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CO_2 & Road Transport

Position & messages of the European Aluminium Industry, 12/07/2007

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Part 1: CO_2 & Cars

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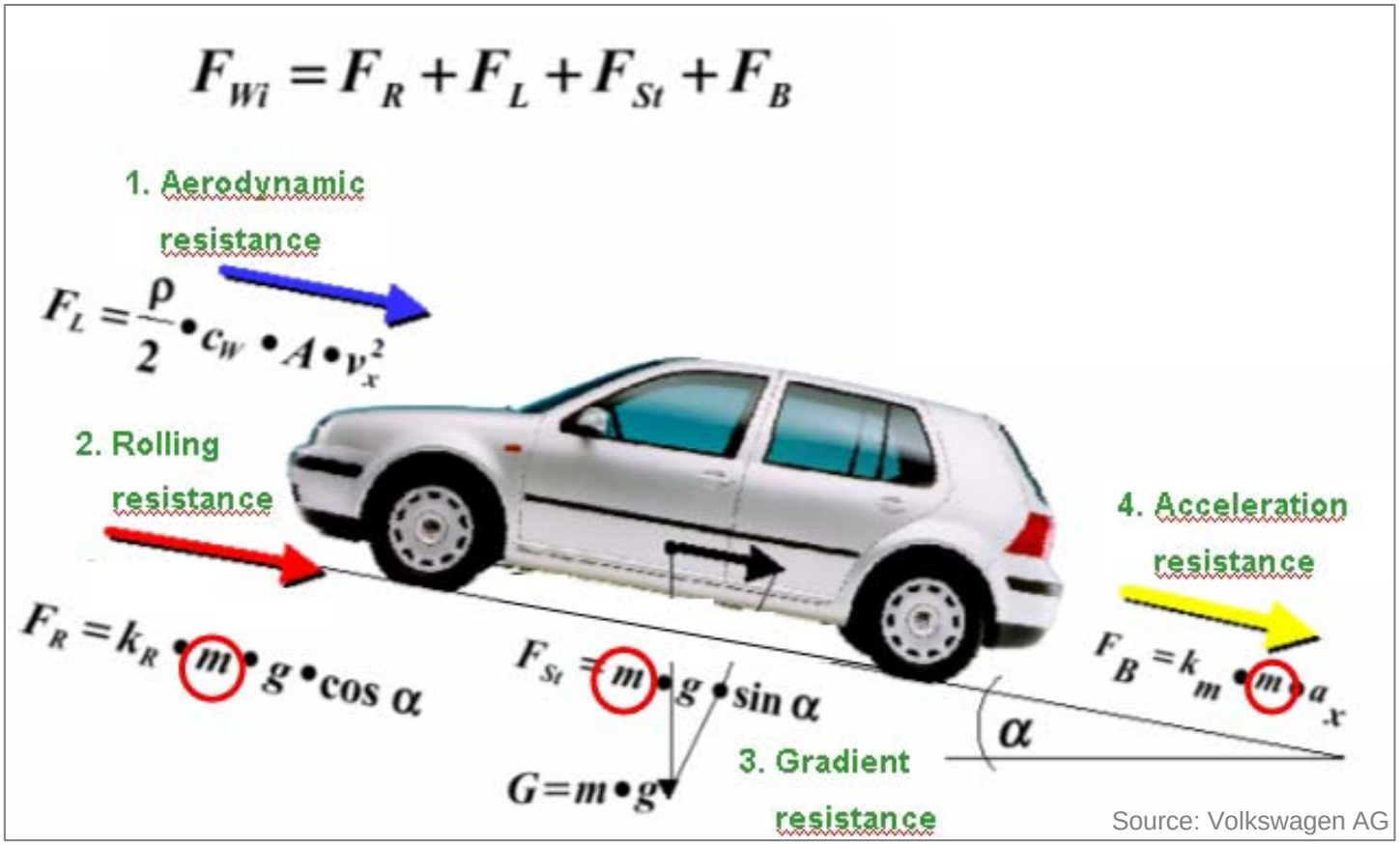
Aluminium for Future Generations

Position of the European aluminium industry

- Innovative technological measures to reduce CO_2 emissions of cars (i.e. those that are intrinsic and independent on drivers behaviour) are the most reliable and sustainable.
- The European Automotive and Aluminium industry is leading world-wide in respect to innovative, cost efficient light-weight solutions and has proven that those can be applied across all car models (i.e. all types, sizes and production volumes)
  - e.g. today 18-20% of cars build in Europe p.a. feature aluminium hoods, saving 40-50% weight in comparison to other materials
- Light-weighting of vehicles is one of the most effective measures and directly impacts CO_2 emissions: 100 kg weight saved is equivalent to a reduction of 9 grams of CO_2
- The aluminium industry supports ambitious CO_2 reduction targets for cars and is prepared to expand its European production capacity to cope with increasing market demand.
- Fuel consumption or emissions are today no key purchase decision criteria for car customers, despite its huge impact on operating costs and the well known environmental consequences. Educating the public, encouraging and stimulating the demand for low CO_2 emitting cars through appropriate incentives is needed in combination with clear targets for emission reduction for the Automotive industry. The aluminium industry welcomes regulatory & fiscal initiatives aiming to stimulate the demand for low CO_2 emitting cars.

