European Commission

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AffordabLe LIghtweight Automobiles AlliaNCE

Future of Automotive Lightweighting Day

September 19, 2019

European Commission

Horizon 2020
European Union funding
for Research & Innovation

AffordabLe LIghtweight Automobiles AlliaNCE

Life Cycle Assessment

University of Florence

Introduction & Objectives

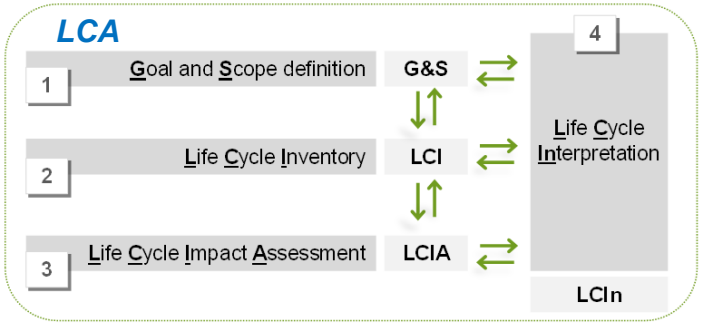
Objectives & Targets

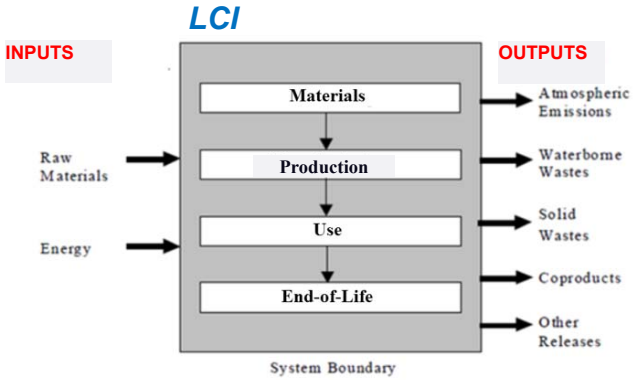
Comparative environmental assessment of ALLIANCE vehicle modules

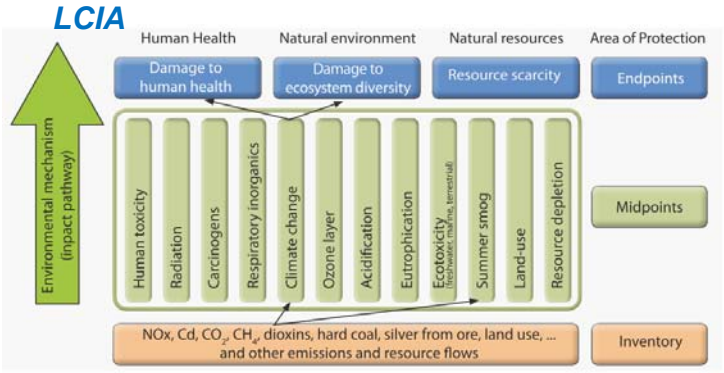
- Reference design
- Lightweight design

Materials and method

- Life Cycle Assessment methodology
- GaBi6 software (Thinkstep)
- Global Warming Potential – kg CO2 eq (LCIA method: CML 2001)







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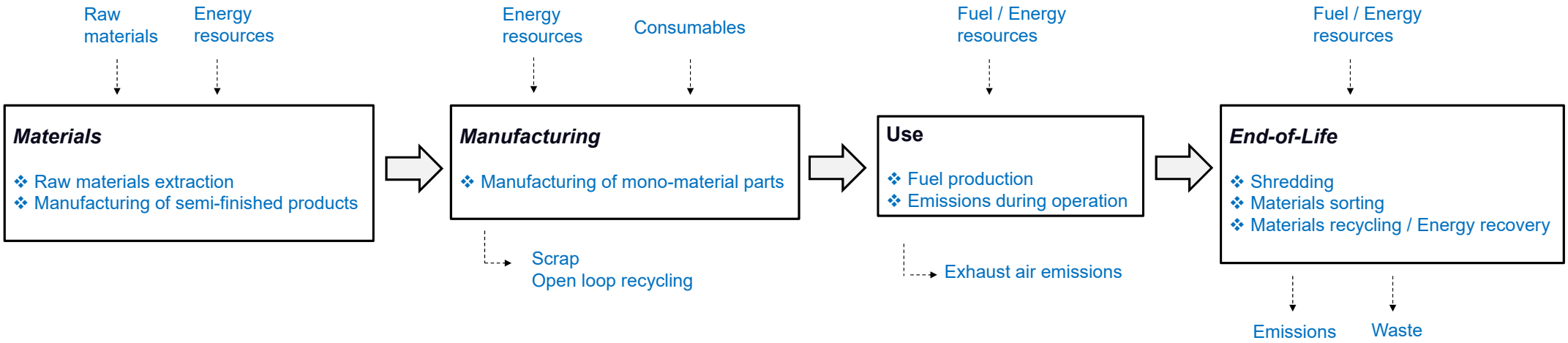
Goal & scope definition

Functional Unit

Module installed on a gasoline vehicle over 230000 km LC mileage

System boundaries



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Life Cycle Inventory

■ Materials & Manufacturing stages: LCI modelling approach

LCI data collection:

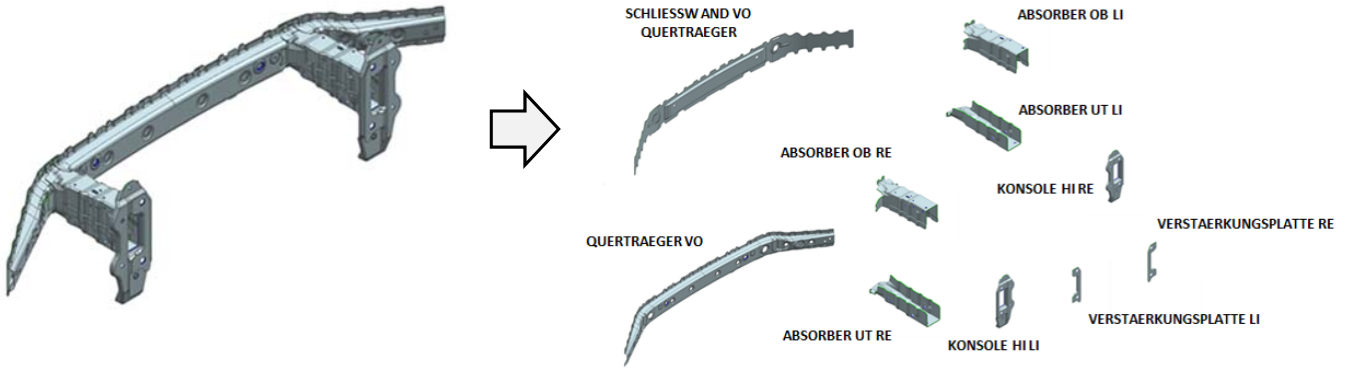
- ❖ Material composition
- ❖ Manufacturing processes data

