European Commission

Horizon 2020
European Union funding
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AffordabLe LIghtweight Automobiles AlliaNCE

Future of Automotive Lightweighting Day

September 19, 2019

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Material development – Aluminium

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Motivations

Aluminium enabling significant weight reductions

JLR

Jaguar Land Rover chose aluminium to reduce weight on the Range Rover and Range Rover Sport models – with weight savings of greater than 400kg per car

RR ~100'000 veh. in 2018

Ford F-150

The aluminium-intensive Ford F-150 is more than 300kg lighter than previous models and achieved the truck's first-ever 5-star safety rating from NHTSA.

Starts $28,155

F Series: 900'000 veh. in 2018

Lightweighting through the intensive use of Aluminium possible for:

- very high volumes
- affordables cars

⇨ not only for exclusive cars !

Targets and objectives

Main criterion for material development

Style

Repair/replace

Comfort

Pedestrian safety — Passenger safety

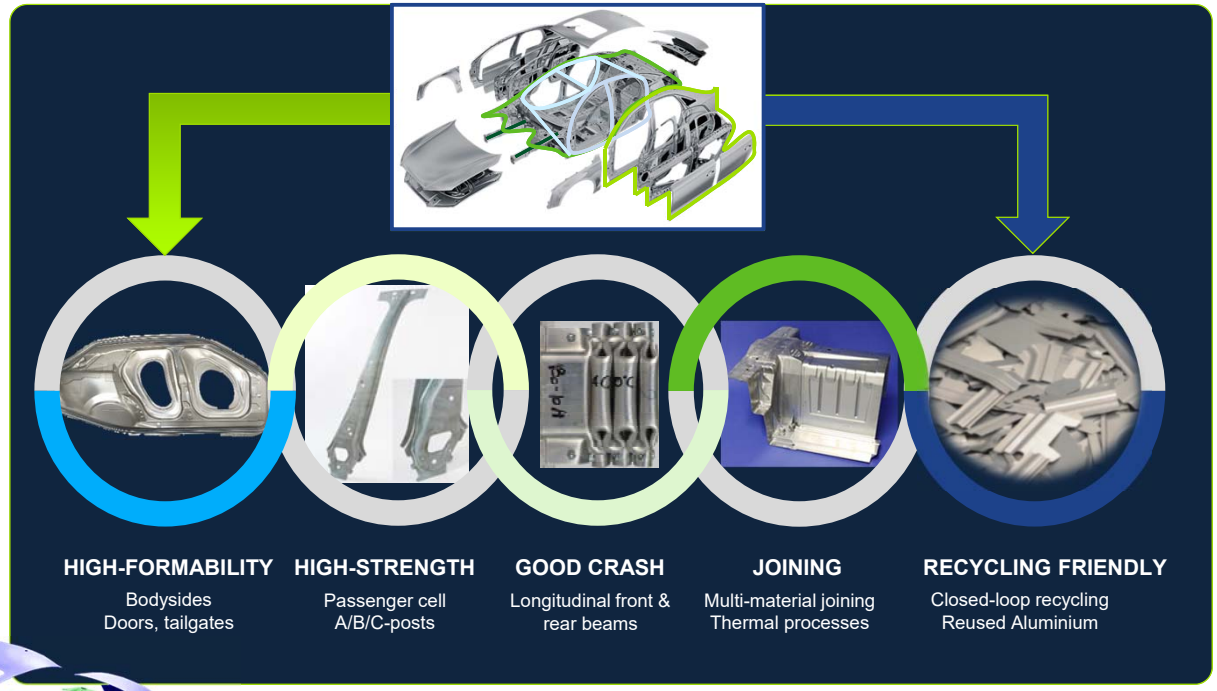
Lightweighting

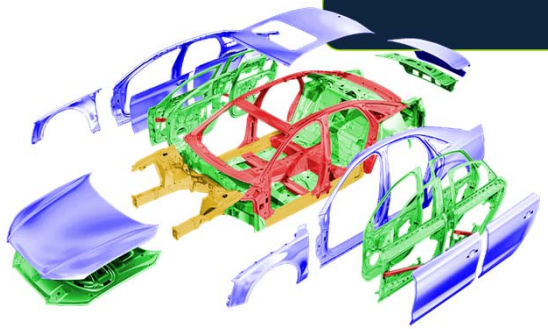