Reducing mass is necessary!



The energy required to move a vehicle is, except for aerodynamic resistance, directly proportional to its mass

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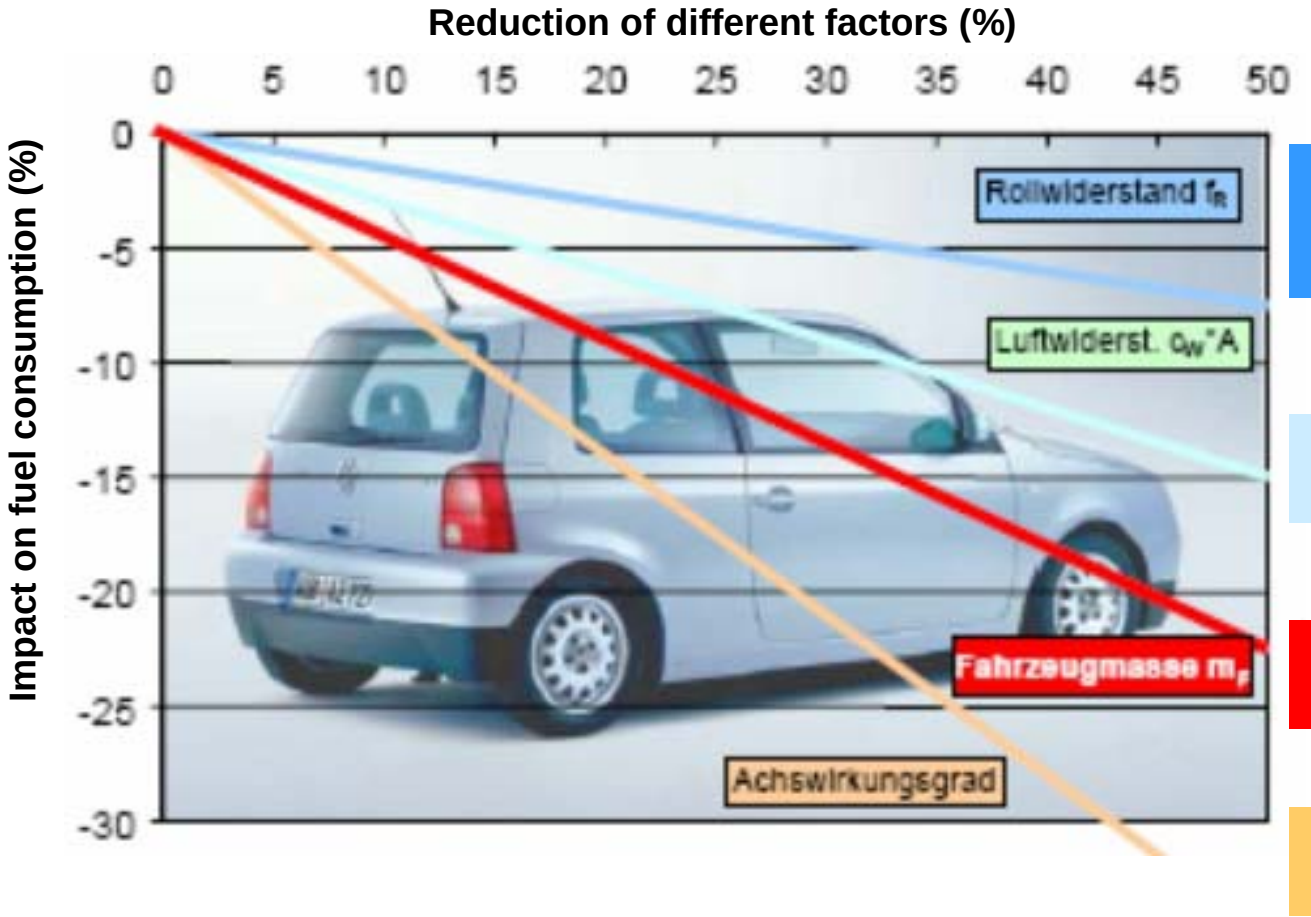
Reducing mass is necessary!

Light-weighting impact on fuel consumption



a) Rolling resistance coefficient

b) Aerodynamic resistance

c) Vehicle mass

d) Powertrain losses

A lot has already been done to improve a), b) & d) so that further progress is limited there.

Fuel saving potential through reduced vehicle mass is still considerable!

Reducing mass is necessary!

