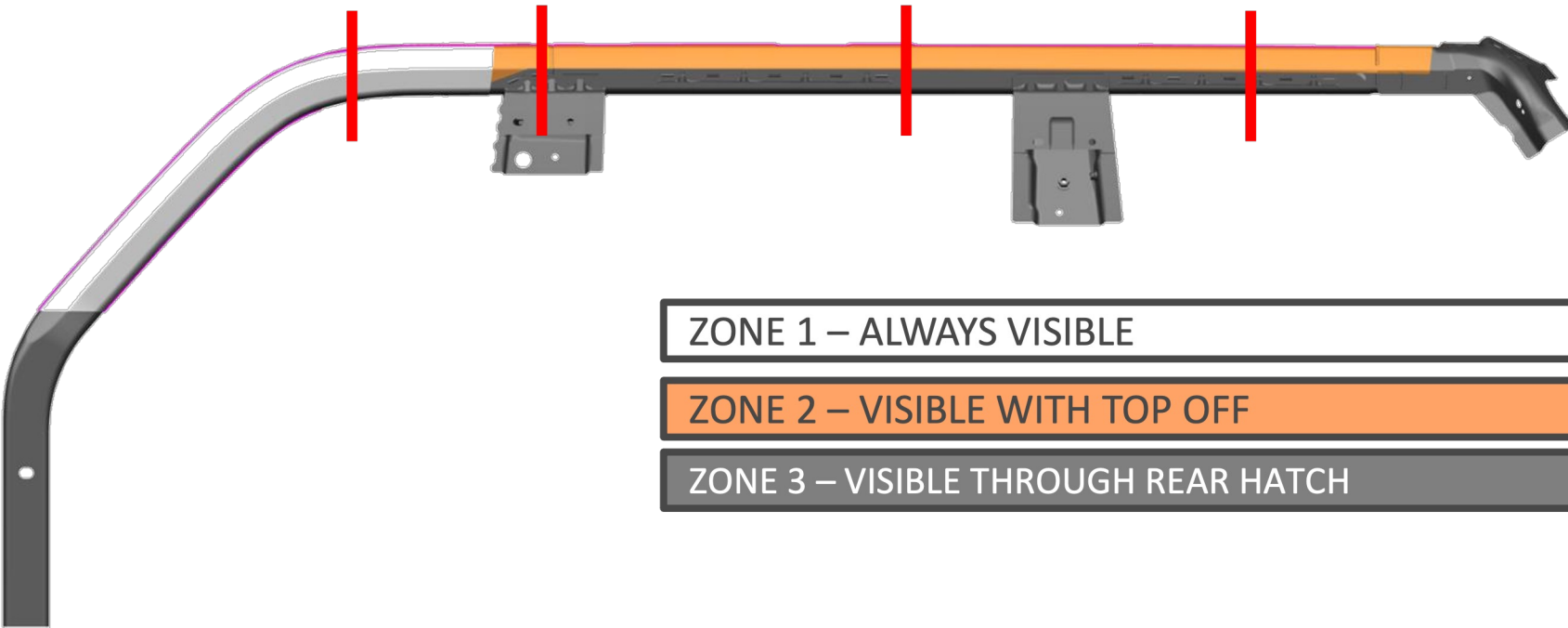
7 Series: 22% PHS
(including BIW+D/C)



- Automotive industry – the big revolution and new normals
- Electrification strategies
- New crash requirements
- PHS usage in conventional and modern architectures
- **Recent PHS usage**
- Competition to PHS
- Industry 4.0

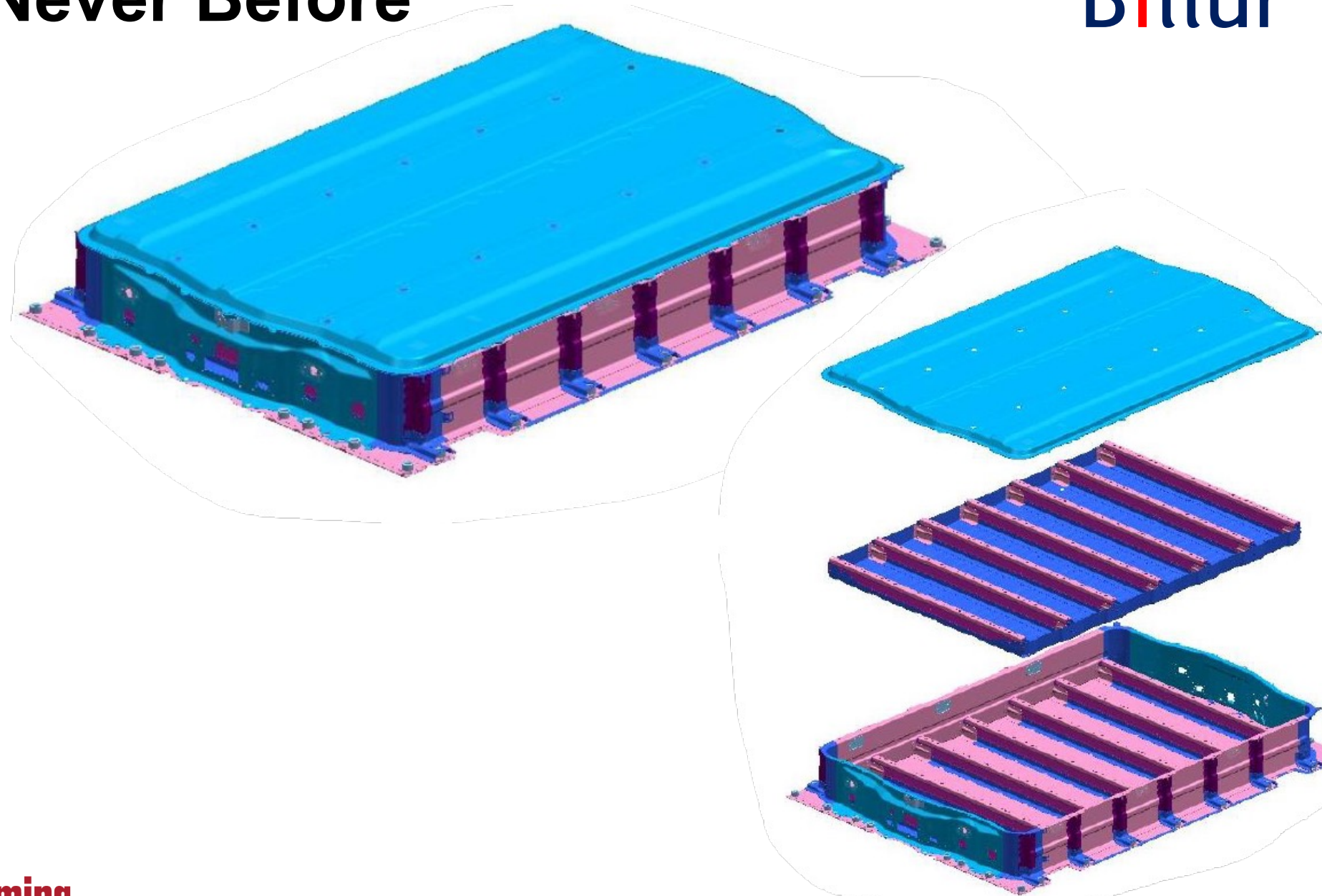
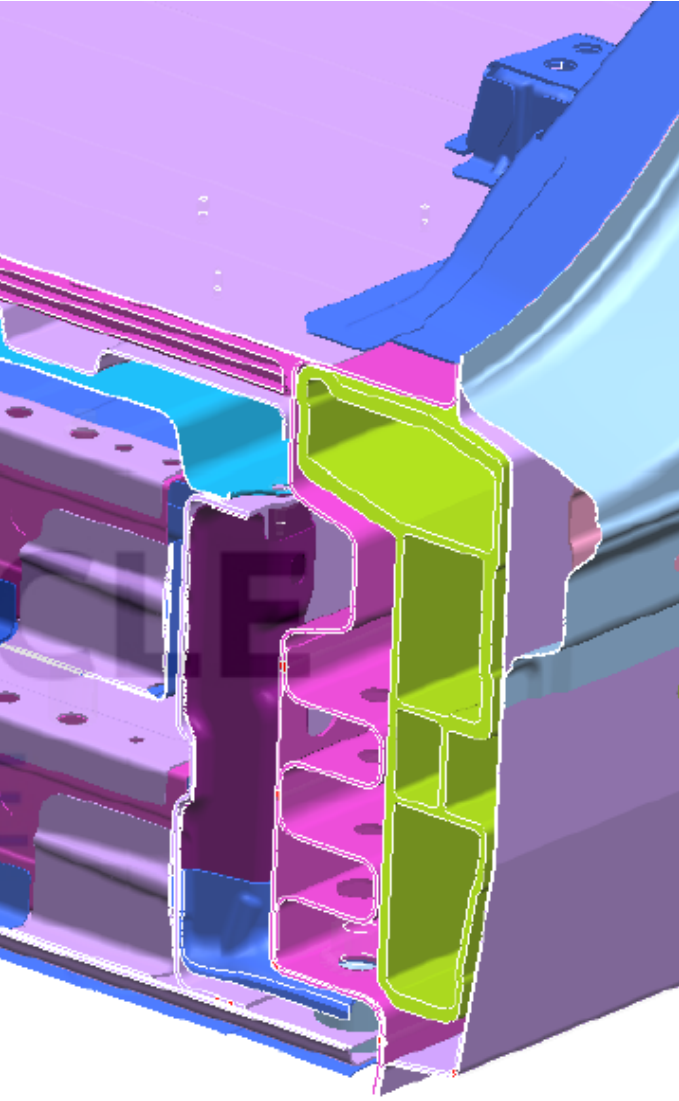
PHS Usage as Never Before

