A Comparison of the Body Structures of WorldAutoSteel FutureSteelVehicle and the EU SuperLIGHT-CAR

Reinventing Steel (Products and Applications)

CARS Magazine
October 1953

“ The day of the passenger car made primarily of iron and steel is on the wane” giving ground to aluminum, magnesium and plastics.

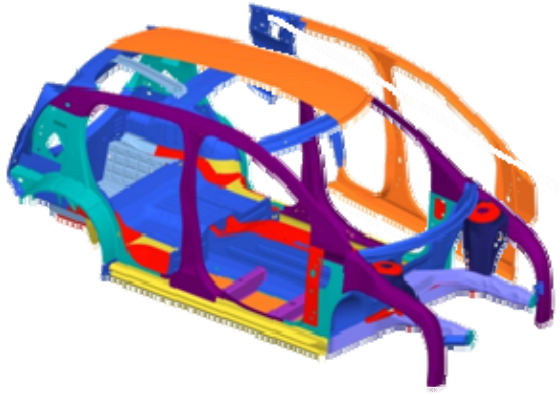
1970s – Body-on-Frame
→ **Body-Frame-Integral**

1980s – Uncoated
→ **Galvanized Rust Resistant**

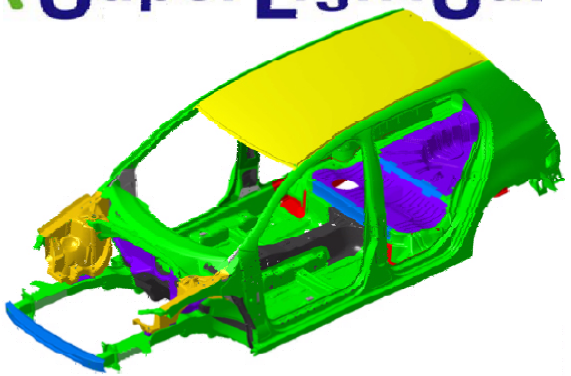
1990s – Mild Steel
→ **HSLA and Bake Hard Steel**

2000s – Mild & HSLA
→ **Advanced High Strength Steels**

FutureSteelVehicle



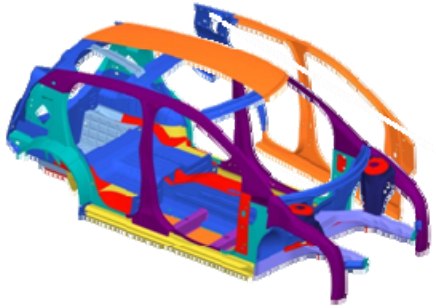
SuperLightCar



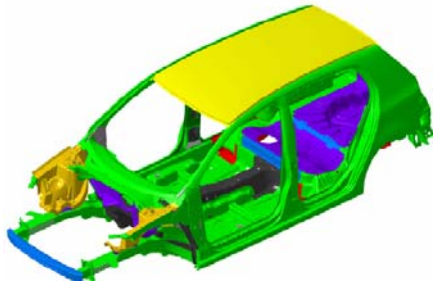
Projects:	**4 Year Multi-Million Euro Advanced Material Lightweighting CAE Concept Body Structure Study**	
Objectives:	**Develop lightweight Structure High Volume Manufacturing Equivalent Performance Reduce Fuel Use Reduce CO2 Emissions**	
	At no additional cost	**Less than €5/kg saved**
Consortium	**17 Steel Partners 3 Engineering Contractors**	**37 Partners**