Light-weighting impact on CO_2 emissions

- On average in Europe, 100 kg mass reduction achieved on a passenger car saves:
  - 0.35 litre of fuel per 100 km
  - 9 grams of CO_2 per km at the car exhaust pipe
  - 10 grams of CO_2 per km, including pre-combustion
  - 1 kg of CO_2 over 100 km, including pre-combustion
  - 2 t of CO_2 over 200,000 km, including pre-combustion
- The above figures are material-independent

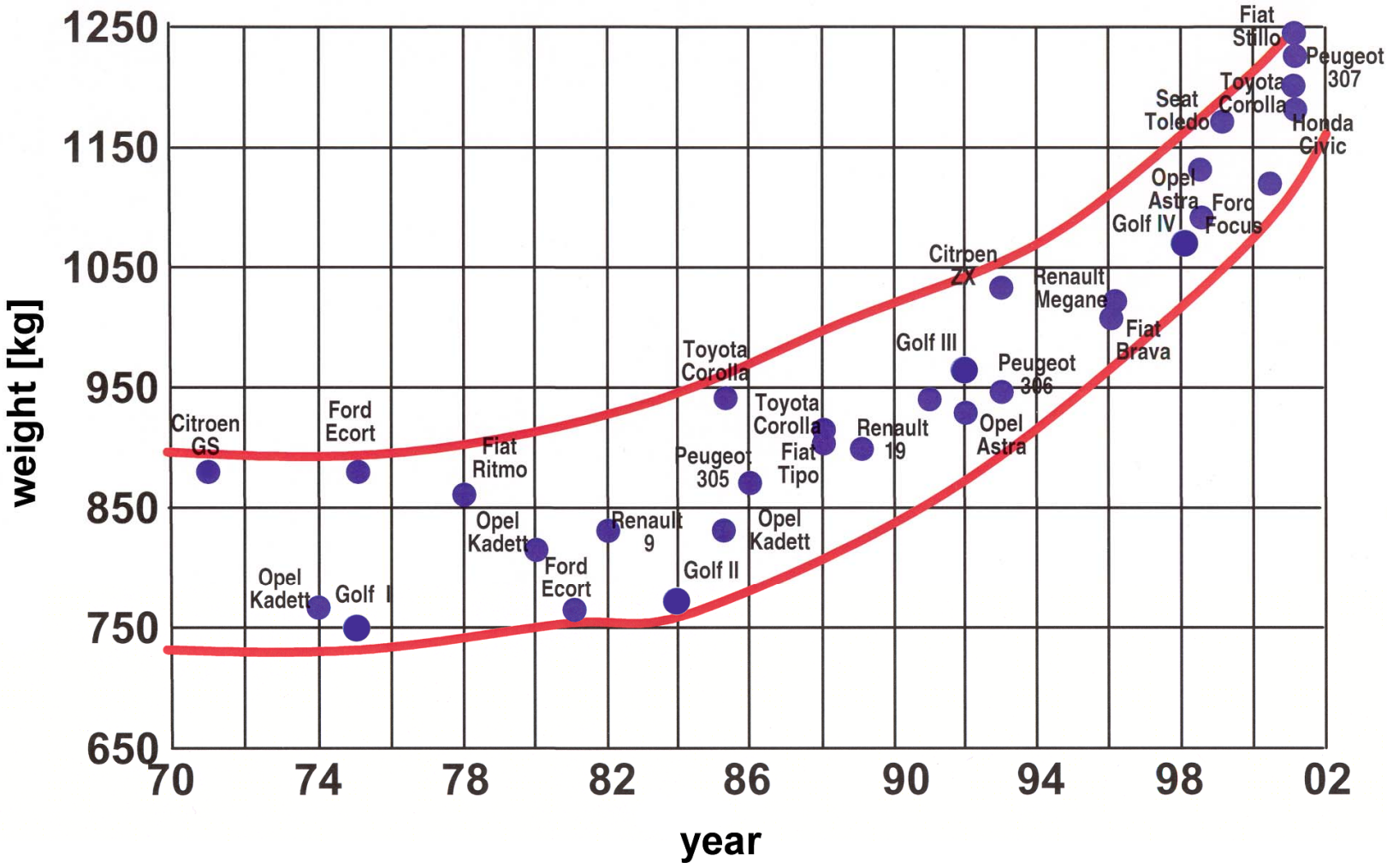
Assuming the following average values for petrol and diesel:

- The combustion of 1 litre of fuel emits 2.5 kg of CO_2 at the car exhaust pipe
- 1 litre of fuel represents 2.8 kg of CO_2 including pre-combustion

Pre-combustion: extraction, refining, transport

Reducing mass is necessary!

Evolution of weight in the compact class



Other light-weighting advantages

- Acceleration:
  - Power train down-sizing => secondary weight savings
- Braking
  - Brakes down-sizing => secondary weight savings
- Safety
  - Improved Pedestrian Safety (active hood systems)
  - Reduced kinetic energy to be absorbed in case of crash
  - Possibility to increase deformation zone without weight increase
- Improved handling
  - Lower centre of gravity
  - Better weight distribution between axles
- Preserving roads

Aluminium as light-weighting material

- With 2,700 kg/m3, the density of aluminium is one third that of steel.
- In a number of applications, it may be necessary to increase the average thickness of aluminium parts compared to steel to give the same stiffness.
- However, the relationship between strength, stiffness and weight is very complex so that there is no absolute rule.