  - Material/energy consumption
  - Emissions to the environment
  - Waste production

BREAK-DOWN APPROACH

Example: Bumper System (DAIMLER)

Module ***Mono-material parts***



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Life Cycle Inventory

■ Materials & Manufacturing stages: LCI primary data

Hood (CRF)	Material composition		Manufacturing process	Scrap rate [%]
	Material	Mass [kg]		
Reference module (total mass: 7.5 kg)	Steel	6.9	Stamping double effect	55.0 - 62.0
	Steel	0.7	Multi operation stamping	65.0 - 80.0
Lightweight module (total mass: 3.6 kg)	AW6111	1.9	Stamping	62.0
	AW5182	1.4		20.0 - 58.0
	Steel	0.3	Multi-operation stamping	30.0

Bumper System (CRF)	Material composition		Manufacturing process	Scrap rate [%]
	Material	Mass [kg]		
Reference module (total mass: 4.5 kg)	Aluminium	4.1	Extrusion	-
	Aluminium	0.5	Stamping	-
Lightweight module (total mass: 3.3 kg)	AW7003	2.0	Extrusion + Forming	25.0-30.0
	AW7003	1.0	Extrusion	25.0-30.0
	AW7003	0.3	Extrusion + Cutting	25.0-30.0

Bumper System (DAIMLER)	Material composition		Manufacturing process	Scrap rate [%]
	Material	Mass [kg]		
Reference module (total mass: 13.1 kg)	CR340LA GI50/50-U	4.6	Deep drawing	26.5 - 47.9
	HR340LA GI50/50-U	2.5		46.2 - 52.0
	PSC950Y1300T	3.2	Annealing	-
	CR330Y590T – DP GI50/50-U	2.9	Deep drawing	22.3
Lightweight module (total mass: 11.9 kg)	CR340LA GI50/50-U	4.6	Deep drawing	26.5 - 47.9
	HR340LA-GI50/50-U	2.5		46.2 - 52.0
	Q&P1180	4.8		22.3 - 42.4

Rear Floor Pan (TME)	Material composition		Manufacturing process	Energy consumption [kWh/kg]	Scrap rate [%]
	Material	Mass [kg]			
Reference module (total mass: 6.9 kg)	Steel	5.3	Cold stamping	-	-
	Acryl/SBR rubber	0.9	-	-	-
	Vynil	0.3	-	-	-
	Urethane	0.4	-	-	-
Lightweight module (total mass: 5.3 kg)	Polypropylene GF 40% reinforced	3.3	Injection (IMC)	1.7-1.9	3.0 - 4.0
	Steel	1.6	Stamping	0.24-0.84	1.0
	Steel	0.3	Cold stamping	1.7-1.9	-
	Urethane	0.2	-	0.24	-

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Life Cycle Inventory

■ Materials & Manufacturing stages: LCI primary data

Rear Bumper system EU (TME)	Material composition		Manufacturing process
	Material	Mass [kg]	
Reference module (total mass: 4.0 kg)	HCT600X	2.1	Cold stamping
	HC420LA	0.1	
	HC260LA	0.1	
	HCT980X	1.6	
Lightweight module (total mass: 2.4 kg)	EN AW7003 LS	1.1	Extrusion
	EN AW7003 HS	1.2	
	EN AW6082	0.1	

Rear Bumper system US (TME)	Material composition		Manufacturing process
	Material	Mass [kg]	
Reference module (total mass: 6.9 kg)	HCT600X	1.8	Cold stamping
	HC420LA	1.1	
	HC260LA	0.1	
	EN AW7003 HS	4.0	
Lightweight module (total mass: 3.8 kg)	EN AW7003 T7	0.3	Extrusion
	EN AW7003 T79	0.8	
	EN AW7046	2.6	
	EN AW6082 T7	0.1	

Door structure (VW)	Material composition		Manufacturing process	Scrap rate [%]
	Material	Mass [kg]		
Reference module (total mass: 35.2 kg)	CR 180BH	6.0	Deep drawing	45.0
	CR4	10.7		45.0
	CR210LA+GI40/40-U	1.3		60.0
	CR1350Y 1700Z-MS	8.0		90.0
	CR300LA+GI40/40-U	5.9		55.0
	CR240LA	2.0		60.0
	DP-K900Y1180T-DH	1.3		60.0
Reference module (total mass: 24.6 kg)	Aluminium TL 094 T6 (600°)*	3.2	Deep drawing	45.0-60.0
	Epoxy Resin GF 42% reinforced	5.2	Resin Transfer Molding	45.0
	CR210LA+GI40/40-U	0.6	Deep drawing	60.0
	MBW-K 1900	8.0		90.0
	CR300LA+GI40/40-U	5.8		55.0
	Aluminium TL 114 T6 (600°)**	0.7		60.0
	DP-K900Y1180T-DH	1.0		60.0

Door structure (VOLVO)	Material composition		Manufacturing process	Energy consumption [kWh/kg]	Scrap rate [%]
	Material	Mass [kg]			
Reference module (total mass: 19.7 kg)	Steel - DC06	16.8	Deep-Drawing	0.22 - 0.28	49.8-60.2
	Aluminum 6060	0.2			33.1
	Steel - DP1000	1.7			33.6
	Steel - DP600	1.0			-
Lightweight module (total mass: 11.0 kg)	DIN EN 6016/e170	3.0	Deep-Drawing	0.22 - 0.28	50.7
	DIN EN 6016/e600PX	3.7			33.3-60.2
	DIN EN 6016/e200	2.6			52.1
	Steel - DP1000	1.7			33.6