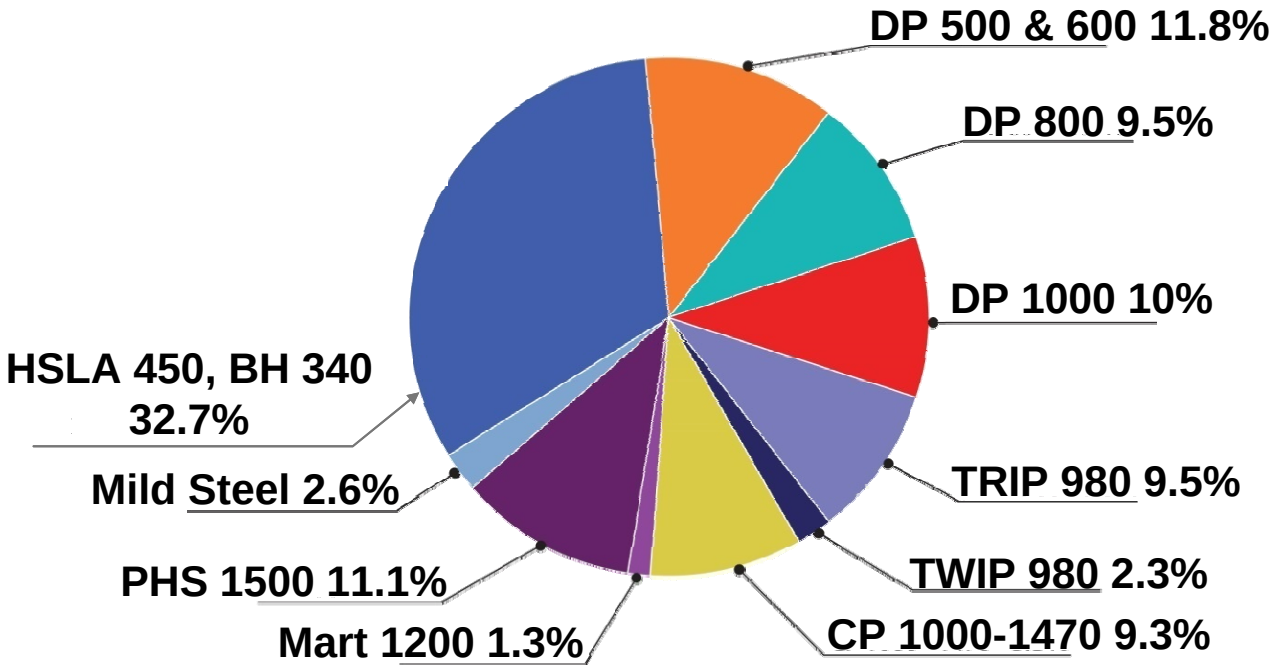
Advanced Lightweighting Materials

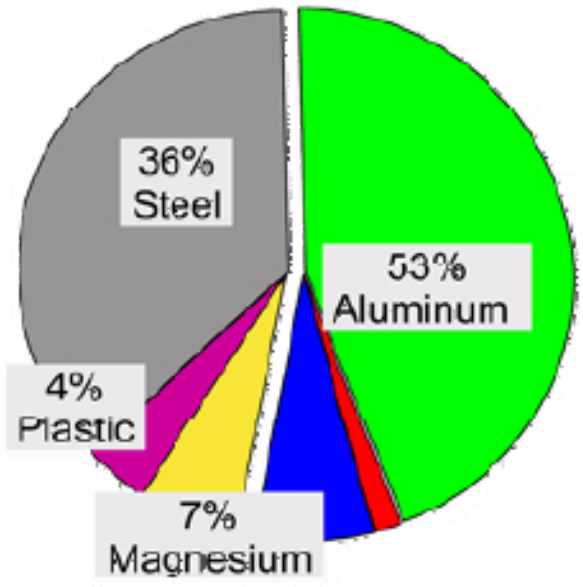
FSV



SLC





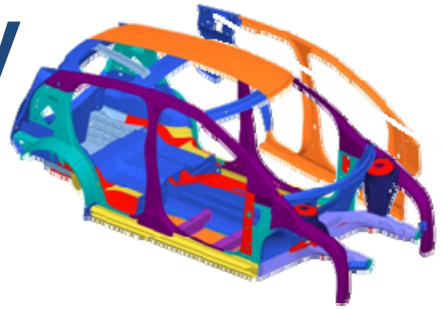


Sheet Only

Sheet, Extrusions, Castings

Vehicle Dimensions

FSV



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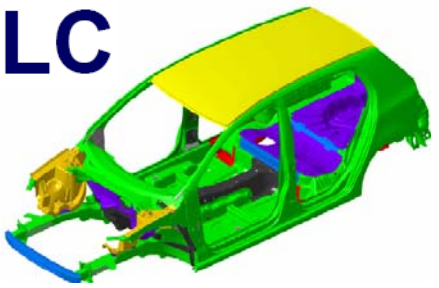
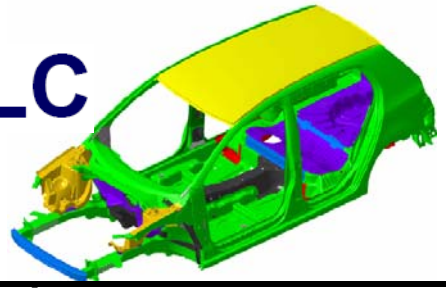


	FSV	SLC
Passenger	5	5
Length	3820 mm	4204 mm
Width	1759 mm	1705 mm
Wheel Base	2524 mm	2512 mm
Track	1470 mm	1493 mm
Height	1495 mm	1452 mm
Front Leg Room	1065mm	1054 mm
Rear Leg Room	850 mm	850 mm
Cargo	509 l.	250 l
Powetrain Mass	BEV 329 kg	ICE 197 kg
Gross Veh. Wt	1433 kg	1615 kg
Curb Wt	958 kg	1108 kg
BIW Mass	187.7 kg	180 kg