Billur



PHS Usage as Never Before

Billur



PHS Usage as Never Before



High-strength steel is used for the anti-intrusion bars, the reinforcements on the main nodes and the B-pillar. Our meticulous attention to detail at the design stage also resulted in the use of different materials within individual components. One example is the single rear door hinge: the fixed part is an aluminium casting, **while the mobile part is constructed from hot-stamped steel.**

PHS Usage as Never Before

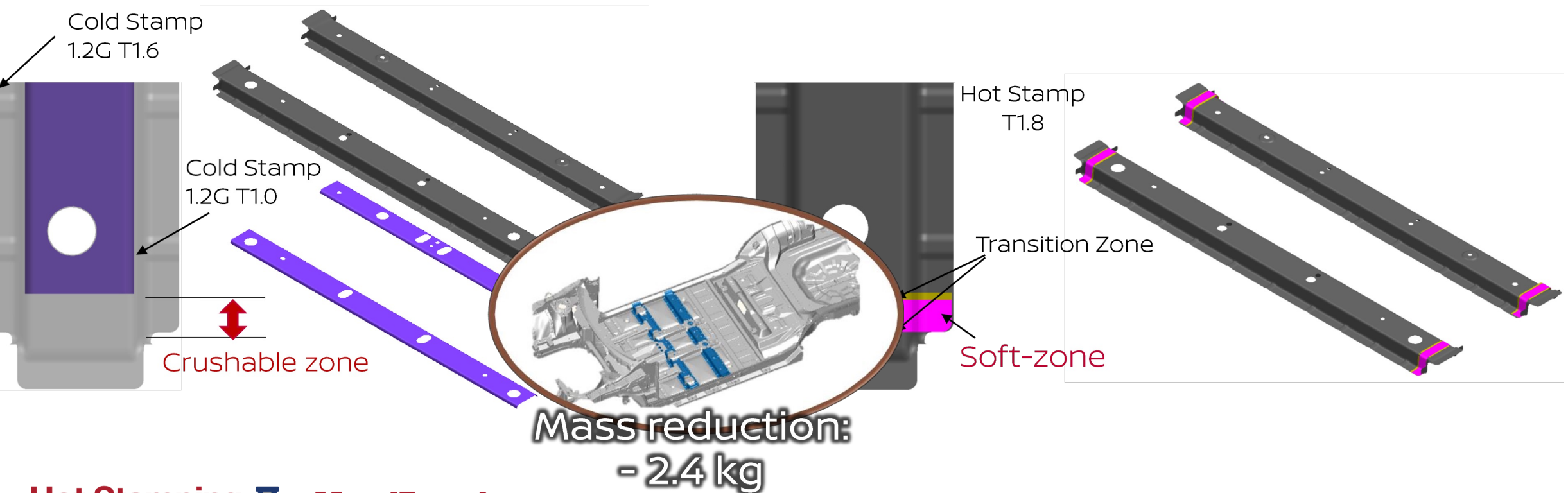
Billur

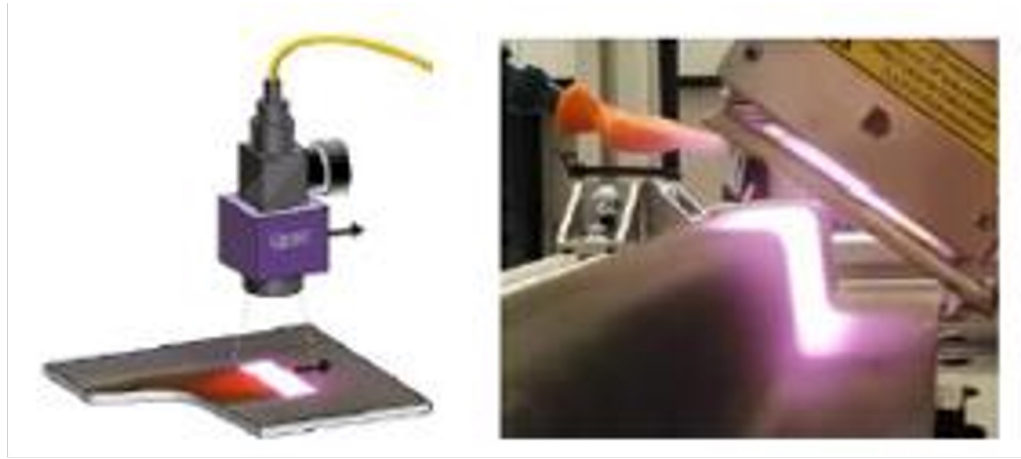