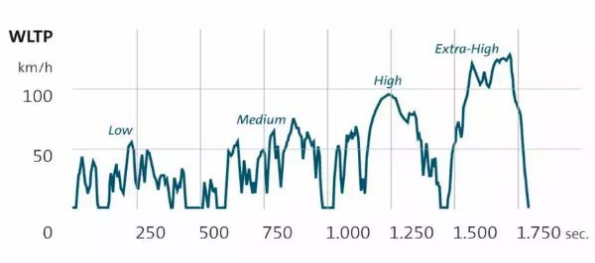
Life Cycle Inventory

- **Use stage: LCI modelling approach**

Well-To-Tank (WTT)

LCI data: Fuel consumption and electricity associated with the module [kg]

$$FC_{module} = \frac{FRV * m_{module} * mileage_{use}}{10000} * \rho_{fuel}$$



FRV [l/100 kg*100 km] (Source: Del Pero et al., 2017)

Tank-To-Wheel (TTW)

LCI data: CO_2 emissions associated with module operation (CO_2 module) [g]

$$CO_{2\,module} = CO_{2\,km} * mileage_{use} * \frac{FC_{module}}{FC_{veh}}$$

$$FC_{veh} = \frac{FC_{100km}}{100} * mileage_{use} * \rho_{fuel}$$

$$FC_{100km} = \frac{CO_{2\,km}}{2370} * 100$$

CO_2 km = 192 [g/km] (European Env. Agency - EEA, 2018)

2370 = mass of CO_2 per litre of petrol [g/l] (Amit et al., 2006)

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Life Cycle Inventory

- **Use stage: LCI primary/secondary data**

	Propulsion technology	Vehicle segment	Mileage [km]	FRV [l/100km*100kg]	CO_2 emissions [g/km]
Hood (CRF)	ICE gasoline turbocharged	Small car	230000	0.168	96
Bumper System (CRF)		Sub-compact Sport Utility Vehicle		0.170	150
Bumper System (DAIMLER)		Mid-size Sport Utility Vehicle		0.178	221
Rear Floor Pan (TME)		Sub-compact Sport Utility Vehicle		0.170	144
Rear Bumper System EU (TME)		Sub-compact Sport Utility Vehicle		0.170	144
Rear Bumper System US (TME)		Sub-compact Sport Utility Vehicle		0.170	144
Door Structure (VOLVO)		Full-size Sport Utility Vehicle		0.178	192
Door Structure (VW)		Large Multi Purpose Vehicle		0.179	159

Life Cycle Inventory

- **End-of-Life stage: LCI modelling approach**

2000/53/EC directive & ISO standard 22628:2002

1. Depollution
2. Dismantling
3. Shredding
4. Post-shredding

EoL processes

- ✓ Shredding
- ✓ Materials separation
- ✓ Materials recycling

Shredding

Materials separation

Materials recycling

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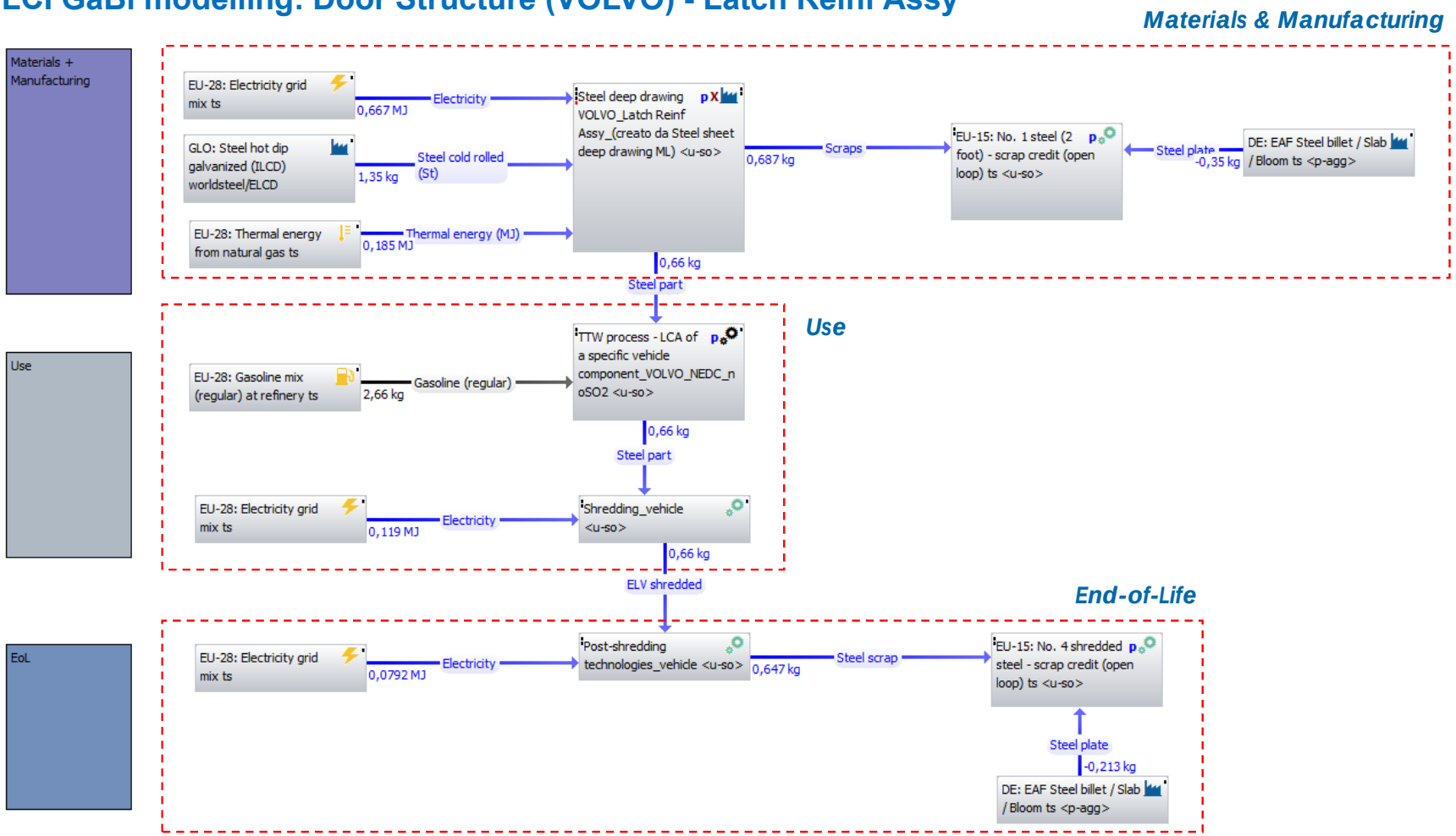
Life Cycle Inventory