Vehicle Crash Performance

FSV

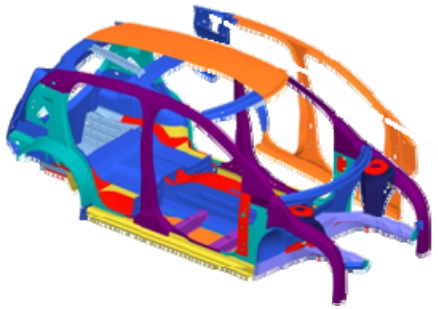
SLC



	EuroNCAP Front	Intrusion Foot Avg.= 91mm Door Opening = 18mm Deceleration Pulse = 41 G	Intrusion Foot Avg.= 45mm Door Opening = 20mm Deceleration Pulse = 56 G
	EuroNCAP Side	B-Pillar Intrusion = 80 mm (Survival Space = 215 mm)	B-Pillar intrusion = 197 mm
	FMVSS 216 Roof Strength	4.25 x Vehicle Weight	3.0 x Vehicle Weight
	EuroNCAP Pole	Door Intrusion = 181 mm (Survival Space = 169 mm)	B-Pillar intrusion = 297 mm
	FMVSS 301 Rear (No Offset)	Passed (No battery dammage, rear door open)	Passed (Met Reference Vehicle)
North American Market Additional 15 kg	US NCAP Frontal	Foot Avg.= 68mm Door = 9mm Pulse = 40 G	
	IIHS Side Impact	B-Pillar Intrusion = 260 mm (Survival Space = 136 mm)	
	FMVSS 301 Rear (70% Offset)	Passed (No battery damage, rear door open)	
	FMVSS 214 Pole	Intrusion = 191 mm (Survival Space = 159)	
	IIHS Roof Strength	4.25 x Vehicle Weight	

Vehicle Stiffness Performance

FSV



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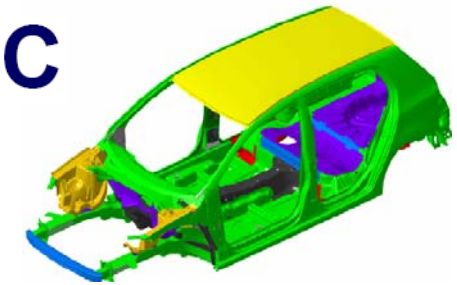
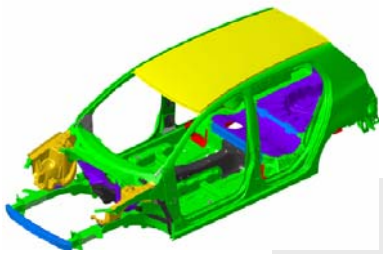


Torsional Stiffeness	19.6 KN-m/deg.	25.5 KN-m/deg.

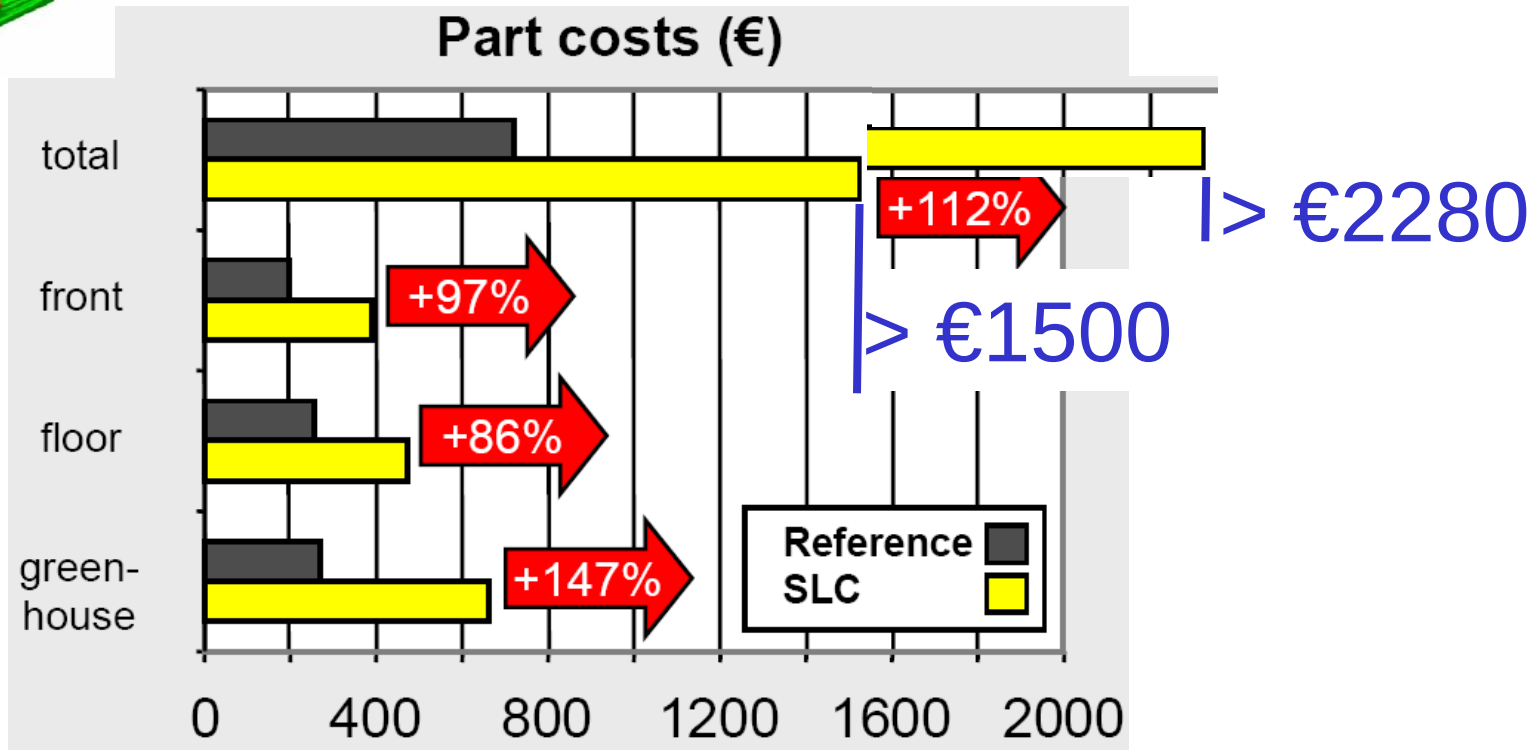
1st Torsional Mode	54.8 Hz	50.0 Hz
1st Bending Mode	60.6 Hz	53.1 Hz