Conventional structure

11.3 kg

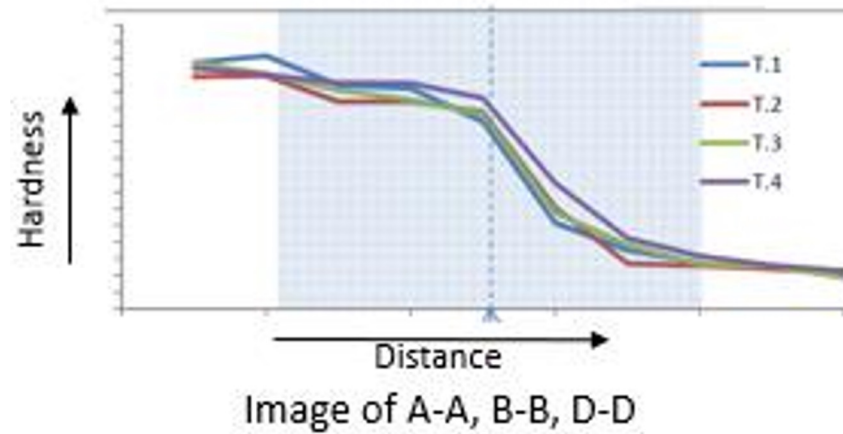
Soft-zone structure

8.9kg



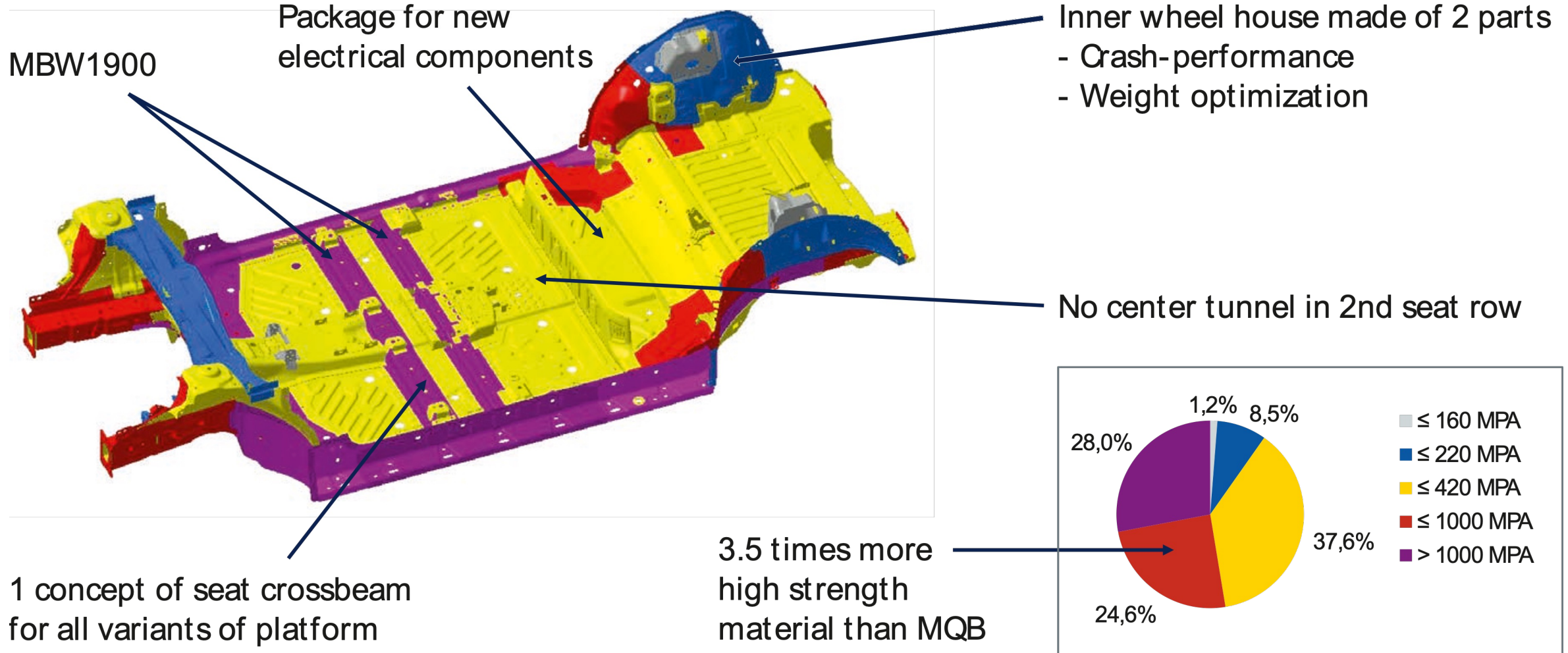


Hardness Measurement



Higher strength grades finally appearing

Billur



Higher strength grades finally appearing

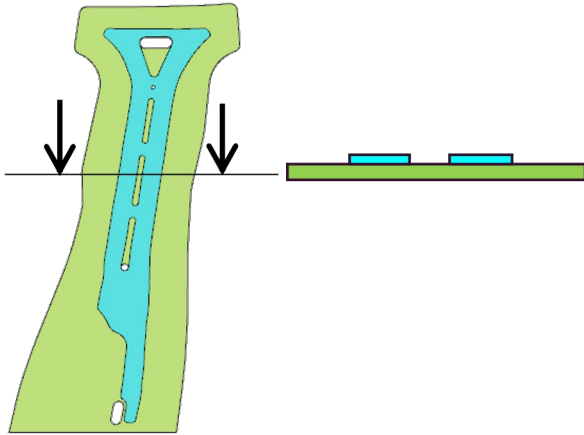
Billur



First B Pillar over 1500 Mpa – 2022!

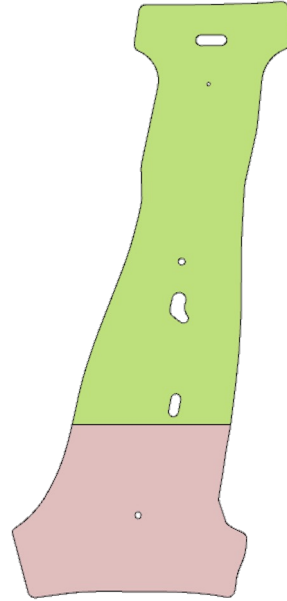
Billur

Patchwork



PHS 1800

LWTB



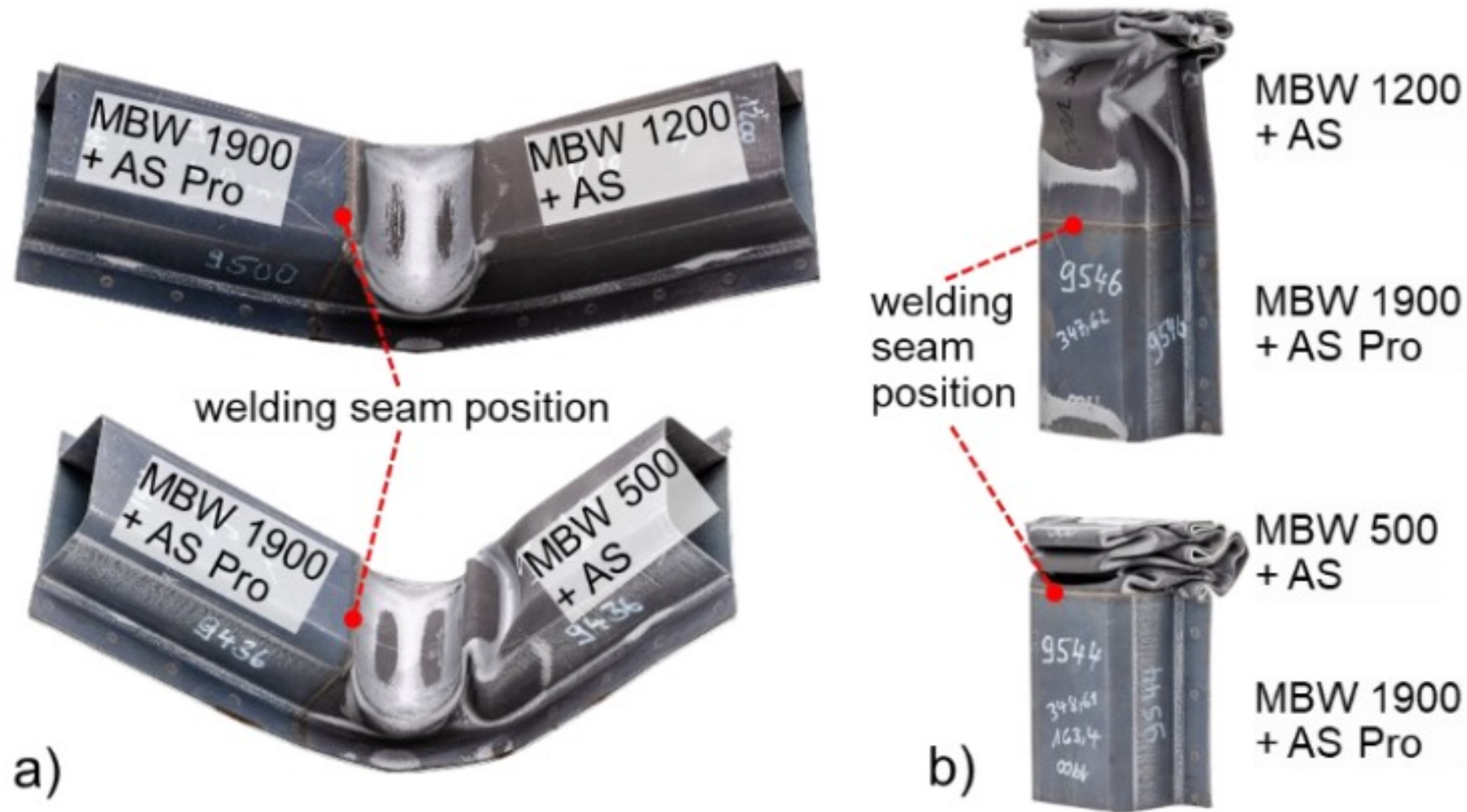
PHS 1300

Final B-pillar



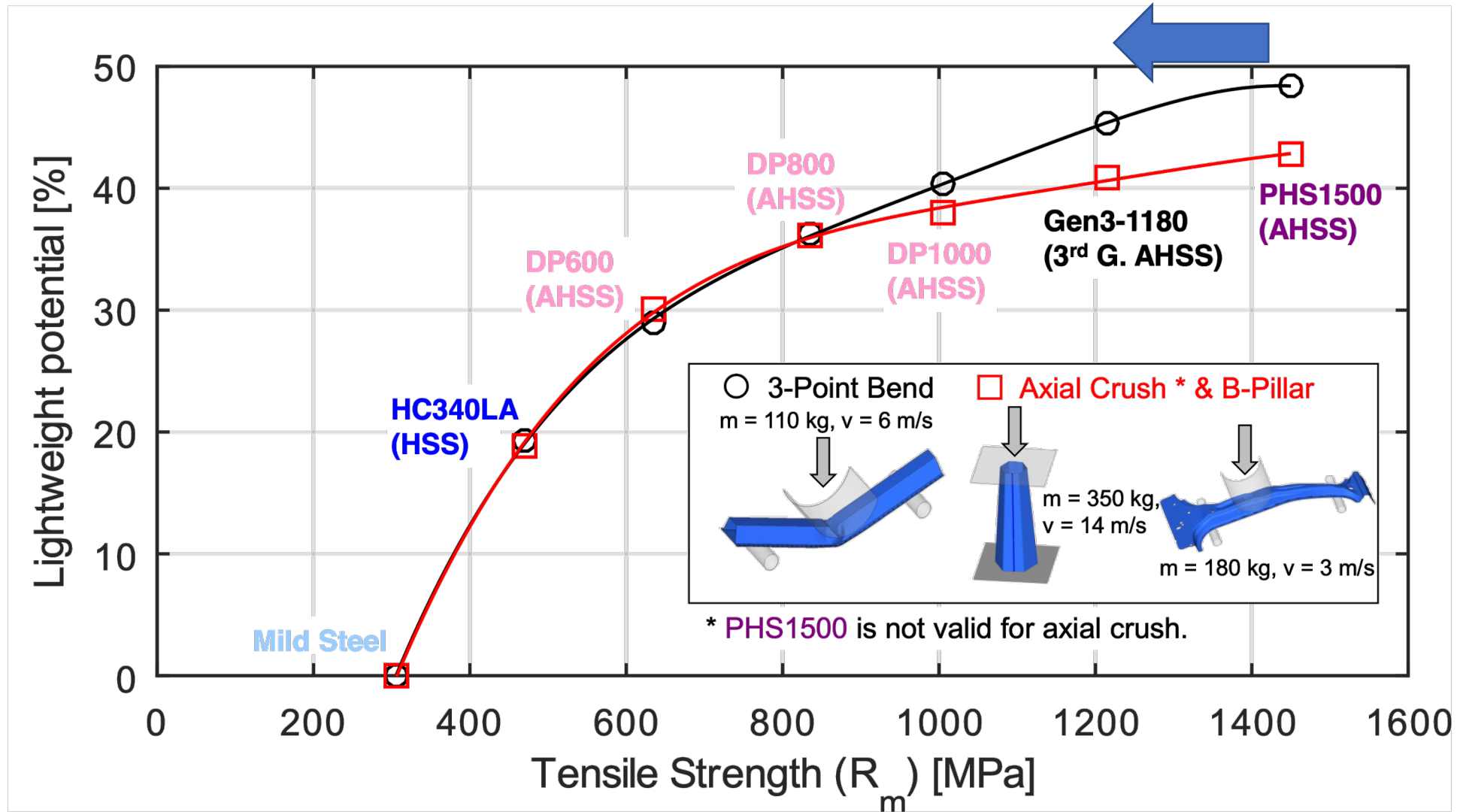
Higher strength grades finally appearing