Safety cell

Crash boxes

Inner panels

Outer skin





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Material development

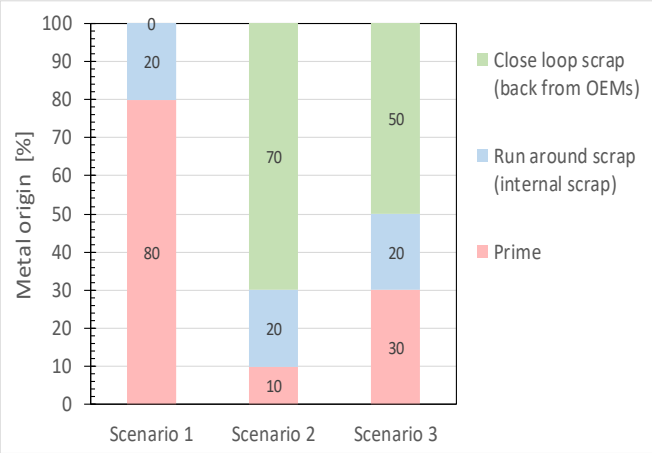
Performance through composition & process

N°	Grade description	Short name	Material features
1	6xxx T4 High Forming Conventional (monolythic)	6xxx HF mono	High elongation, deep drawing
2	6xxx T4 High Forming Fusion™ (sandwich)	6xxx HF Fusion	High elongation, deep drawing + able for very sharp radii
3	6xxx High Strength	6xxx HS, HSv2	Higher strength in service allowing for downgauging
4	6xxx Fusion Welding (High formable variant)	6xxx LW HF	6xxx HF mono in the core + clad allowing laser welding without filler wire
5	6xxx Fusion Welding (High strength variant)	6xxx LW HS	6xxx HS in the core + clad allowing laser welding without filler wire
6	7xxx High Strength	7xxx	Significantly higher strength than 6xxx

Material development

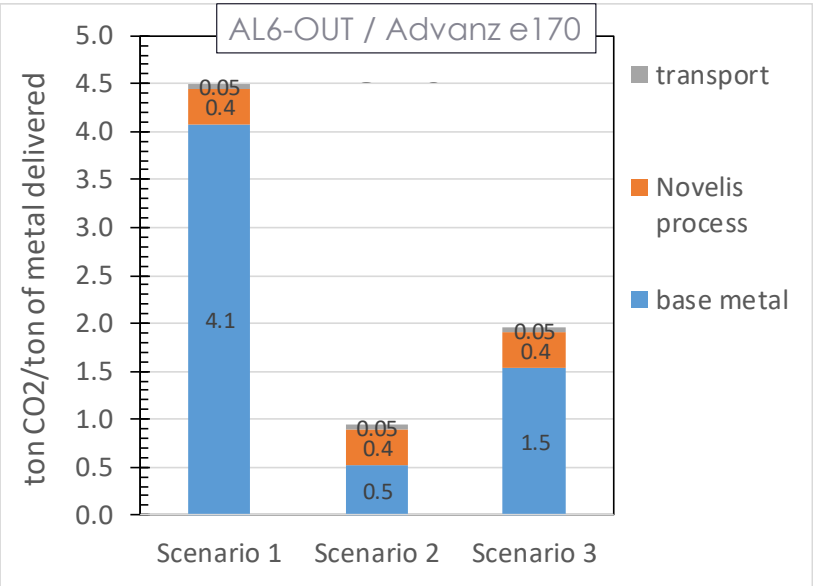
Compatibility for close loop recycling – impact on CO_2 footprint

electricity source	g CO2 / KWh	ton of CO2 to make 1 ton of prime from Alumina
nuclear	10	0.15
wind	20	0.3
hydro	10	0.15
photovoltaic	70	1.05
gas	400	6
coal	1000	15