Aluminium as light-weighting material

- Primary weight savings, typical values:
  - Aluminium typically allows saving between 50% and 30% of weight, depending on the application
  - Slide 12 show the example of aluminium body of Jaguar XJ
- Secondary weight savings, typical values:
  - 10 to 30% additional savings
  - However, when aluminium is intensively used (e.g. Audi A2), secondary weight savings can be higher than 50%
- Primary + secondary weight savings
  - Slide 13 shows the practical example of an aluminium intensive car, the Audi A2
  - The average weight saving achieved by the substitution of heavier materials with aluminium in today's cars (slide 14), is estimated at 50%

Aluminium as light-weighting material

Aluminium-Einsatz in der Karosserie
Gesamtaluminium-Karosserie

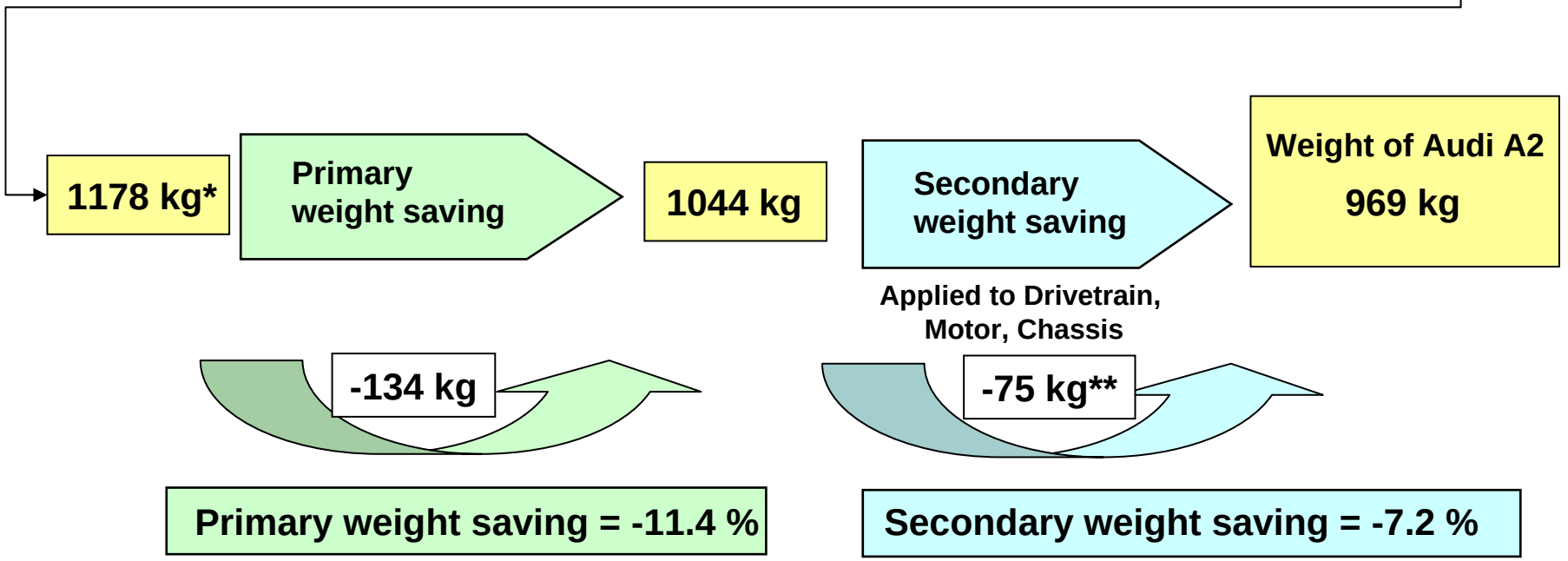
aec aluminium engineering center aachen

- **In Sonderanwendungen Gesamt-Aluminiumkarosserie**
- **Jaguar XJ:**
  - Gewicht der gesamten Karosserie: 220 kg
  - Stahl-Referenz-Gewicht: 369 kg

Gewicht: - 40 % Steifigkeit: + 60 %

Aluminium as light-weighting material

Audi A2 (Weight of a conventional car of this size: 1220 kg)



Primary weight saving = -11.4 %

Secondary weight saving = -7.2 %

$$\text{Weight saving factor } (f_{WS}) = \frac{\text{Secondary weight saving [\%]}}{\text{Primary weight saving [\%]}} \qquad f_{WS} = \frac{7.2}{11.4} = 0.63$$

* adjusted for 42 kg fuel weight / ** adjusted for 21 kg fuel + tank weight

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Aluminium in cars today

Study of 15 million mass produced cars in 2005

Car body

- **20 components analyzed**
- **Highest alu application:**
  - Bonnets & doors
  - Front structure
  - Bumper beams
- **Aluminium content: 26 kg**

Chassis & suspension

- **17 components analyzed**
- **Highest alu application:**
  - Wheels
  - Suspension arms
  - Steering system
- **Aluminium content: 37 kg**

Drivetrain

- **25 components analyzed**
- **Highest alu application:**
  - Engine block & cylinder head
  - Transmission housings
  - Radiators
- **Aluminium content: 69 kg**