Vehicle Cost Performance



SuperLIGHT-CAR Cost tool

SLC



ARB Lightweighting Workshop May 18, 2010

- Body part cost for BIW is +112% over reference body
  - This yields a 7.85 Euro/kg light weight cost for body parts only

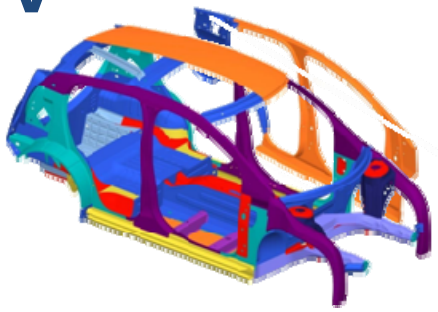
VW Group analysis

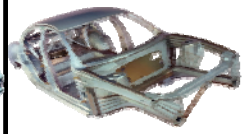
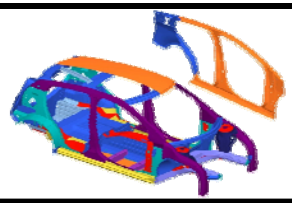
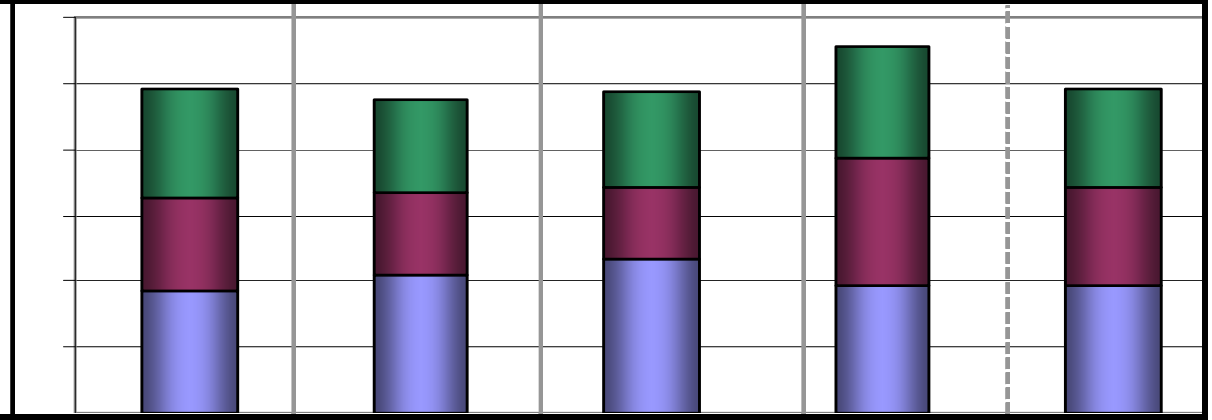
- SLC project did not consider full joining costs, assembly cost, tooling cost and factory alterations to accommodate new materials
  => True cost/kilogram will be doubled

Vehicle Cost Performance

MIT Technical Cost Model

FSV



	 1994 Ref Vehicle	 ULSAB	 ULSAB-AVC	 FSV	
Units/Yr (x1000)	**225**	**225**	**225**	**100**	**225**
Manufactuing Cost ($)					
Steel	**$369**	**$416**	**$468**	**$388**	**$388**
Forming	**$282**	**$250**	**$213**	**$387**	**$298**
Assembly	**$328**	**$281**	**$291**	**$340**	**$295**
Body Cost	**$997**	**$947**	**$979**	**$1,115**	**$981**

€740

Vehicle Mass Performance

Mass Normalization Comparison

- A2MAC1 Tear Down Data Base – 108 Vehicles
- Body Structure Mass = BIW + Paint and Sealer + Engine Cradle
- Performed Regression Analysis for Vehicle Attributes (non-performance)