Billur

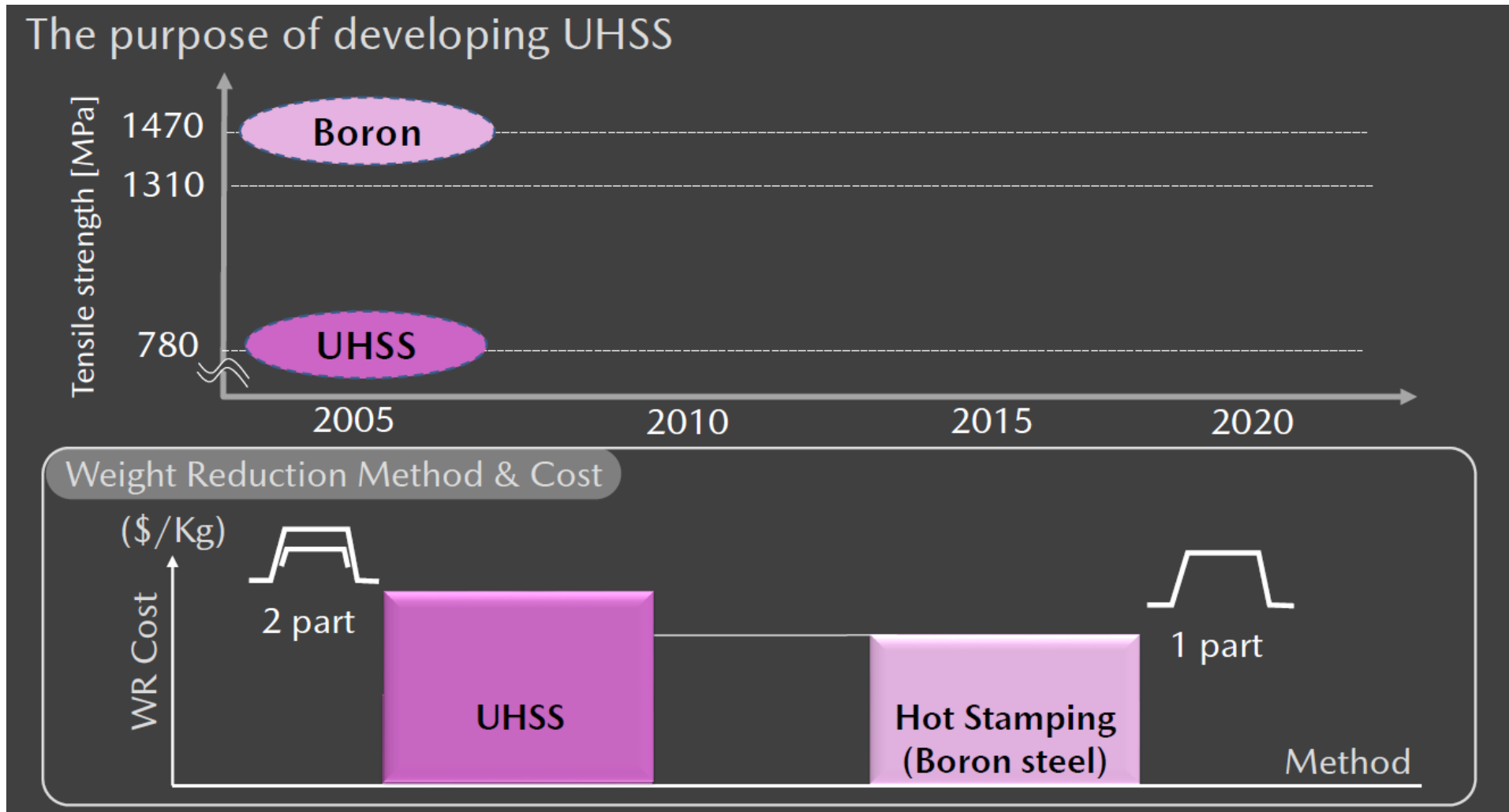


- Automotive industry – the big revolution and new normals
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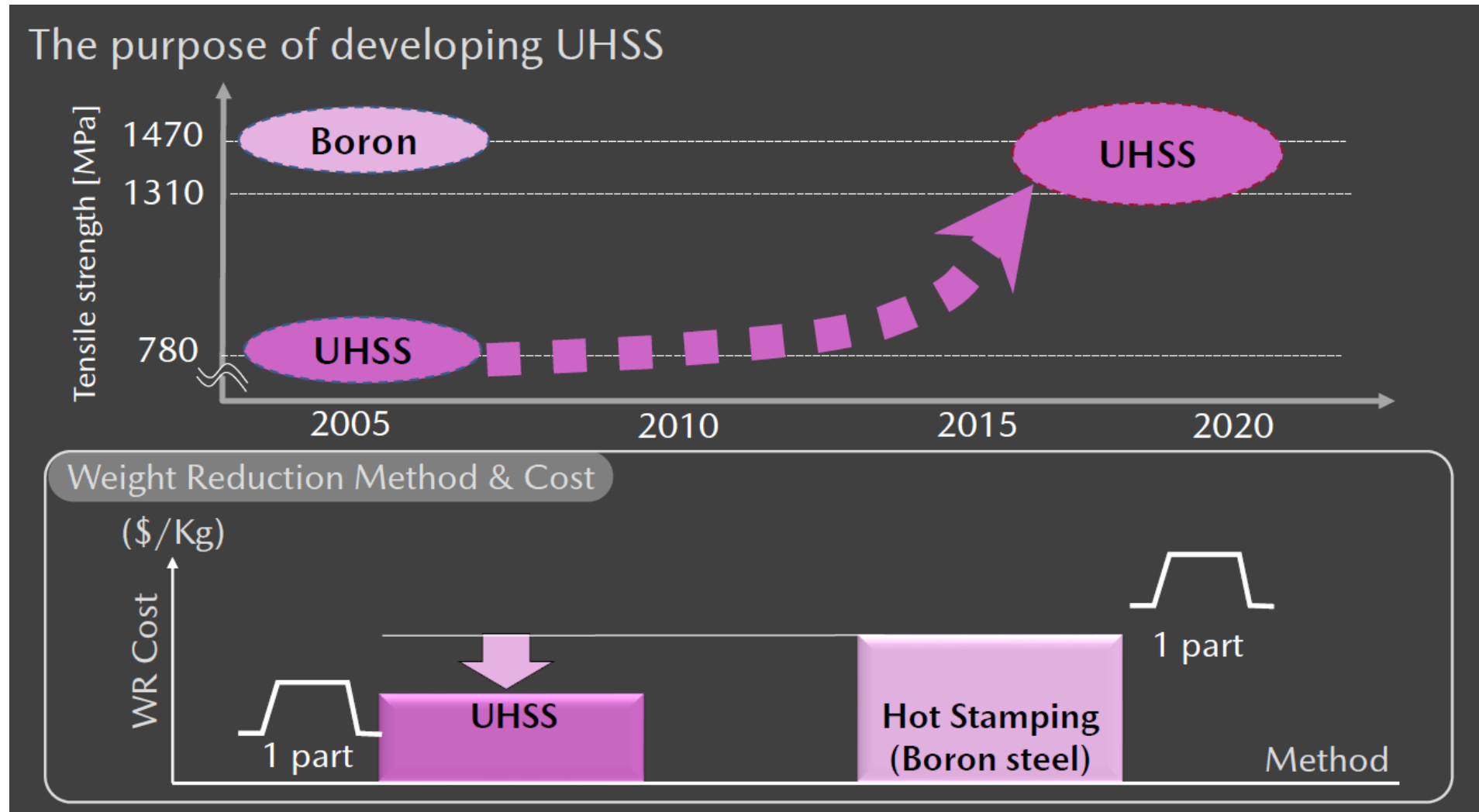
PHS seems to be increasing, but there is competition **Billur**