End-of-Life stage: LCI secondary data

			Electricity for shredding [MJ/kg]	Electricity for materials sorting [MJ/kg]	Separability rate [%]	Substitution ratio [%]
REFERENCE	*Hood (CRF)*	*Steel parts*	0.18	0.12	98	33
	Bumper System (CRF)	*Aluminium parts*			98	42
	Bumper System (DAIMLER)	*Steel parts*			98	33
	Rear Floor Pan (TME)	*Steel parts*			98	33
		Polymeric materials parts			-	-
	Rear Bumper System EU (TME)	*Steel parts*			98	33
		Aluminium parts			51	42
	Rear Bumper System US (TME)	*Steel parts*			98	33
		Aluminium parts			51	42
	Door Structure (VOLVO)	*Steel parts*			98	33
		Aluminium parts			51	42
	Door Structure (VW)	*Steel parts*			98	33
LIGHTWEIGHT	*Hood (CRF)*	*Steel parts*	0.18	0.12	98	33
		Aluminium parts			98	42
	Bumper System (CRF)	*Aluminium parts*			98	42
	Bumper System (DAIMLER)	*Steel parts*			98	33
	Rear Floor Pan (TME)	*Steel parts*			98	33
		Polymeric materials parts			-	-
	Rear Bumper System EU (TME)	*Aluminium parts*			51	42
	Rear Bumper System US (TME)	*Aluminium parts*			51	42
	Door Structure (VOLVO)	*Steel parts*			98	33
		Aluminium parts			51	42
	Door Structure (VW)	*Steel parts*			98	33
		Polymeric materials parts			-	-

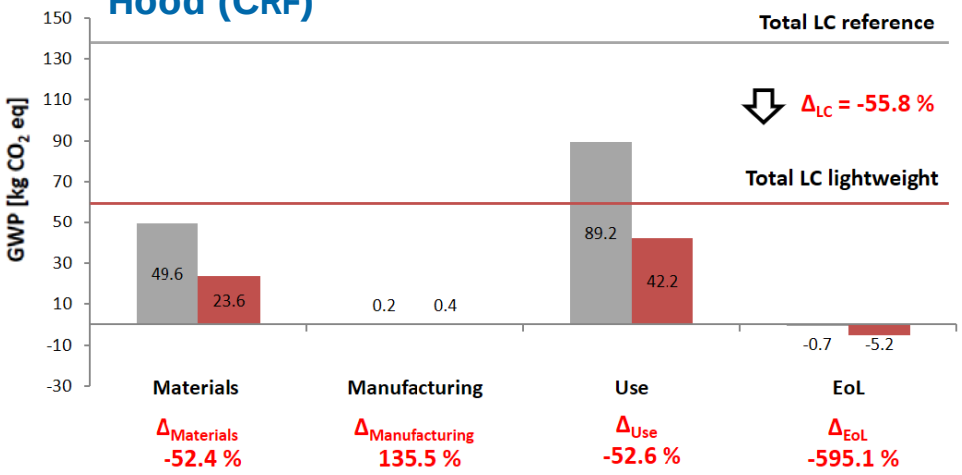
Life Cycle Inventory

- **LCI GaBi modelling: Door Structure (VOLVO) - Latch Reinf Assy**



LCIA – Comparative assessment reference/lightweight

Hood (CRF)



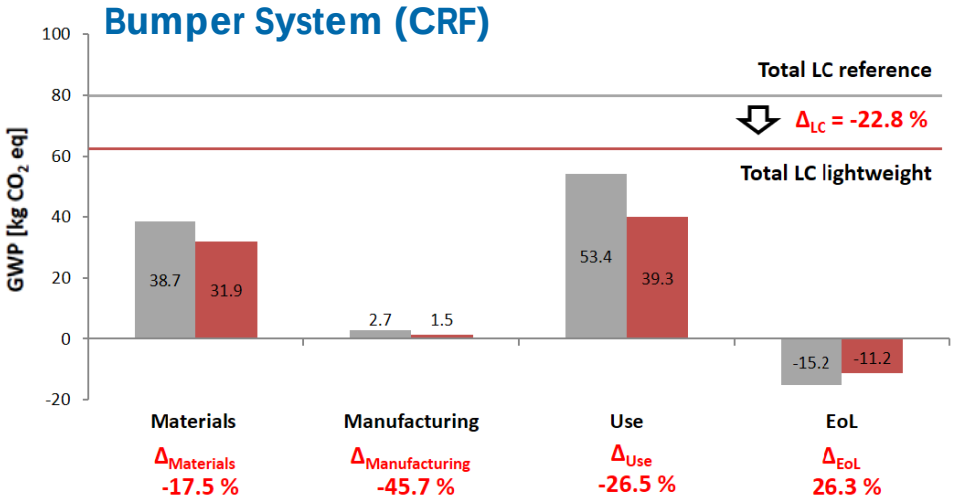
Reference design (7.5 kg)
- 100% Steel (stamping)

Lightweight design (3.6 kg)
- 91% Alu 5000/6000s (stamping)
- 9% Steel (stamping)