Average vehicle

- **Aluminium content: 132kg**
- **Lifespan saving: -2.6t of CO_2 per car**

  -39Mt of CO_2 for 15 million cars
- **Lifecycle saving: -2.2t of CO_2 per car**

  -33Mt of CO_2 for 15 million cars

Each kg of aluminium

- **Lifespan saving: -20kg CO_2**
- **Lifecycle saving: -17kg of CO_2**

1kg of aluminium lightens the car by 1kg, conservative end-of-life recycling hypotheses

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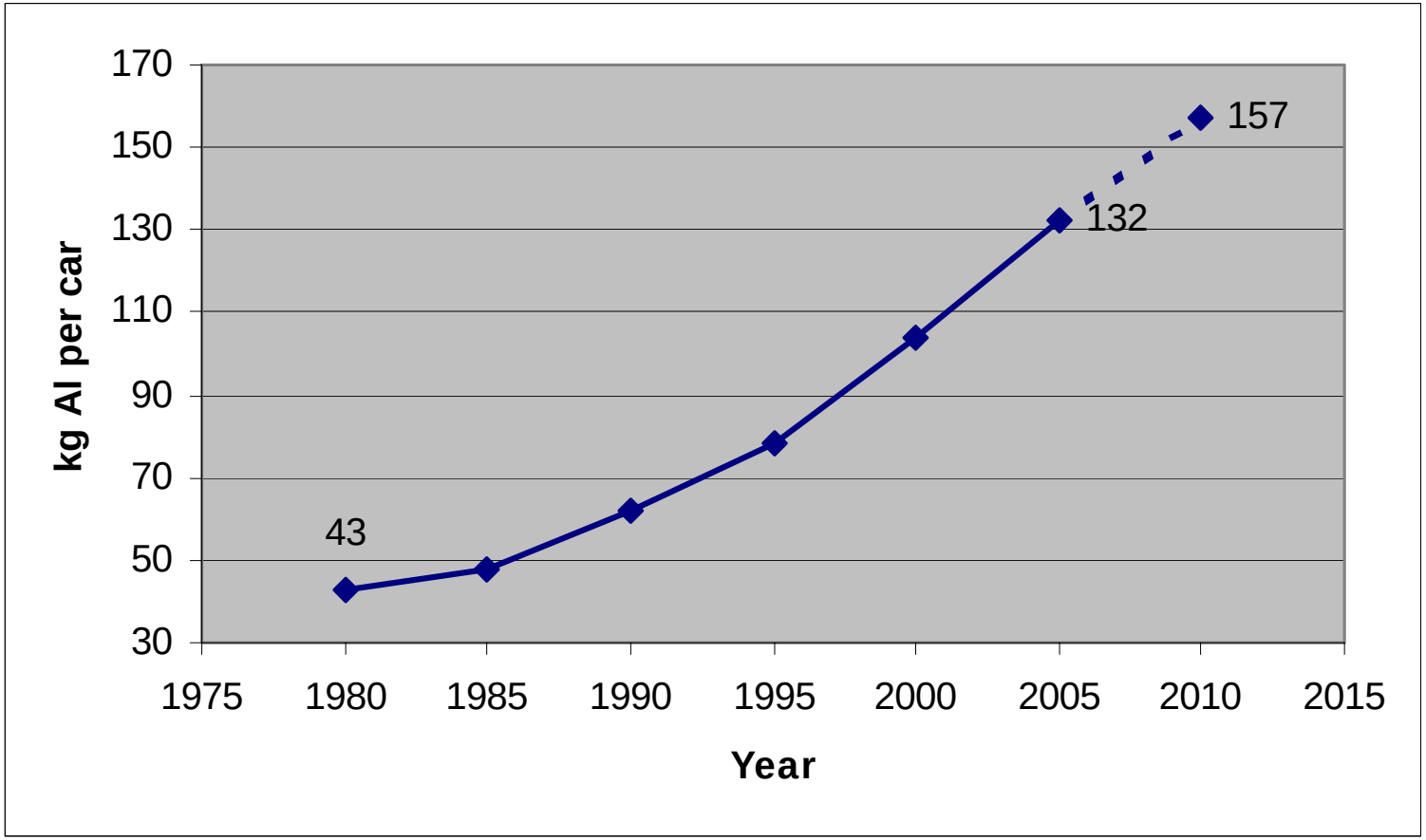
Evolution of aluminium in cars

Average for cars produced in Europe



The Audi A2 contains more than 300 kg of aluminium

The Audi A8 contains about 520 kg of aluminium

Aluminium in cars tomorrow ?

- As first step, increasing aluminium penetration is expected in **car body** applications

- For mass produced cars, mainly doors, hoods, roofs
  - Primary weight reduction potential exceeding 40kg

- For niche models: complete aluminium bodies
  - Primary weight reduction of 100 to 150 kg

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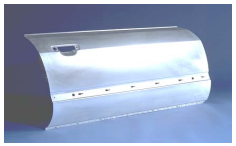
Major Aluminium Car Body Applications

Increasing Complexity ↓

Aluminium Application		Aluminium Share			Main Drivers for Aluminium
		Europe	NA	Asia	
Hoods		18%	8%	3%	Weight Reduction Driving Dynamics Pedestrian Safety
Fenders		4%	1%	<1%	Weight Reduction Pedestrian Safety
Doors & Tailgates		2%	1%	<1%	Weight Reduction Ease of Handling Driving Dynamics
Structure Front Structure		2%	0%	2%	Weight Reduction Driving Dynamics Front Axle Load
Roofs (incl. hard tops)		< 1%	0%	<1%	Weight Reduction Driving Dynamics

Europe is leading!