DP Steels were not a big threat to PHS



But Gen 3 may be game changing



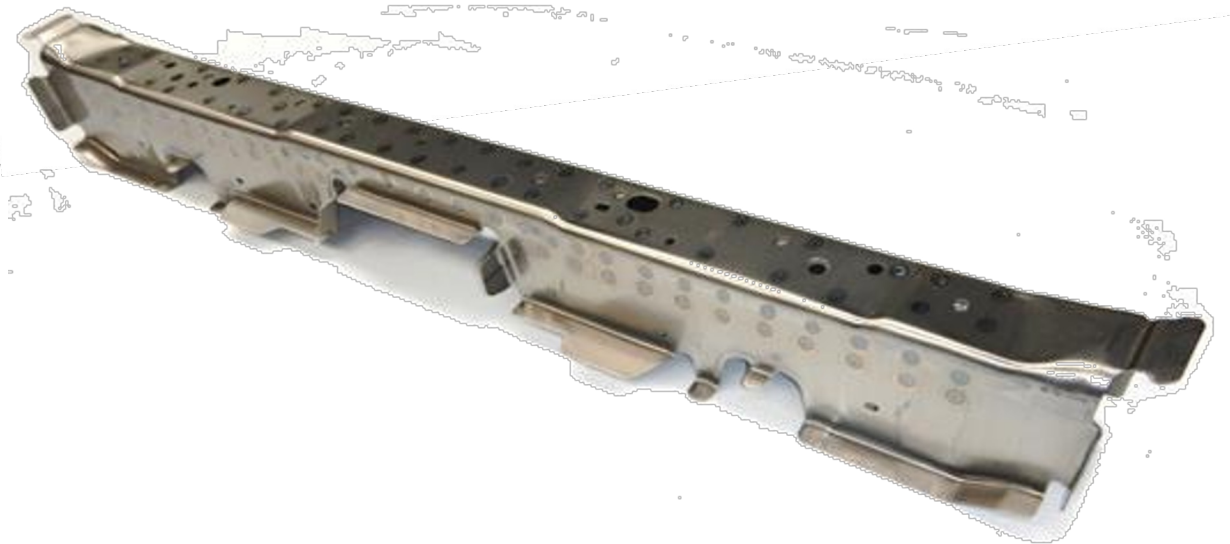
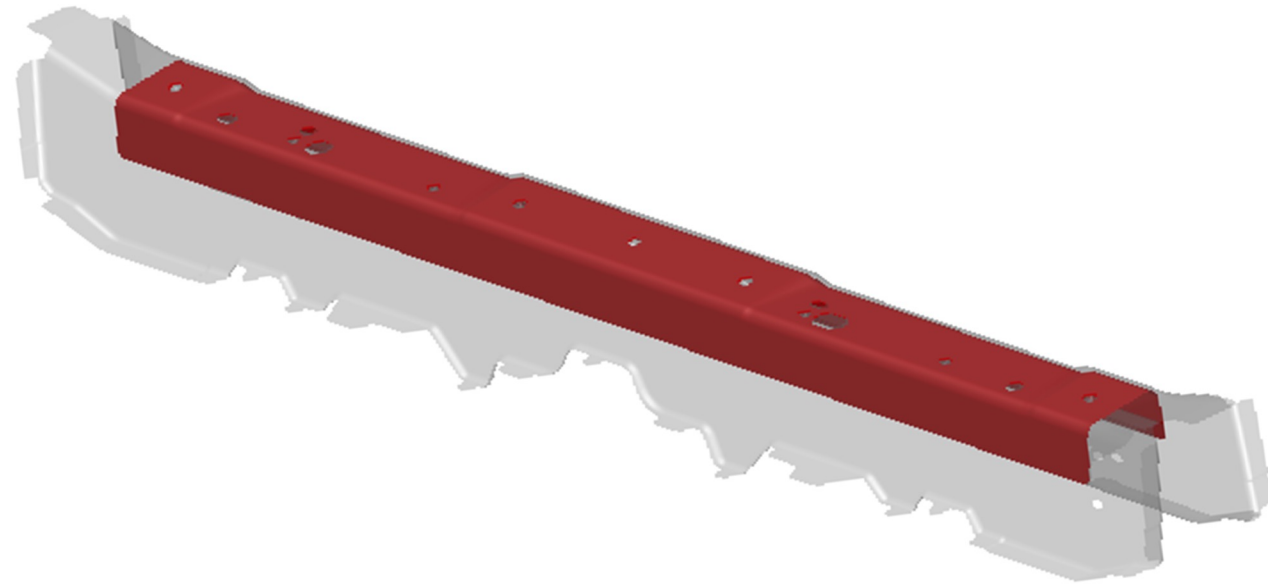
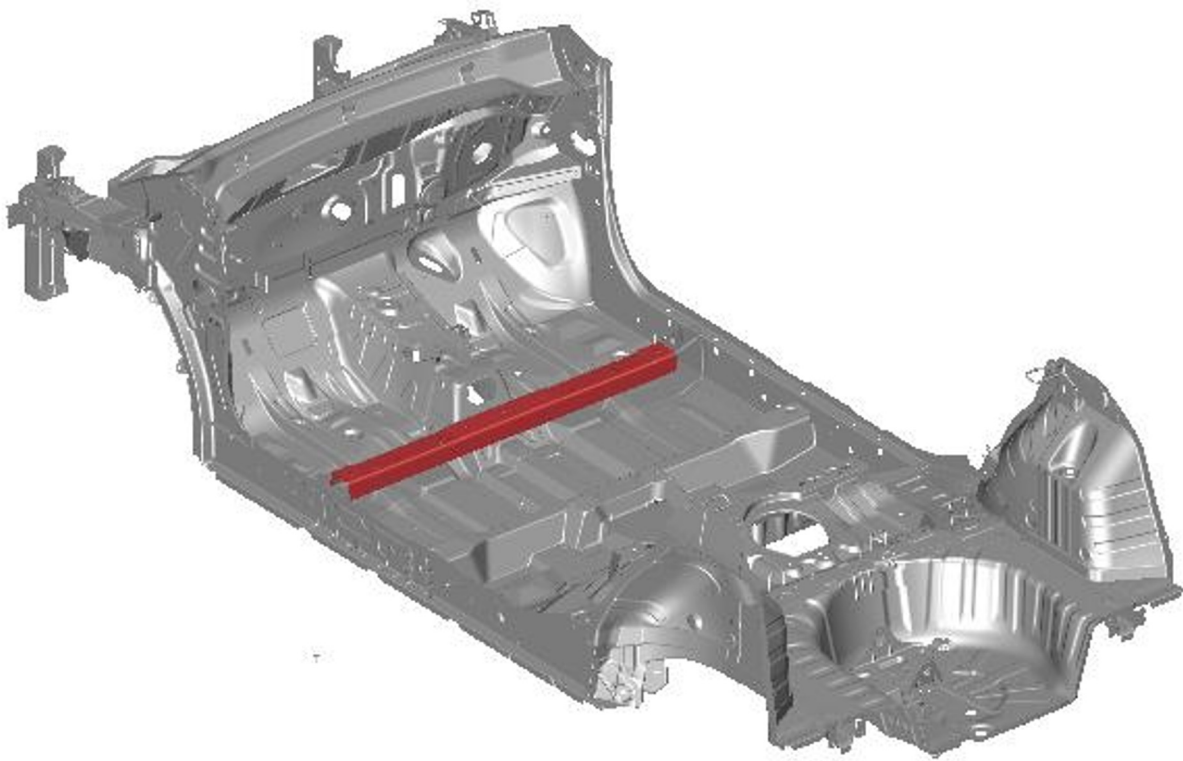
Comparison of PHS and Gen3

PHS1500			
Blanking	Heating	Hot forming and die quenching	Trimming
Easier to cut soft steel		Easy to control springback	

Gen3 Steel			
Blanking	Transfer press forming		Trimming
	No need of heating	Short cycle time	Hard trimming possible

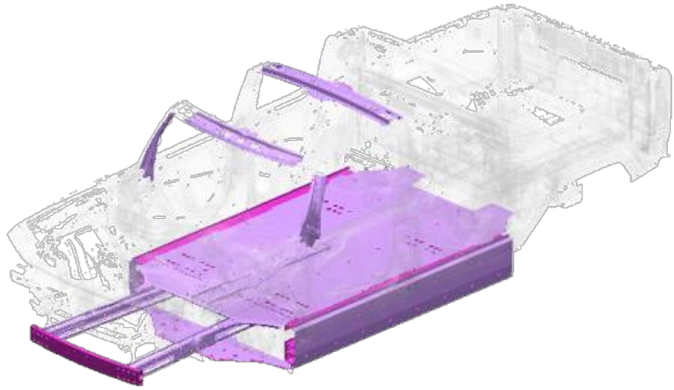
1500 MPa can be now cold stamped.