Various scenarios of input metal mix

- **Smelting operation Al_2O_3 (oxide) ➔ Al (metal) requires 15'000 kWh to make 1 ton of primary Aluminium from Alumina**
- **Even smelter with green sources of electricity emit a lot of CO_2: 4 to CO_2 / 1 to of primary metal produced (carbon electrodes)**



CO_2 emissions to manufacture and deliver std AL6-OUT material to Volvo for hood manufacturing

Realistic figures are probaly between 2.5 and 1 to CO_2 to produce and deliver 1 to of Aluminium sheet to OEM (while initial numbers accounted for in Alliance show 5.6 to CO_2 for 1 to of Aluminium)

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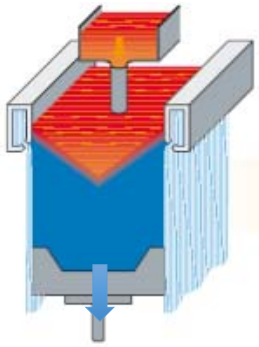
Material development

Fusion™ casting vs conventional DC

Direct-chill (DC) casting

- Semi-continuous process
- As the metal fills the mold (permanent, water cooled) and begins to solidify, the bottom block is lowered at a controlled rate
- Ingots are typically cast 4 to 6 at a time and weigh 10-15 tons each



Fusion™ casting

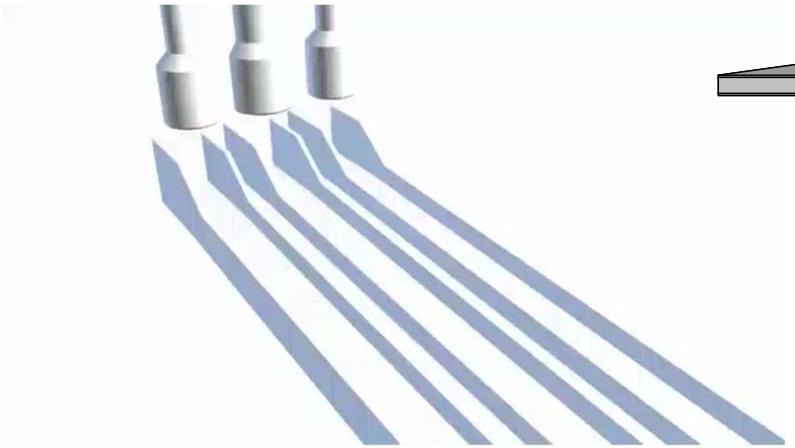
- Simultaneous casting of different alloys, high quality interface (metallurgical bond)
- Large freedom of alloys combinations → optimisation to the application

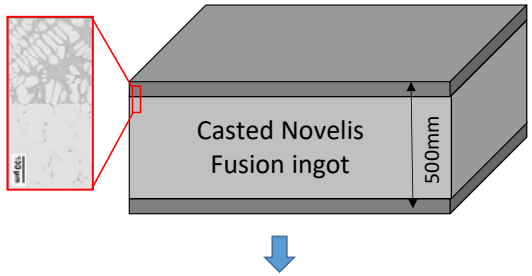
Core menu

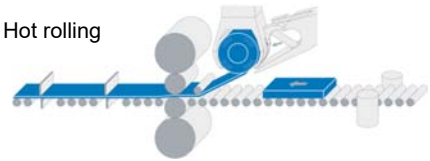
1. High formable
2. High strength
3. Very high strength
4. Crash
5. …