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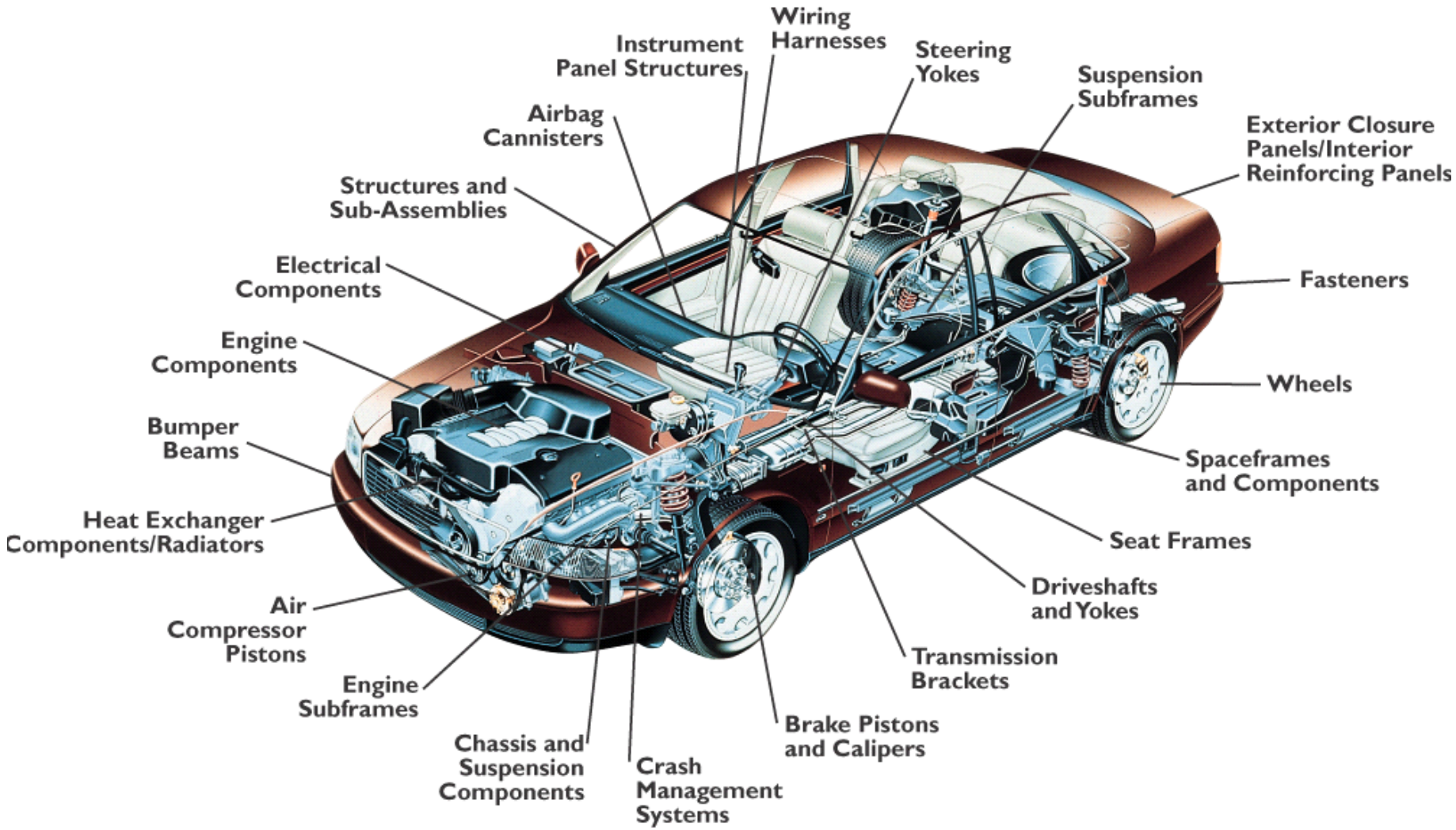
The number of potential aluminium applications is practically endless



Aluminium in cars tomorrow ?

An aluminium front section for C-Class cars*

- Institut für Kraftfahrwesen Aachen (IKA) analyzed the application of aluminium for structural components of a typical C-Class vehicle front section
- Results, with ≥ crash performance, bending & torsion stiffness:
  - 35% primary weight saving for a Conservative approach
  - 41% primary weight saving for a Progressive approach**
- 5 million C-Class cars with an aluminium front section have the potential to save 2.2 Mt of CO_2 over their lifespan

* C-Class car examples: Audi A3, Peugeot 307, Fiat Stilo, Opel Astra, Renault Megane, VW Golf

** For the Progressive Concept the design space was expanded, as far as possible with respect to the major package components of the reference vehicle, in order to achieve more design freedom and encourage innovative ideas

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Part 2: CO_2 & Trucks

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Aluminium for Future Generations

Articulated trucks: Light-weighting effects

- Voluminous goods, partial loads or empty trips:

Lower vehicle weight
=
Lower fuel consumption / km

Saving 1000 kg on one truck saves **600** litres of fuel per 100.000 km

- Heavy goods & fully loaded trips, i.e. weight-limited:

Increased payload
=
Fewer kilometres

Saving 1000 kg on one truck saves **1500** litres of fuel per 100.000 km

Relative environmental benefit

1 : 2.5

The percentage of weight-limited kilometres over the life of a vehicle strongly influences the environmental benefits that light-weighting can bring.