Δ_{mass} ~ -53%

- About 56% GWP reduction mainly in use and materials stages
- GWP reduction in use stage: lower FC and operation CO_2 emissions
- GWP reduction in Materials stage: 53% saving in materials used and environmental credits due to closed loop recycling of scrap
- GWP reduction in EoL stage: higher substitution factor of primary material for Alu

Bumper System (CRF)



Reference design (4.5 kg)
- 100% Alu (extrusion & stamping)

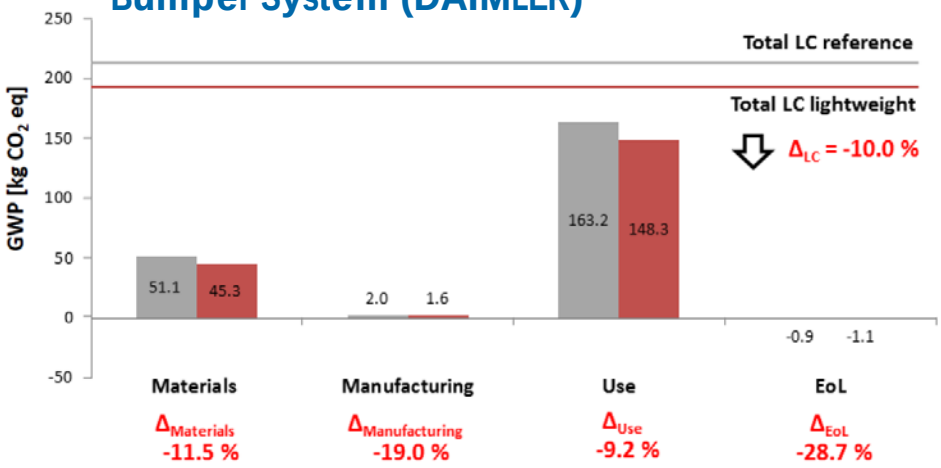
Lightweight design (3.3 kg)
- 100% Alu 7000s (extrusion)

Δ_{mass} ~ -27%

- About 23% GWP reduction mainly in use and materials stages
- GWP reduction in Materials stage: 27% mass decrease
- GWP increase in EoL stage: lower mass of Alu forwarded to recycling activities in the lightweight design alternative

LCIA – Comparative assessment reference/lightweight

Bumper System (DAIMLER)



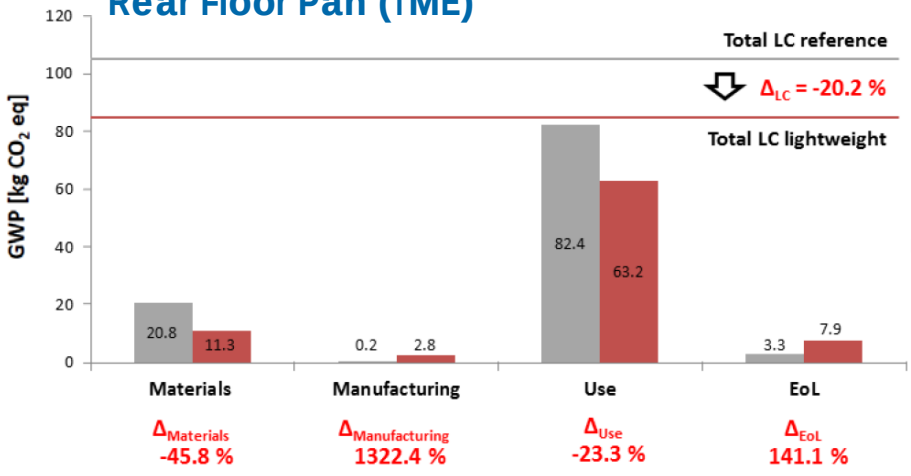
Reference design (13.1 kg)
- 100% Steel (deep drawing)

Lightweight design (11.9 kg)
- 60% Steel (deep drawing)
- 40% Steel Q&P (deep drawing)

Δ_{mass} ~ -9%

- 10% GWP reduction mainly in use and materials stages
- GWP reduction in Materials stage: 9% saving in materials used and similar GWP of conventional and Q&P steel
- EoL stage: negligible impact reduction achieved through lightweight design solution

Rear Floor Pan (TME)



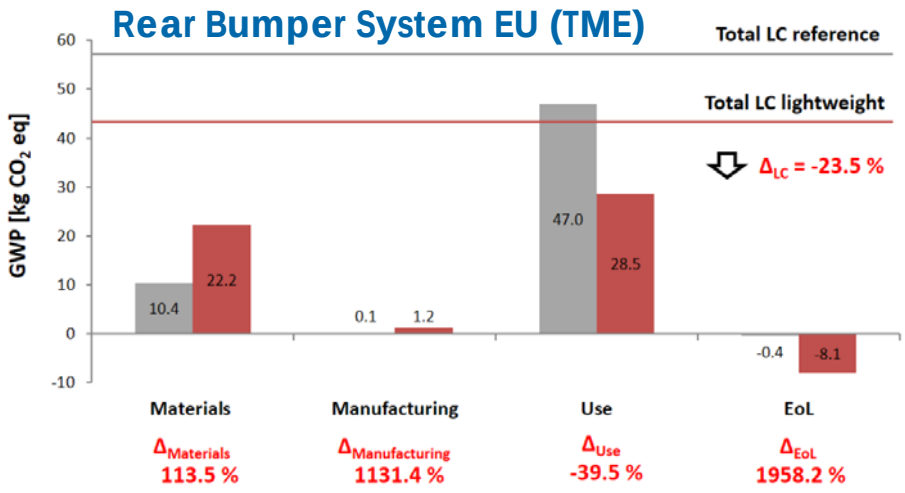
Reference design (6.9 kg)
- 76% Steel (stamping)
- 24% Acryl/SBR-Vynil-Urethane

Lightweight design (5.3 kg)
- 62% PPGF40
- 34% Steel (stamping)
- 4% Urethane

Δ_{mass} ~ -23%

- About 20% GWP reduction in use and materials stages
- GWP reduction in Materials stage: lower mass-specific impact of PPGF40 with respect to steel
- GWP increase in EoL stage: higher amount of polymeric materials forwarded to incineration