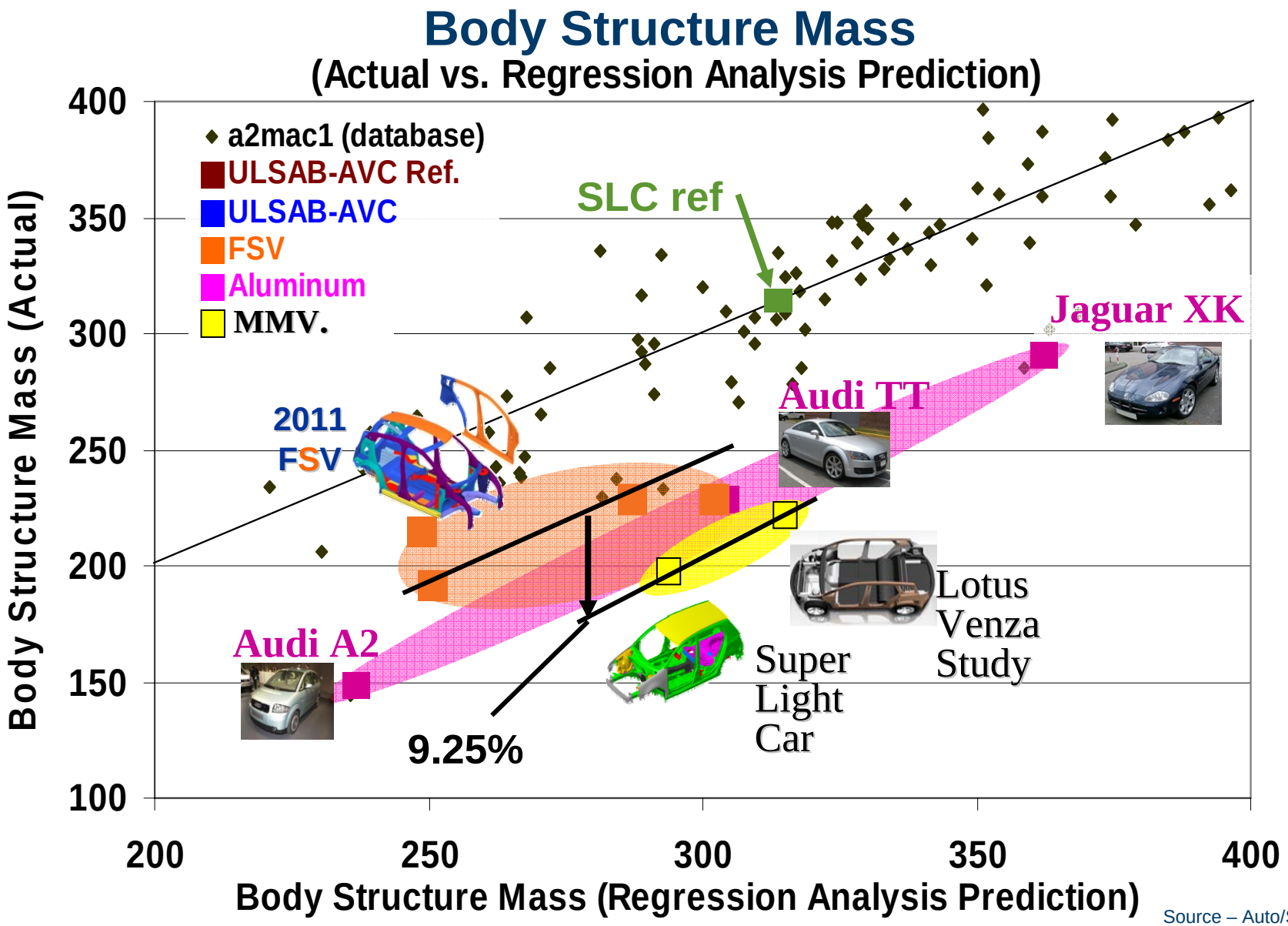
Attribute	Type
GVW (kg)	continuous variable
Area (m^2)	continuous variable
material	(Aluminum), (Steel)
Body Type	Sedan, Hatchback, SUV, Van, Pickup, Convertible, Station Wagon
Drive Configuration	FWD, RWD, 4WD, AWD
Model Year	Continuous variable

- Correlation Attributes were GVW, Area, Drive Configuration, Material

$$\hat{m} = 3.418(GVM, kg)^{0.438}(Area, m^2)^{0.599}\begin{pmatrix} 1.02FWD \\ 1.00RWD \\ 1.08AWD \end{pmatrix}$$