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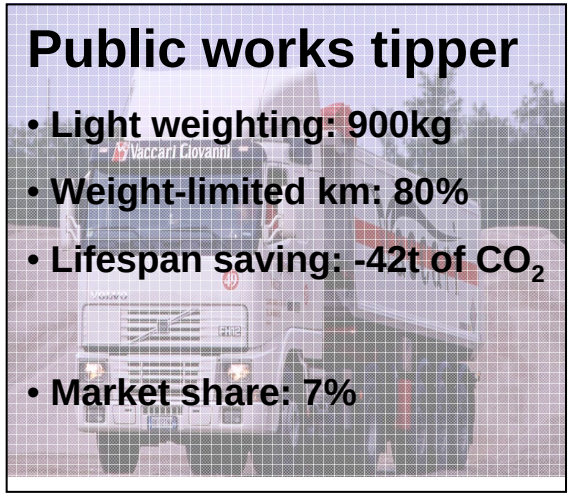
Aluminium for Future Generations

Articulated trucks: Today

General cargo

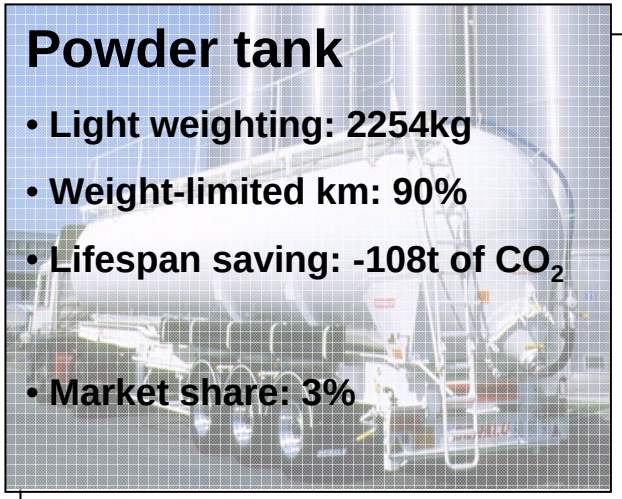
- Light weighting: 255kg
- Weight-limited km: 15%
- Lifespan saving: -6.7t of CO_2
- Market share: 65%

Public works tipper



- Light weighting: 900kg
- Weight-limited km: 80%
- Lifespan saving: -42t of CO_2
- Market share: 7%

Powder tank



- Light weighting: 2254kg
- Weight-limited km: 90%
- Lifespan saving: -108t of CO_2
- Market share: 3%

Average vehicle

- Light weighting: 811kg
- Lifespan saving: -28.4t of CO_2 per truck

  -3,7 Mt of CO_2 for 130.000 trucks
- Lifecycle saving: -26.8t of CO_2 per truck

  -3,5 Mt of CO2 for 130.000 trucks

Each kg of aluminium

- Lifespan saving: -29.1kg CO_2
- Lifecycle saving: -27.5kg of CO_2

1kg of aluminium lightens the vehicle by 0.83 kg, 80% end-of-life recycling, truck lifespan of 1.2 million km

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Aluminium for Future Generations

Articulated trucks: Further potential

General cargo

Public works tipper

Powder tank

Same methodology

Average vehicle

- **Light weighting: 1990kg**
- **Lifespan saving: -51.5t of CO_2 per truck**

  -6,7 Mt of CO_2 for 130.000 trucks
- **Lifecycle saving: -47.8t of CO_2 per truck**

  -6,2 Mt of CO_2 for 130.000 trucks

Each kg of aluminium

- **Lifespan saving: -21.6kg CO_2**
- **Lifecycle saving: -20.0kg of CO_2**

1kg of aluminium lightens the vehicle by 0.83 kg, 80% end-of-life recycling, truck lifespan of 1.2 million km

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Aluminium for Future Generations

Components for tractors & rigid trucks:

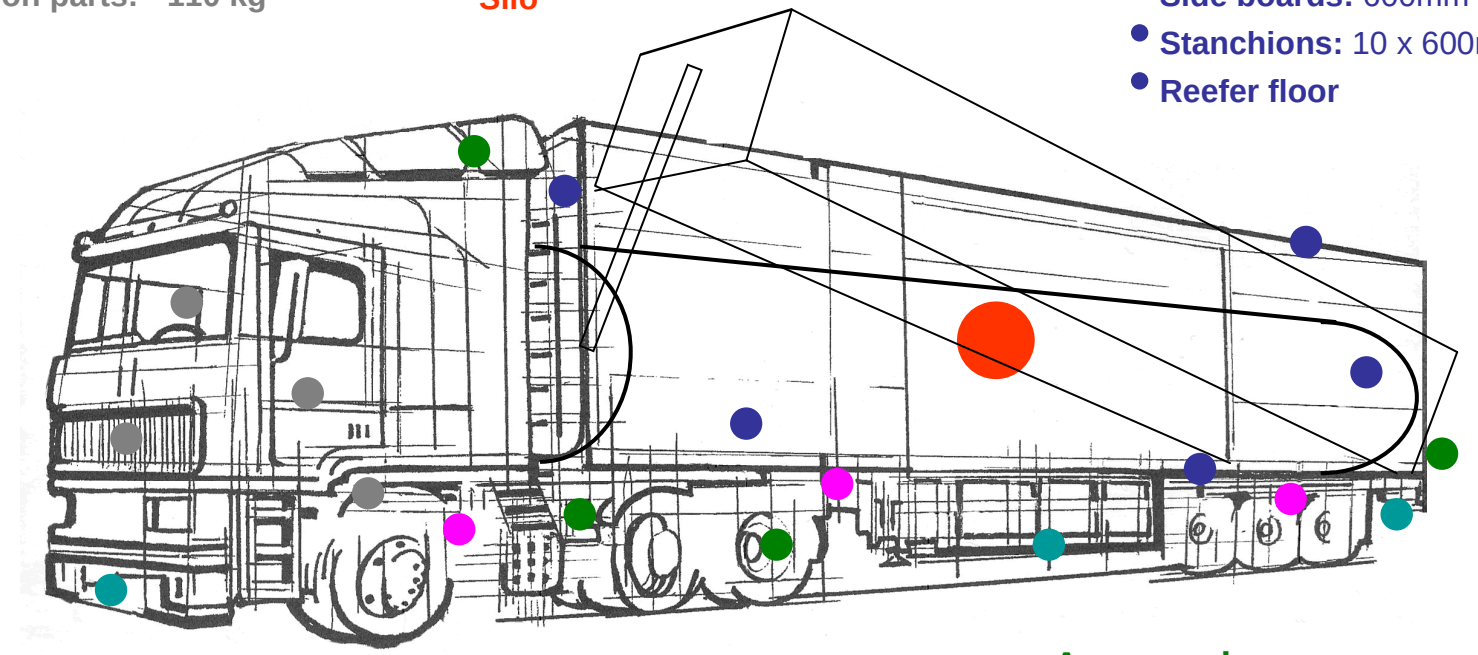
- Cabin & doors: -200 kg
- Chassis: -350 kg
- Powertrain parts: -125 kg
- Suspension parts: - 110 kg

Complete superstructures:

- **Rigid body:** 90 m2 = **-800 kg**
- **Tipping body: -800 to -2000 kg**
- **ADR fuel tank:** 43.000l = **-1100 kg**
- **Self-discharging body**
- **Silo**

Components for superstructures:

- **Curtain rails:** 2x13.5m = **-100 kg**
- **Front wall: -85 kg**
- **Rear door: -85 kg**
- **Side boards:** 600mm **= -240 kg**
- **Stanchions:** 10 x 600mm **= -50kg**
- **Reefer floor**



Safety parts:

- **Front bumpers: -15 kg**
- **Rear bumper: -15 kg**
- **Side bumpers: -20 kg**
- **Front and rear under-run protections**

Trailers sub-structure:

- **Chassis:** 13.5m = **-700 kg**
- **Chassis:** 6 m **= -300 kg**
- **Chassis+floor:** 13.5m = **-1100kg**
- **Legs: -35kg**

Accessories:

- **Air pressure vessels**: 6x60l **= -54 kg**
- **Diesel tank**: 600l **= -35 kg**
- **Toolbox: -15 kg**
- **Tail lift: -150 kg**
- **Wheels**: 14 rims **= -300 kg**

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Conclusions

Conclusions

- Today's aluminium contribution to CO_2 reduction from road transport is already significant
  - Aluminium put on the road every year will save more than 45 Mt of CO_2 over the lifespan of vehicles
  - Buses, non articulated and light commercial vehicles are not included in the above figure
- For tomorrow's cars, aluminium is an excellent solutions to reduce CO_2 emissions per km
  - 100kg saved = -9 grams of CO_2 at the pipe and -10 if pre-combustion is included
- For tomorrow's trucks, aluminium is also an option to reduce CO_2 emissions per ton-km of goods, but that topic is absent from EU discussions
  - A truck is said to be "clean" if he has a clean engine, independently from its load capacity

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Annexes

Aluminium and road safety

- Vehicle safety is mainly a design issue and not a material question.
- To increase the chances of survival in an accident, vehicles must be designed to keep deformation out of manned areas and to dampen the shock undergone by the occupants.
- In other words, the safety for occupants will be characterized by the rigidity of the passenger cell and the capacity to absorb kinetic energy by deformation of the unmanned area.
- Last but not least, the safety strongly depends on the compatibility between vehicles or obstacles involved in an accident.

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Aluminium for Future Generations

The life-cycle of aluminium