LCIA – Comparative assessment reference/lightweight

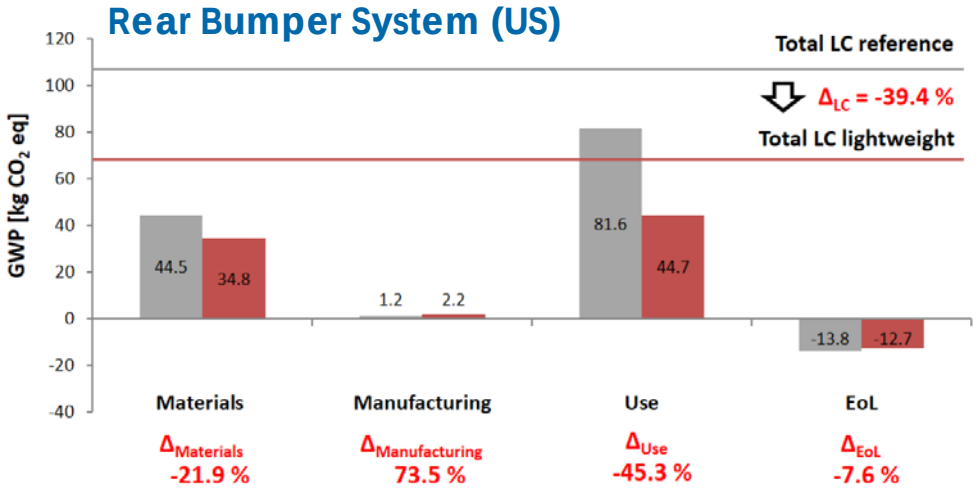


Reference design (4.0 kg)
- 100% Steel (deep drawing)

Lightweight design (2.4 kg)
- 100% Alu 6000/7000s (extrusion)

Δ_{mass} ~ -40%

- About 24% GWP reduction in use and EoL stages
- GWP increase in Materials stage: higher impacts of Alu in the manufacturing of semi-finished products
- GWP reduction in EoL stage: lower energy consumption of recycling processes and higher substitution factor of primary material for Alu



Reference design (6.9 kg)
- 58% Alu 7000s (extrusion)
- 42% Steel (stamping)

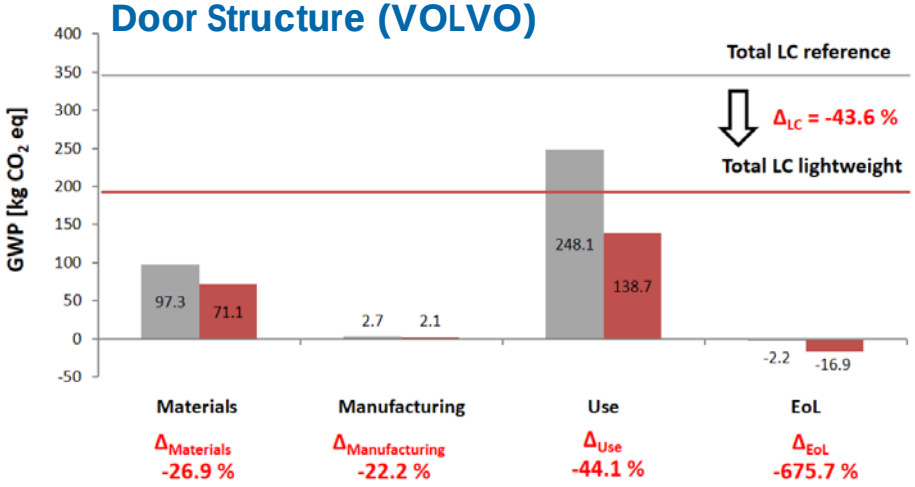
Lightweight design (3.8 kg)
- 100% Alu 6000/7000s (extrusion)

Δ_{mass} ~ -45%

- About 39% GWP reduction in use and materials stages
- GWP reduction in Materials stage: about 45% saving in materials used (lower amount of Alu)
- GWP increase in EoL stage: mass reduction makes that environmental credits from Alu recycling are lower lower

LCIA – Comparative assessment reference/lightweight

Door Structure (VOLVO)



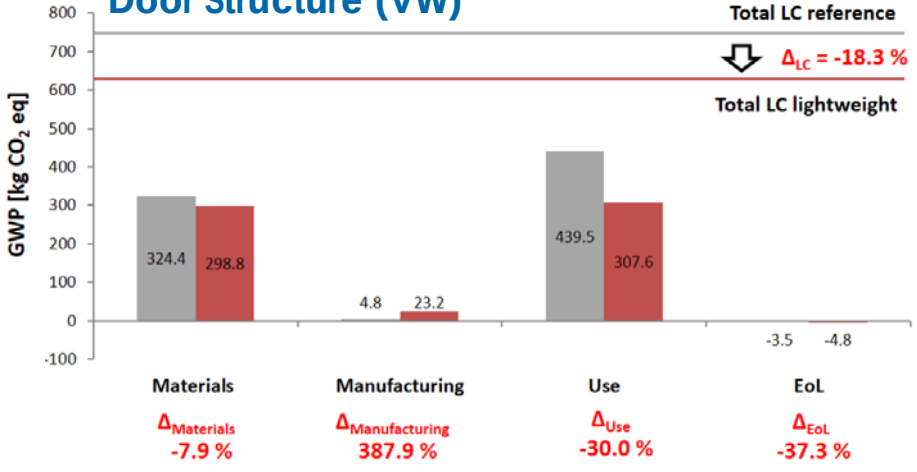
Reference design (19.7 kg)
- 99% Steel (deep drawing)
- 1% Alu 6000s (deep drawing)

Lightweight design (11.0kg)
- 85% Alu 6000s (deep drawing)
- 15% Steel (deep drawing)

Δ_{mass} ~ -44%

- About 44% GWP reduction mainly in use, materials and EoL stages
- GWP reduction in Materials stage: 44% saving in materials used and environmental credits due to closed loop recycling of scrap
- GWP reduction in EoL stage: lower energy consumption of recycling processes and higher substitution factor of primary material for Alu