**Material not included in equation for more direct comparison*

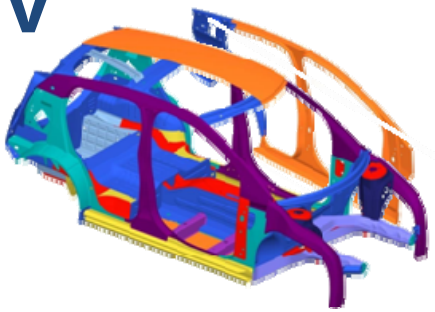
FSV Compared to UltraLight – Mass



Source – Auto/Steel Partnership
- USS internal analysis

Vehicle Mass Performance

FSV



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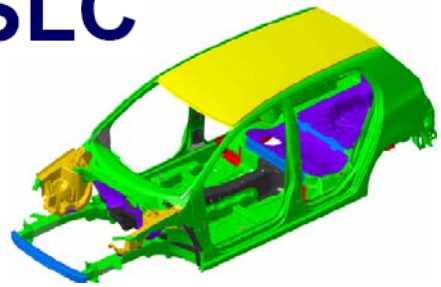
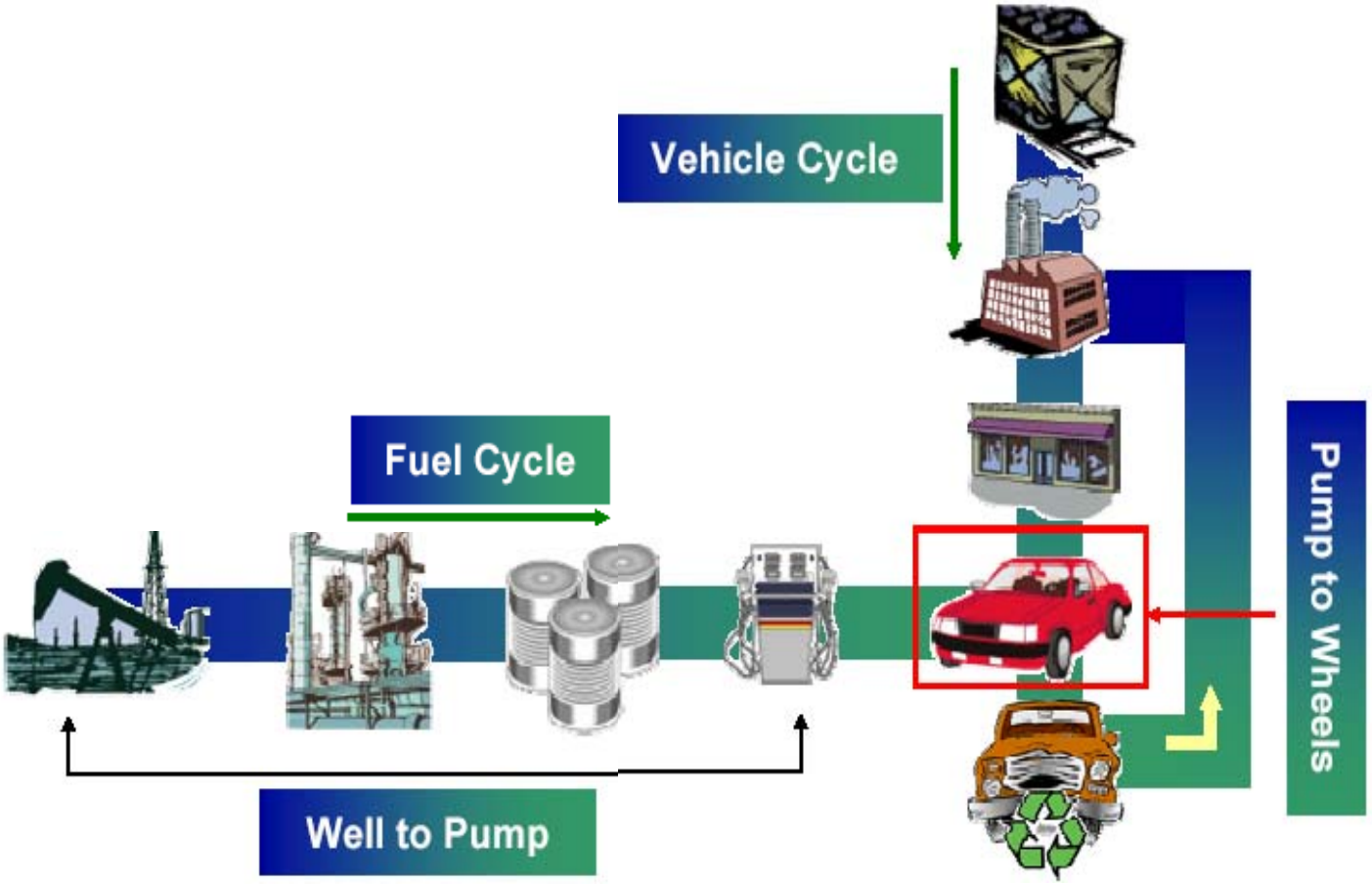


Base Line Mass	187.7 Kg	180 Kg
Normalized to SLC ICEg Variant	206.8 Kg	180 Kg
Normalized to FSV BEV Variant	187.7 Kg	163 Kg