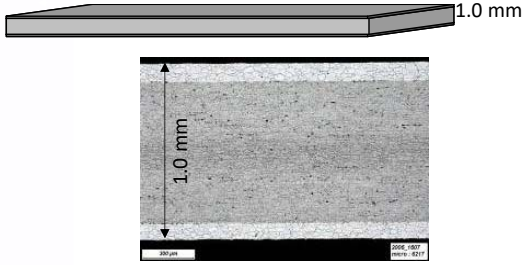
Clad menu

1. Improved bending
2. Weldable to Al or steel without filler nor gas
3. Corrosion protection
4. …









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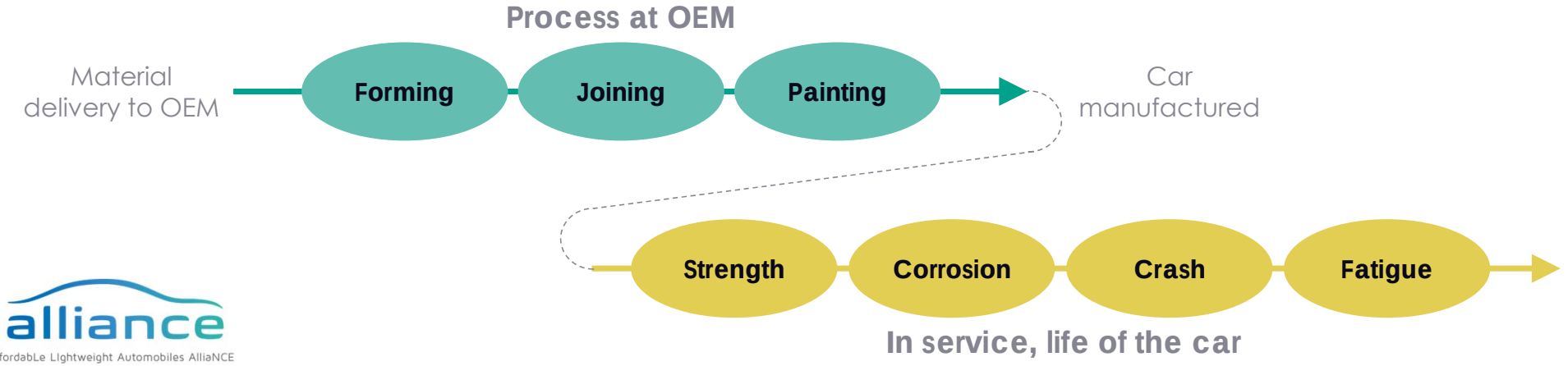
Material characterisation

Coupon level test matrix

	Test
Mechanical Properties and Forming Behaviour (as delivered)	Tensile test
	Bending, hemming
	Shear test
	Notched tensile
	Hole expansion
	Deep-drawing
	Bulge
	Surface Hardness
	Deep-drawing
Mechanical Properties (in service: BH, T6)	Tensile test
	Tensile shear
	Notched tensile
	Bulge
	Surface Hardness
Corrosion	Corrosion
	Phosphating
	ED Coat

	Test
Resistance Spot Welding	HAZ characterisation
	Tensile Shear
Adhesive Bonding	Pre-Treatment
SPR plus Adhesive Bonding	Cross section
	Tensile Shear
	Cross Tension
	Coach Peel
	Fatigue S-N curve
Laser Welding	HAZ characterisation
	Tensile Shear
	Coach Peel
	Cross Tension
	Torsion
	Welding Speed
MIG/MAG Welding	HAZ characterisation
	Tensile Shear
	Coach Peel
	Cross Tension
	Torsion
	Welding Speed

	Test
CAE Crash Card Data (tbc)	Tensile flow curve in 0° and 90°
	Tensile flow curve in 0° and 90°
	Notched tensile, notch radius 5mm
	Notched tensile, notch radius 80mm
	Shear test
	High speed tensile test
	Bulge test
CAE fatigue Card Data (tbc)[2]	Fatigue test
	Fatigue test