Door Structure (VW)



Reference design (35.2 kg)
- 100% Steel (deep drawing)

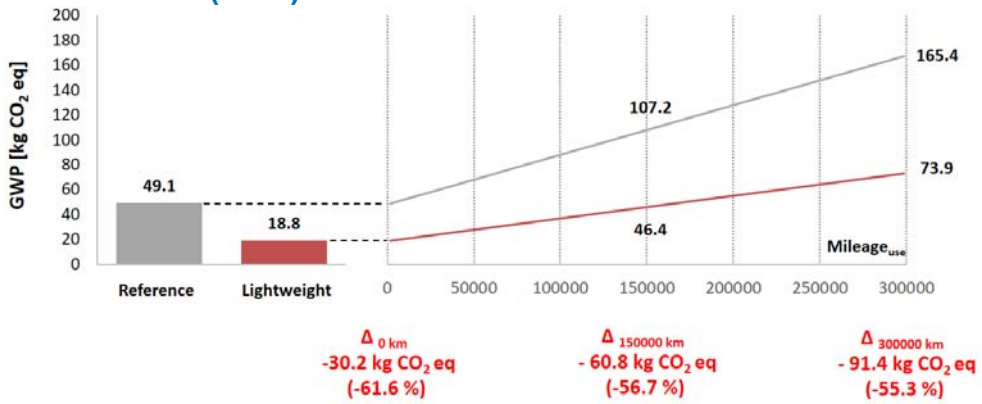
Lightweight design (24.6 kg)
- 63% Steel (deep drawing)
- 21% Epoxy resin GF42
- 16% Alu 6000s (deep drawing)

Δ_{mass} ~ -30%

- About 18% GWP reduction in use and materials stages
- GWP reduction in Materials stage: 30% saving in materials used and environmental credits due to closed loop recycling of scrap
- GWP increase in Manufacturing stage: higher energy intensity of manufacturing processes of epoxy resin composite component

LCIA – Break-even point analysis

Hood (CRF)

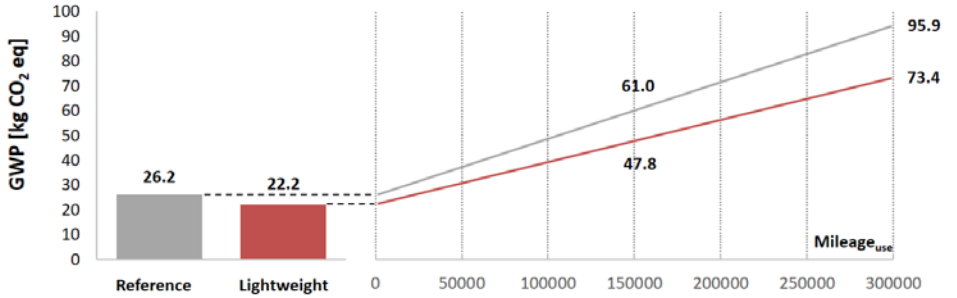


Δ 0 km
-30.2 kg CO_2 eq
(-61.6 %)

Δ 150000 km
- 60.8 kg CO_2 eq
(-56.7 %)

Δ 300000 km
- 91.4 kg CO_2 eq
(-55.3 %)

Bumper System (CRF)

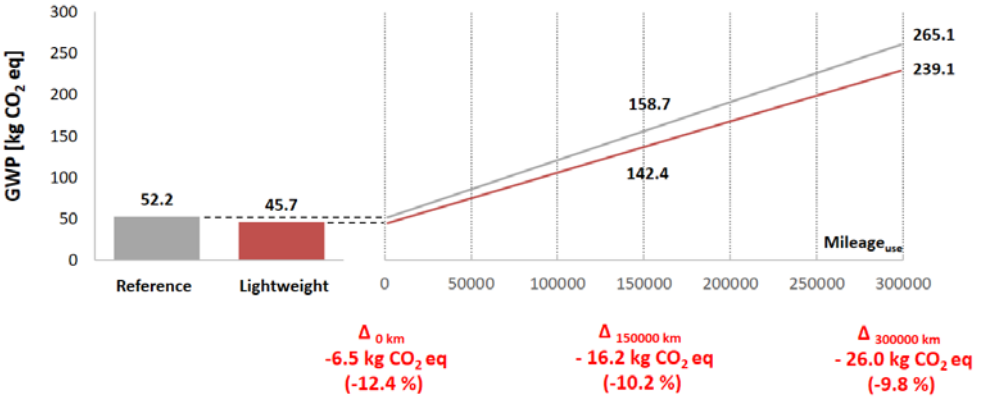


Δ 0 km
-4.0 kg CO_2 eq
(-15.3 %)

Δ 150000 km
-13.2 kg CO_2 eq
(-21.7 %)

Δ 300000 km
-22.5 kg CO_2 eq
(-23.4 %)

Bumper System (DAIMLER)

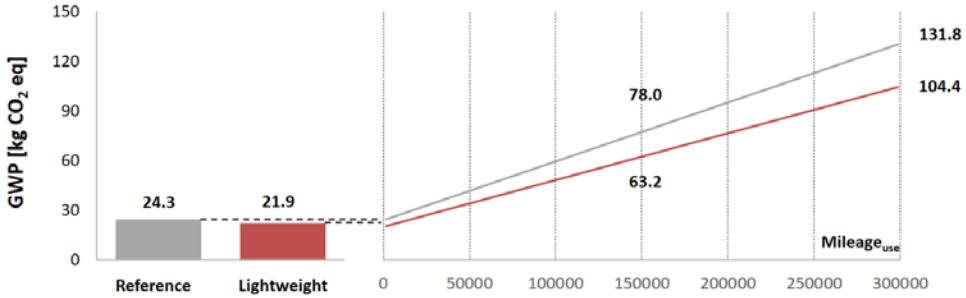


Δ 0 km
-6.5 kg CO_2 eq
(-12.4 %)

Δ 150000 km
- 16.2 kg CO_2 eq
(-10.2 %)

Δ 300000 km
- 26.0 kg CO_2 eq
(-9.8 %)