Vehicle CO_2 Emissions Performance
Life Cycle Assessment



Source – Argonne national lab

Vehicle CO_2 Emissions Performance
Life Cycle Assessment

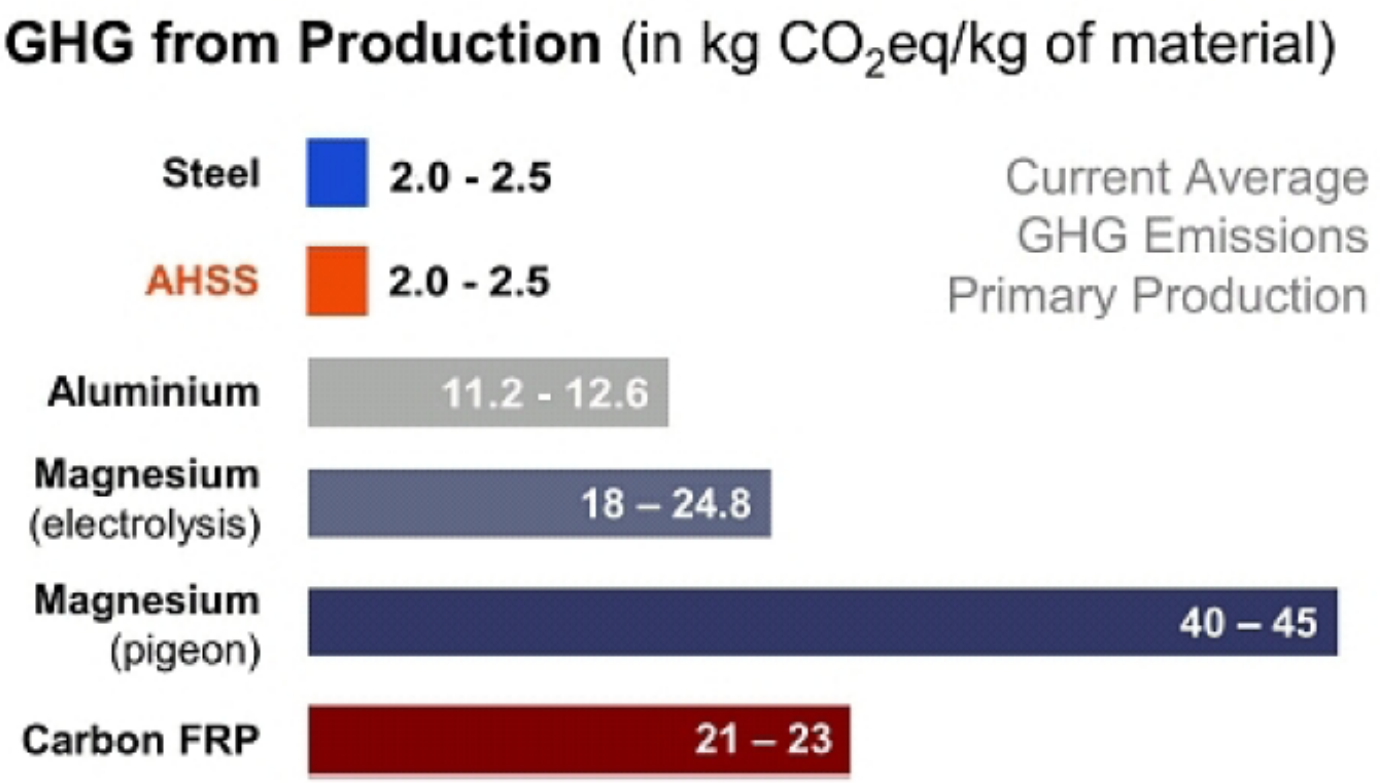


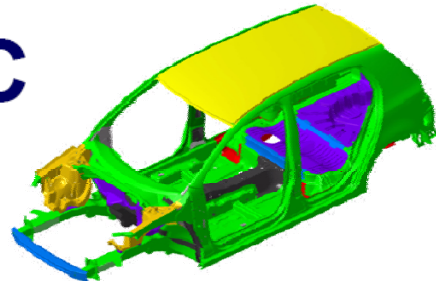
Figure 2.9: *Material production Green House Gas (GHG) emissions*

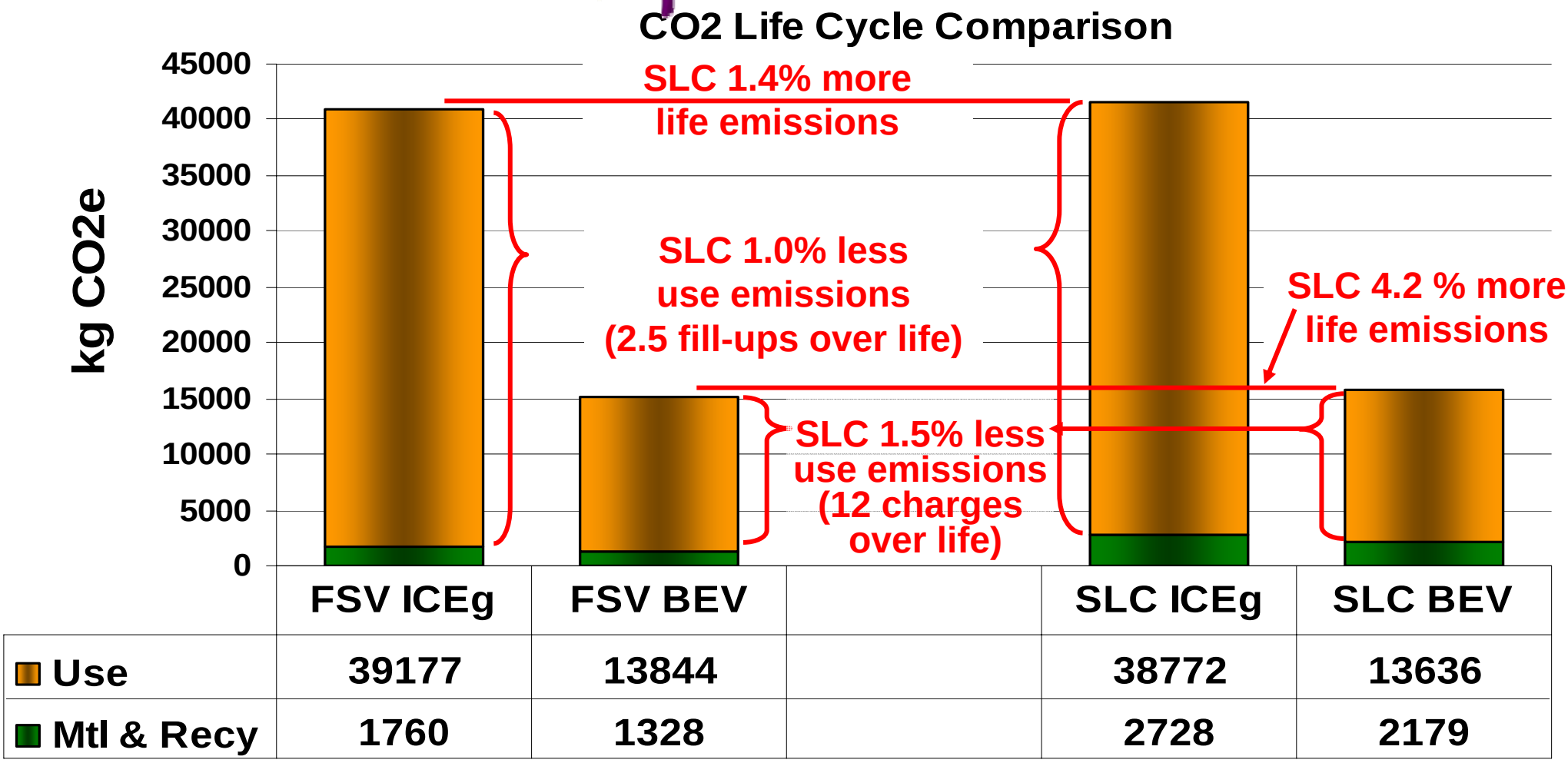
Source – World Steel association
- International Aluminum Association
- Roland Guirer UC Santa Barbara