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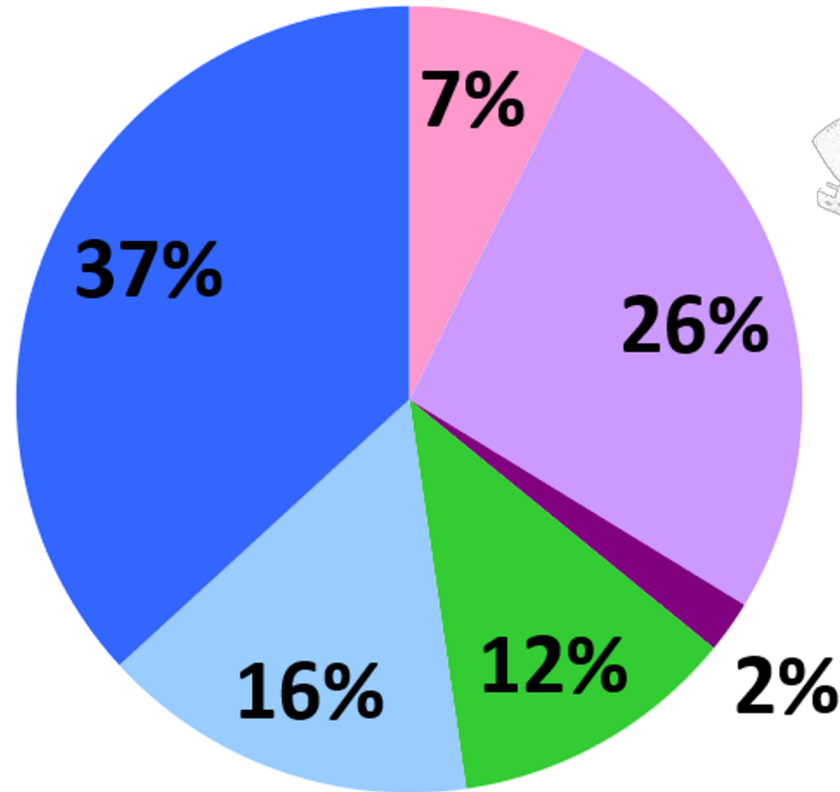
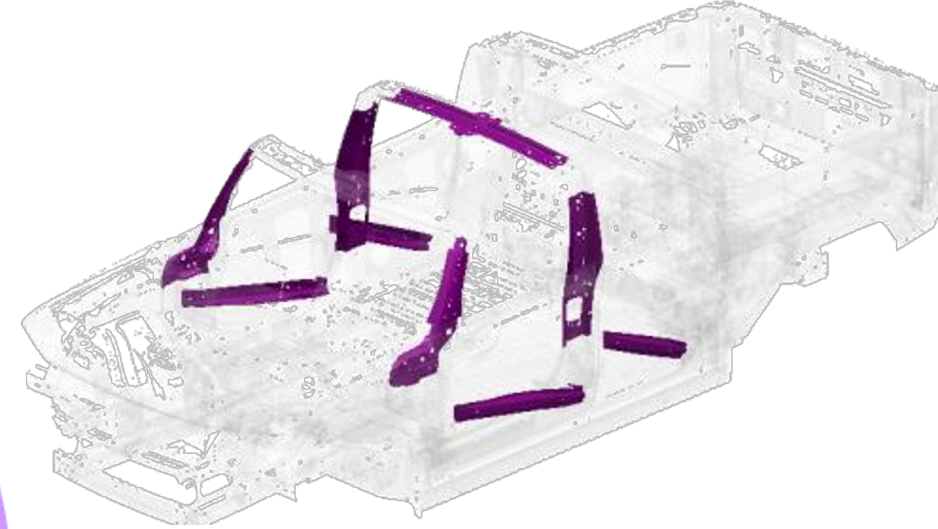


Martensitic steels can be used in simple geometries **Billur**

Ultra High
Strength Steel



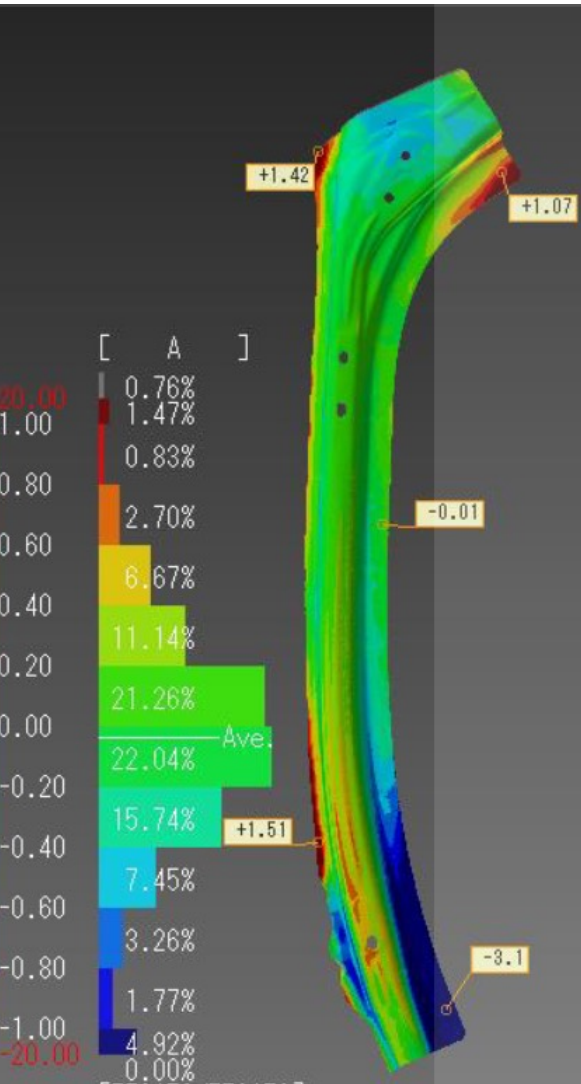
Press Hardened Steel



2% PHS
18.5% CP
14.3% MART

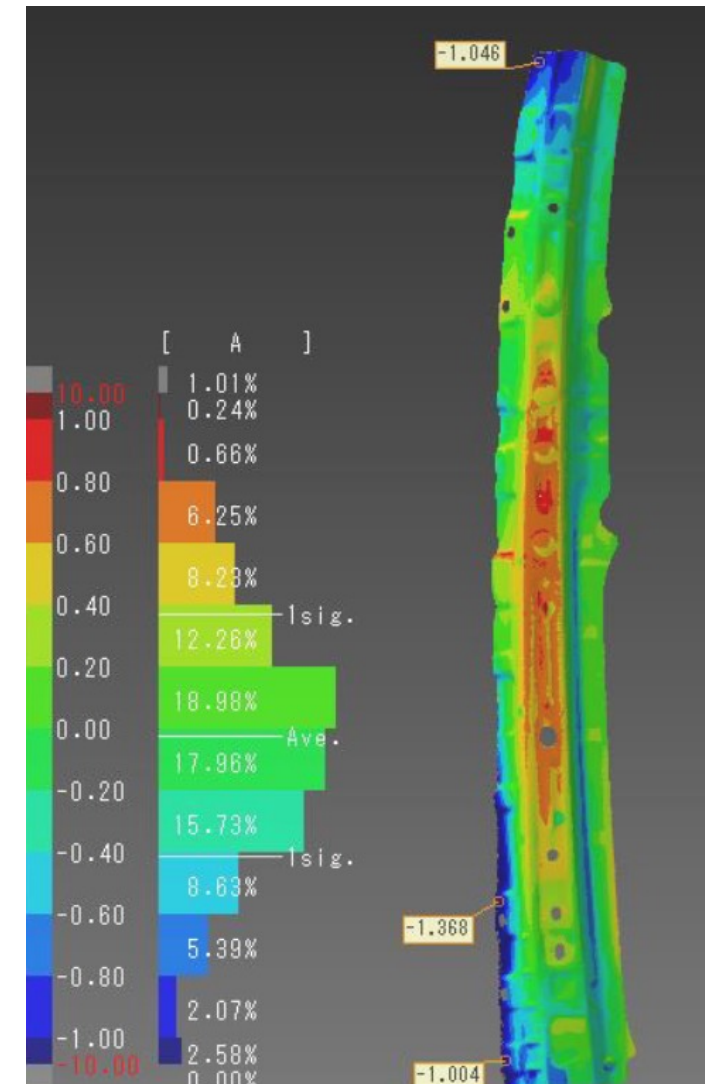
But Gen 3 can be used even in A-Pillars!