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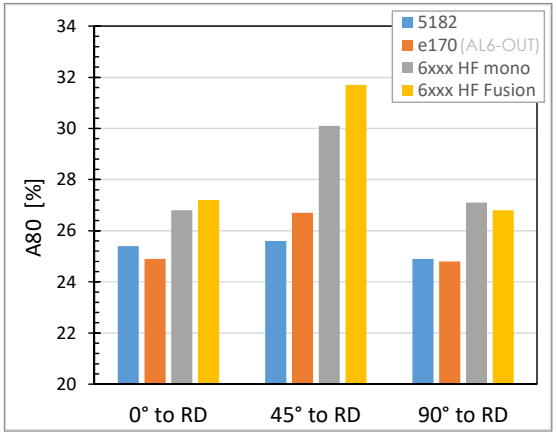
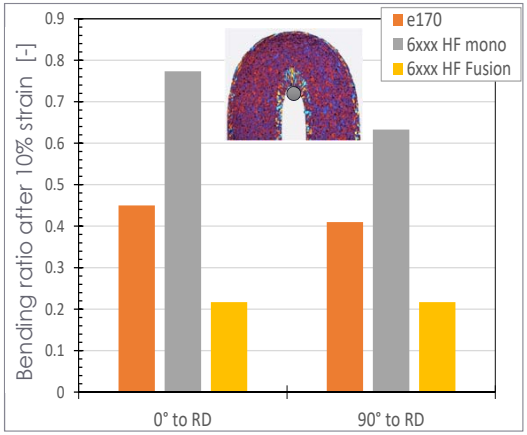
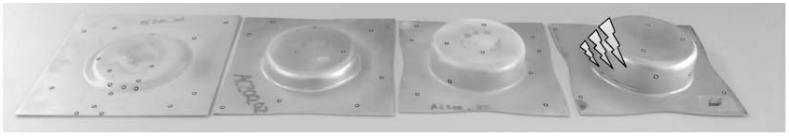
Material final properties