Vehicle CO_2 Emissions Performance

FSV

SLC

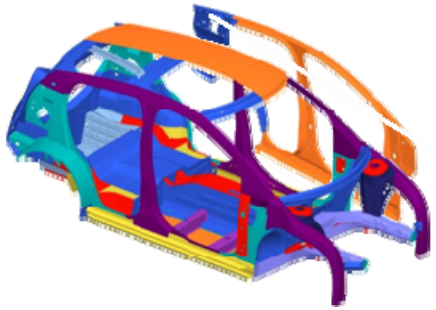
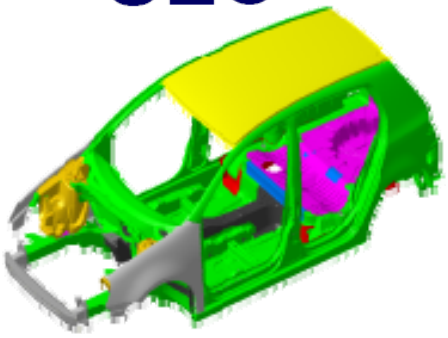




	FSV ICEg	FSV BEV		SLC ICEg	SLC BEV
Use	39177	13844		38772	13636
Mtl & Recy	1760	1328		2728	2179

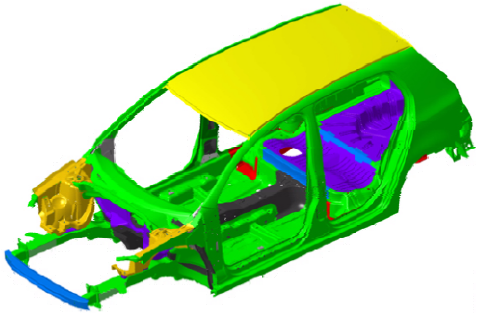
FSV Compared to Multi-Material

Weight, Cost, GHG Emissions

		FSV 	SLC 	SLC Relative to FSV
	Weight	188 kg	180 kg	(9.25%)
	Cost	€740	€2280	308%
ICEg	Use GHG	39,177 kg	38,772 kg	(1.0%)
	Life Cycle GHG	40,937 kg	41,500 kg	1.4%
BEV	Use GHG	13,844 kg	13,636 kg	(1.5%)
	Life Cycle GHG	15,172 kg	15,815 kg	4.2%

Acknowledgements

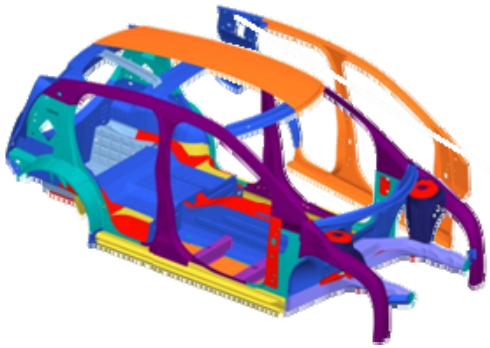
SuperLightCar



All research activities are integrated in the european funded project **SLC** (**S**ustainable **P**roduction Technologies of **E**mission **R**educed **Light** weight **Car** concepts) with 6th Framework Programme

- SLC Sub-project & task leaders
- SLC consortium partners
- Supporting external organizations
- European Community

FutureSteelVehicle



FurtureSteelVehicle was accomplished by the technical contributions of the 17 member companies and the engineering contractors of EDAG, ETA and LMS

EDAG eta LMS ENGINEERING INNOVATION

Thank you for your attention