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1.2 mm
1470 MPa
Cold Stamp
A-Pillar

1.4 mm
1470 MPa
Cold Stamp
Roof Rail



There are 4 big challenges in cold forming:

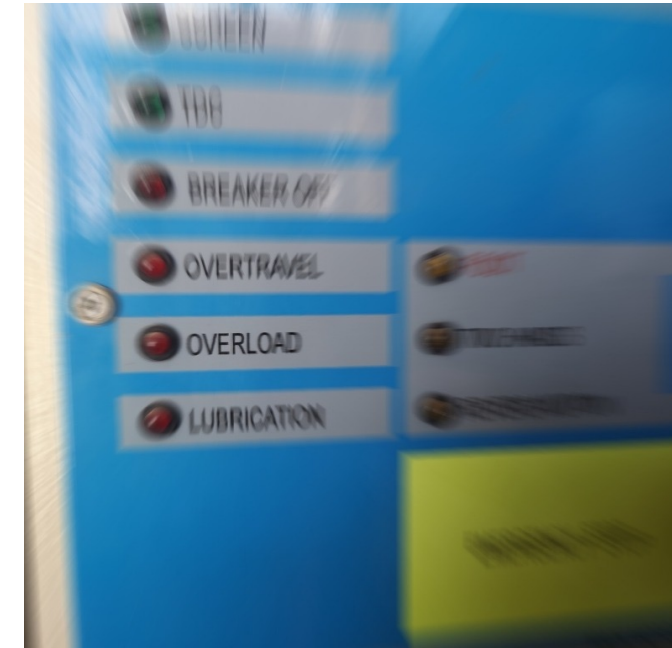
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Hard to control springback



Low formability



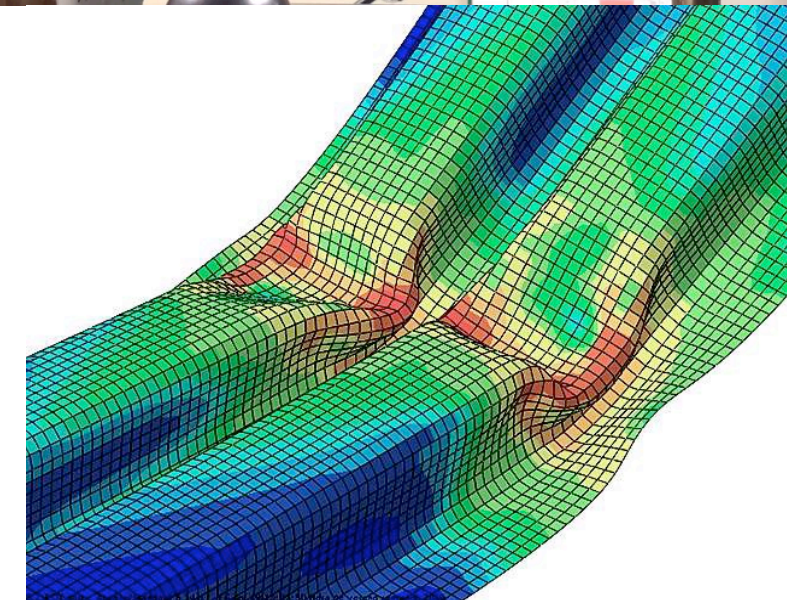
Tonnage/Energy

Tool Life?

Another competitor : Hot Formed Aluminum

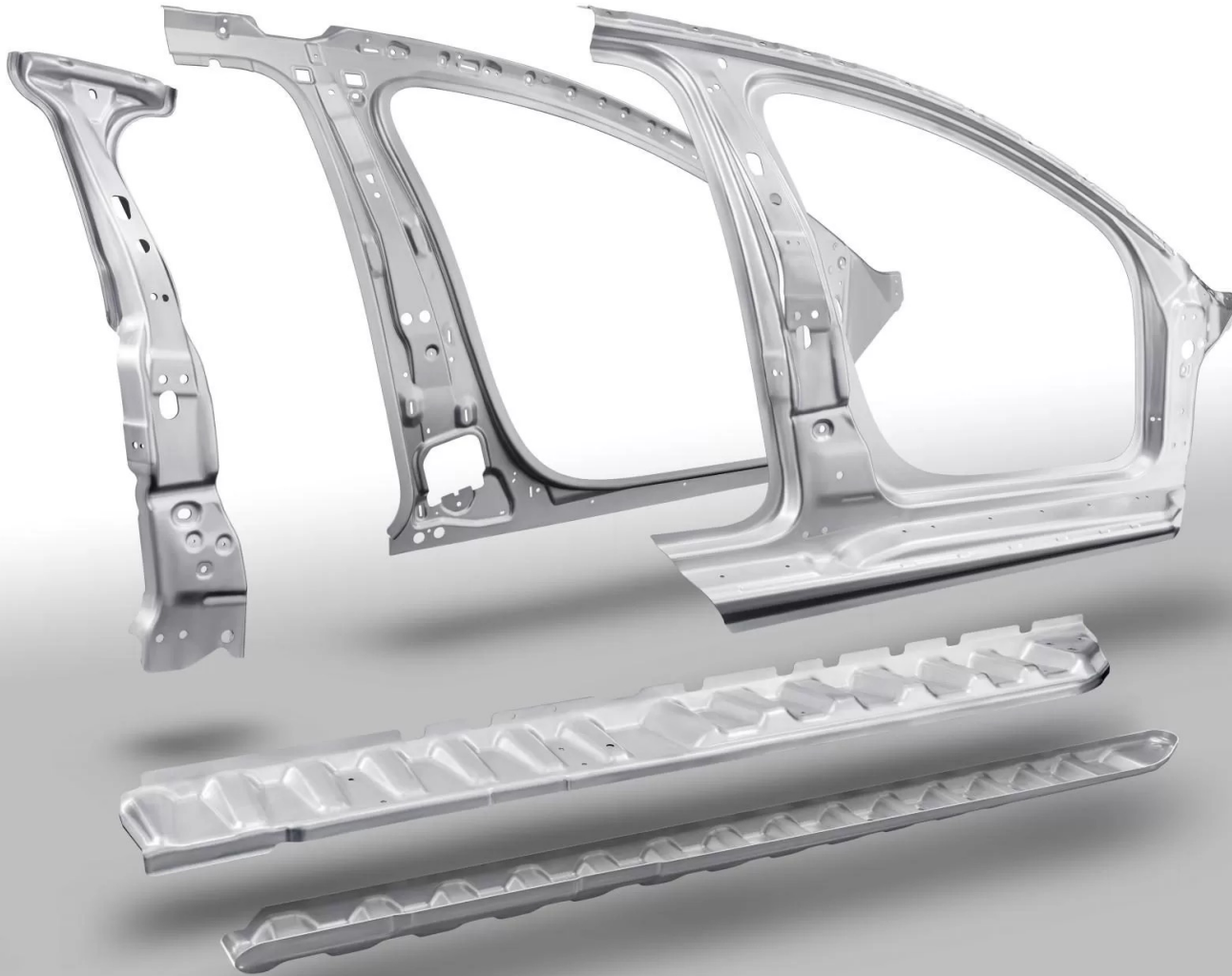
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DP 980	1.50 mm	1.42 kg
TBF 1050	1.38 mm	1.26 kg
PHS 1500	1.29 mm	1.17 kg
HFQ 6082 – T6	2.91 mm	0.84 kg
HFQ 6111 – T6	2.56 mm	0.75 kg
HFQ 7075 – T6	2.26 mm	0.71 kg