Rear Floor Pan (TME)



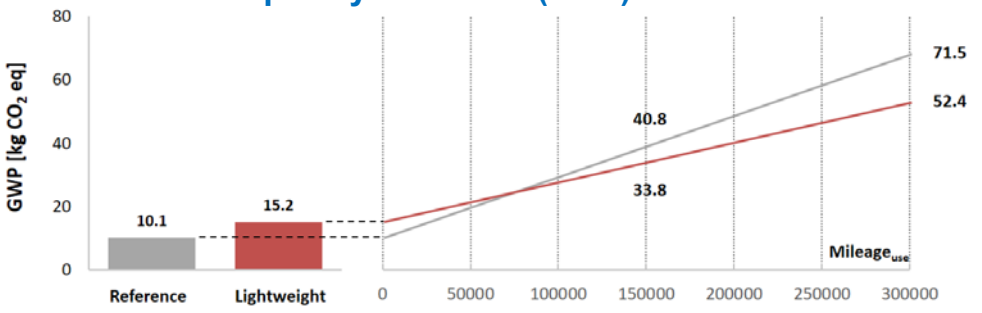
Δ 0 km
-2.3 kg CO_2 eq
(-9.5 %)

Δ 150000 km
-14.9 kg CO_2 eq
(-19.0 %)

Δ 300000 km
-27.4 kg CO_2 eq
(-20.8 %)

LCIA – Break-even point analysis

Rear Bumper System - EU (TME)

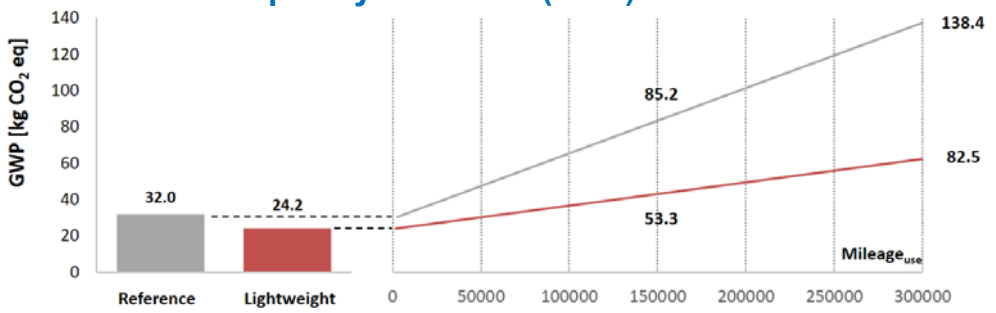


Δ 0 km: 5.1 kg CO_2 eq (51.0 %)

Δ 150000 km: -7.0 kg CO_2 eq (-17.0 %)

Δ 300000 km: -19.1 kg CO_2 eq (-26.7 %)

Rear Bumper System - US (TME)

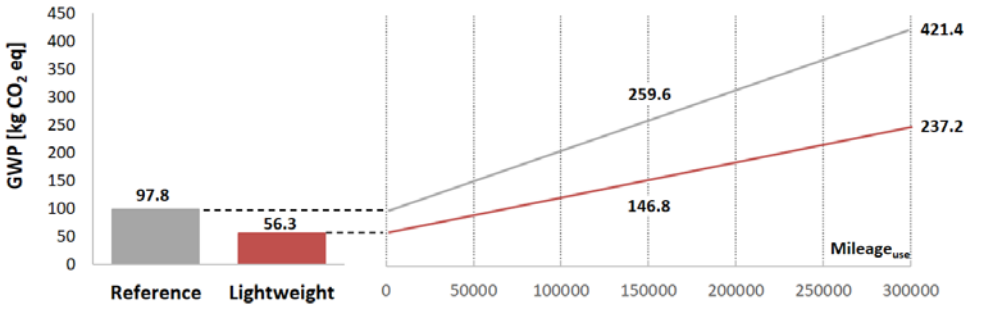


Δ 0 km: -7.8 kg CO_2 eq (-24.4 %)

Δ 150000 km: -31.9 kg CO_2 eq (-37.4 %)

Δ 300000 km: -56.0 kg CO_2 eq (-40.4 %)

Door Structure (VOLVO)

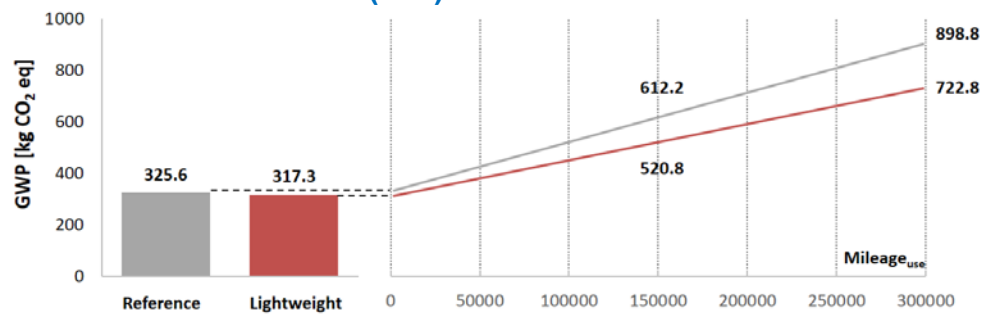


Δ 0 km: - 41.5 kg CO_2 eq (-42.4 %)

Δ 150000 km: - 112.8 kg CO_2 eq (-43.5 %)

Δ 300000 km: - 184.2 kg CO_2 eq (-43.7 %)

Door Structure (VW)



Δ 0 km: -8.3 kg CO_2 eq (-2.6 %)

Δ 150000 km: -94.4 kg CO_2 eq (-15.4 %)

Δ 300000 km: -180.3 kg CO_2 eq (-20.1 %)

Conclusion

- Comparative LCA between reference and lightweight design versions of the modules
- LCA of reference vehicle for the ALLIANCE project
- GWP reduction at module level within the range 10-56 %
- Implementation of innovative design at full-vehicle level: prediction for GWP reduction of 6-8 %

Thank you for your attention

MOVING research group

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