High formable grades

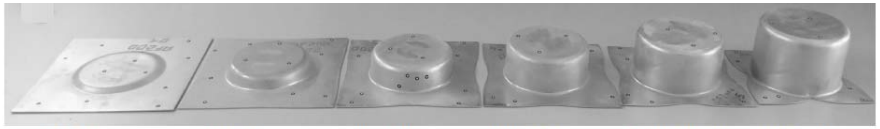




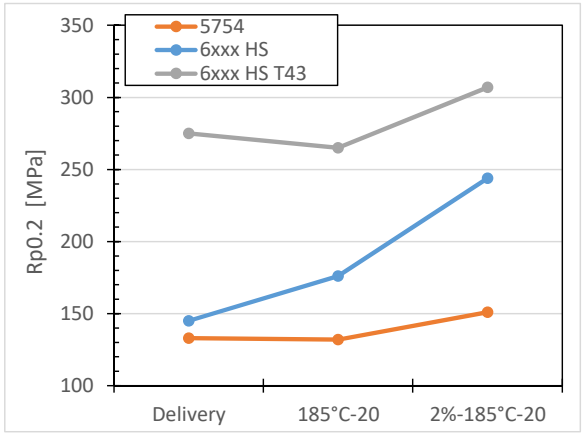
6xxx HF mono

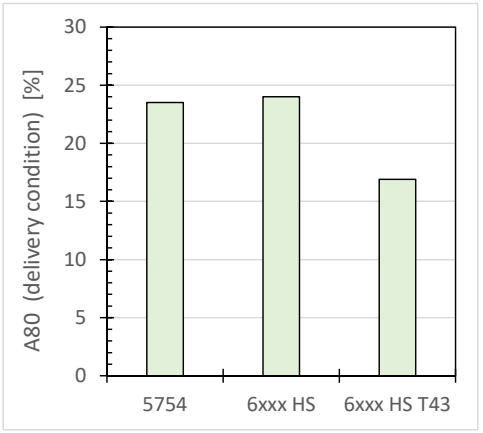


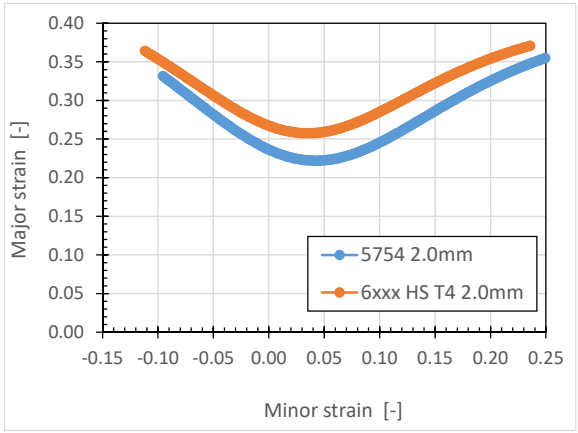
6xxx HF Fusion



High strength grades







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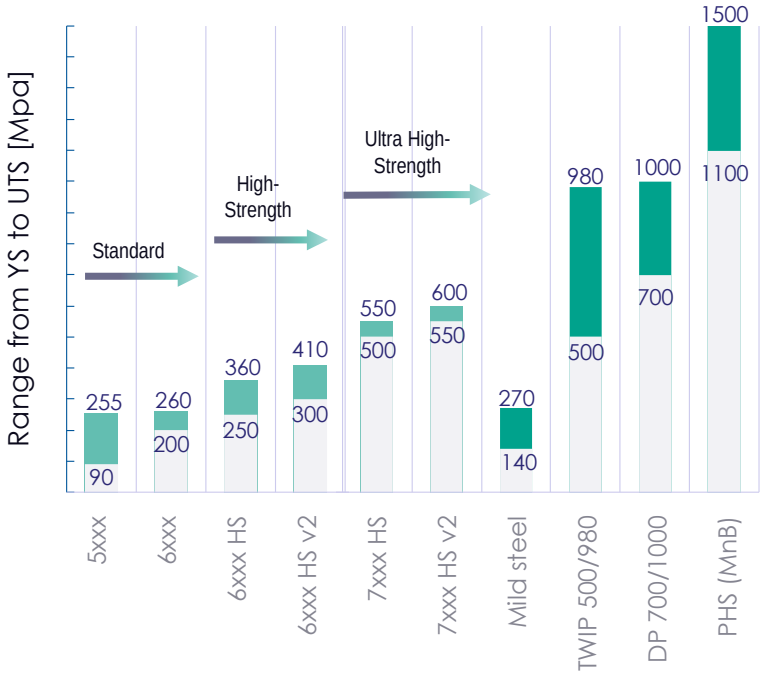
Material final properties

In-service Strength [MPa]



In-service specific Strength [MPa/(g/cm3)]

- **New high high strength Aluminium grades developed to compete against steel**

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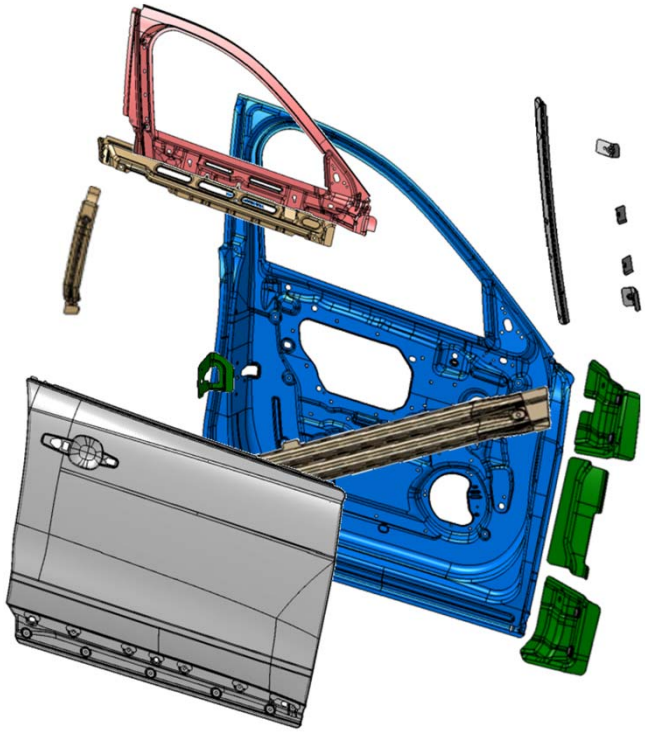
Material utilisation example 1

Aluminium sheet door concept

Reference vehicle: compact crossover SUV,SOP 2015, 75'000 veh/y - Reference steel door: 17.70 kg/door, 54.8 €/door