First Hot Formed Aluminum Door Ring

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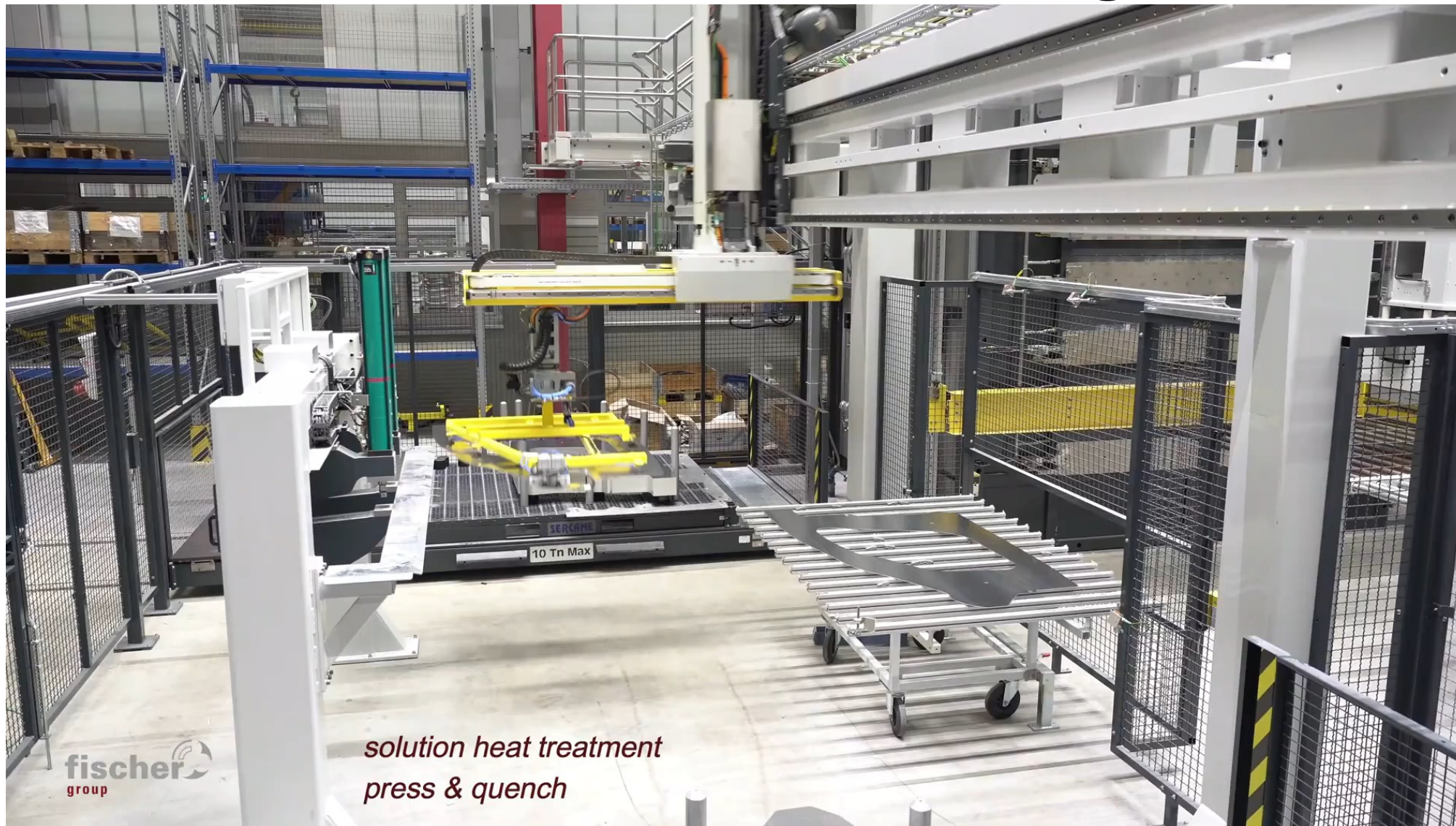
HFQ Aluminum usage had started with Aston Martin, but now continues with Lucid Air.

Left and right, a total of 10 parts are used in Lucid Air.

These include inner and outer door rings.

First Hot Formed Aluminum Door Ring

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VOLKSWAGEN

AKTIENGESELLSCHAFT

Konzernnorm

PV 1076

Ausgabe 2018-09

Klass.-Nr.: 51322

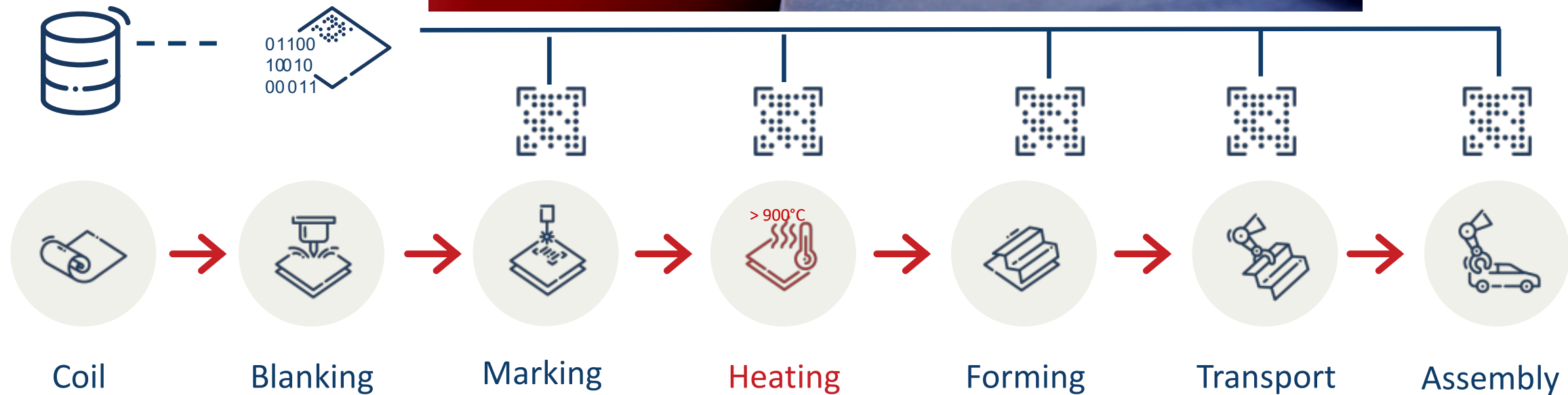
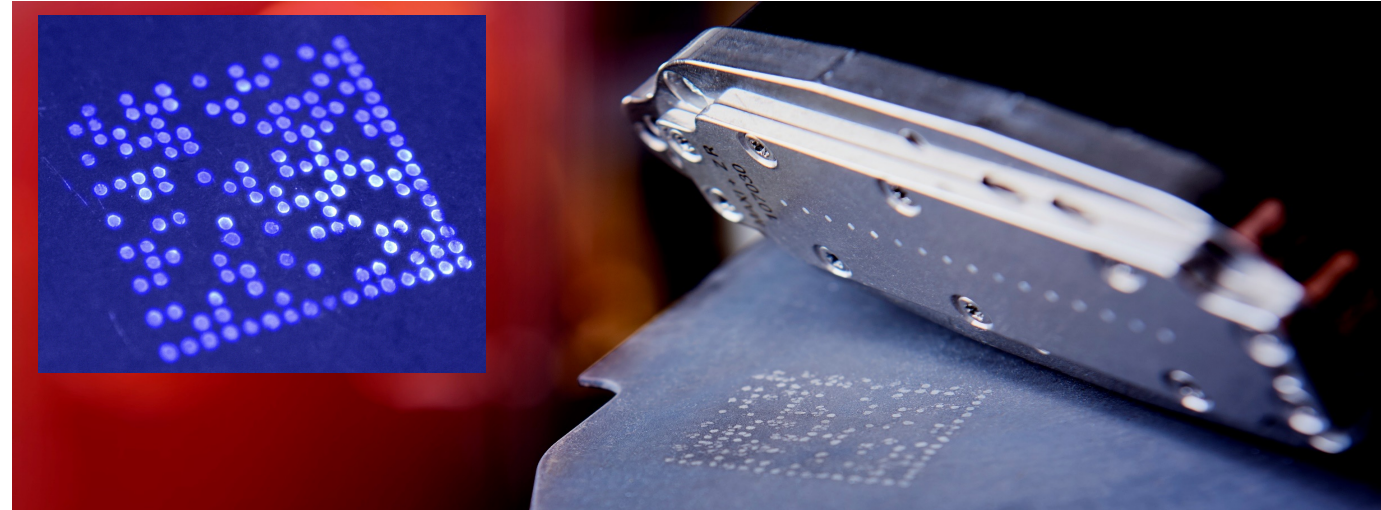
Schlagwörter: Formhärten, Karosserie, Stahl, Warmumformen, Warmumformung, zerstörungsfrei

Formgehärtete Bauteile

Zerstörungsfreie mikromagnetische Prüfung (3MA-Prüfung) an formgehärteten Bauteilen aus 22MnB5

Industry 4.0 applications in PHS

Individual part tracking with ceramic QR codes.



- Automotive industry is being disrupted by Covid-19, chip crisis, electrification and start-ups.
- Electrification will take place faster than expected. Range and safety issues may increase the PHS usage.
- Due to stiffer structure, some OEM's reduced the PHS usage in upper body. This was not the case prior to 2021.
- New areas of use for PHS are still being developed: hinges, battery risers, exposed areas.

- PHS is not unrivaled. Especially Asian OEM's are working for cold forming of Gen3 steels.
- Hot formed aluminum may be of interest in low-volume niche cars (which are expected to grow).
- Industry 4.0 applications are still being developed for PHS industry.

Q&A Session

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