Front door	Al sheet concept
Concept	Al sheet
Materials	Uni alloy 6x
Door Inner	6xxx HF EDT 1.2mm
Door outer	6xxx HF EDT 0.9mm
Windows frame	6xxx LW HS 1.4mm
Reinforcements	6xxx HS / 6xxx HS v2 MF 1.2, 1.4, 2.5mm
SIB	s701 hot formed 2.0mm
Joining	Laser welding, SPR, RSW, hemming
Door weight	9.42 kg/door
Door cost	84.06 €/door
On cost vs Steel	**3.55 €/kg saved**

Next steps:

- **Improve material "utilization rate"**
- **Introduce close-loop recycling to reduce cost by keeping the value of the press-shop scrap and reduce CO_2 footprint**
- **Investigate cheaper / higher recycle content grades**

Preliminary study shows realistic scenario 3 €/kg saved !

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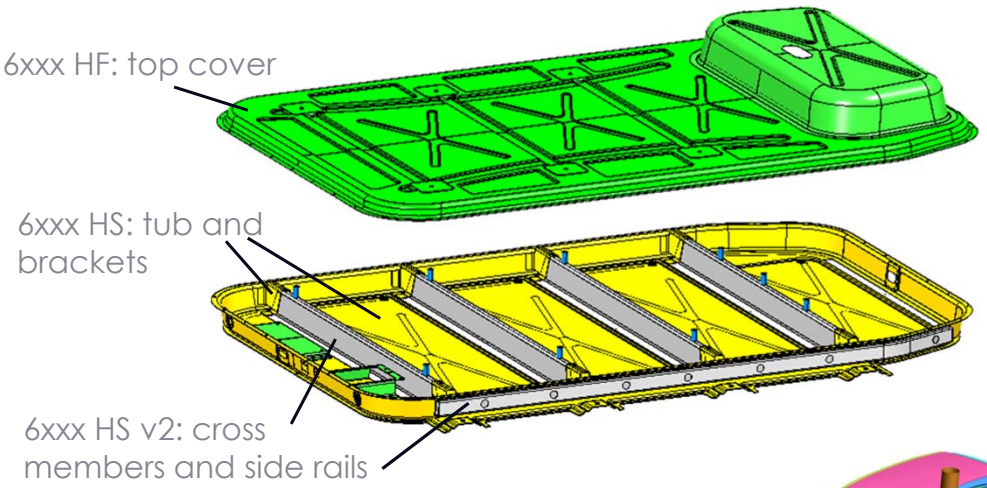
Material utilisation example 2

Aluminium sheet battery enclosure concept

- High formable and high strength grades used to make an Aluminium sheet battery enclosure
- Formability and dynamic load cases validated
- Affordable cost: 2.3 $/kg saved compared to equivalent steel sheet solution

OEM	Model	Storage (kWh)	Structural Weight (kgs)	Total Weight (kg)	Pack Energy Density (Wh/kg)	Vehicle Curb Weight (kg)	Range (km) (EPA or WLTP)
Tesla	Model 3 Long Rng	75	75	460	163	1847	450
Tesla (2013)	Model S Standard	60	131.5	500	120	1955	335
General Motors	Bolt	60	81.3	427	140	1625	383
Jaguar	iPace	90	108	606	149	2133	377
Audi	eTron Quattro	95	Not known	684	139	2611	328
Hyundai	Kona EV	63	86.7	452	139	1715	449
Novelis	**Design 1.0**	**90**	**63**	**554**	**162**	**N/A**	**375 – 500?**

Sources: evspecifications.com, A2Mac1, ev-database.org, InsideEVs



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Conclusion

Summary

- New high formable (6xxx) and high strength (6xxx + 7xxx) have been characterized
- Enhanced properties compared to standard reference grades
- Data available for forming, joining and in service evaluation available
- Samples for lab trials and physical demonstrators available

- Materials have been used for demonstrators in Alliance WP5
- Materials have been used for Novelis internal demonstrators (Aluminium sheet door concept, Aluminium sheet battery enclosure concept), resulting in sheet intensive, performant and affordable solutions
- Alloy composition developped to be compatible with close loop recycling and thus significantly reduce the CO_2 footprint and keep the value in the metal (recycled in the same grade, no down-grading)

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