IAI

Transport and Aluminium

european aluminium association

The Aluminum Association

Improving Sustainability in the Transport Sector through Weight Reduction and the Application of Aluminium

The energy required to power motor vehicles is more than four times that required to produce and recycle them. Correspondingly, over 80% of the transport sector's greenhouse gas emissions are produced during the operating life.

The Institute for Energy and Environmental Research (IFEU), a Heidelberg-based centre of excellence for environmental research, undertook a quantitative research project in 2003 (Helms, Lambrecht & Höpfner, 2003[i]) to determine how reductions in the mass ("light-weighting") of different types of vehicle impacted energy usage and greenhouse gas emissions in the use stage of the transport sector. The Institute's analysis revealed that a 100 kilogram reduction in the mass of a standard passenger car results in fuel savings of between 300 to 800 litres over the lifetime of the vehicle, while for taxis and city buses these figures are significantly higher at over 2500 litres. A 100 kilogram mass reduction also reduces a standard car's greenhouse gas emissions by around 9 grams of CO_2 equivalent per kilometre, proving that mass reduction can significantly contribute to the required reduction of greenhouse gas emissions from cars.

The IFEU study did not only focus on road vehicles; it also analysed the potential energy and greenhouse gas savings from trains, nautical vessels and aircrafts. Greenhouse gas emissions reductions from light-weighting are particularly high for fast ferries, achieving savings of almost 1200 kilograms of CO_2 equivalent per kilogram of mass reduction. For container ships this figure is 120 kilograms of CO_2 equivalent.

The light-weighting and current design of vehicles has the potential to avoid almost 700 million tonnes of carbon dioxide emissions from the transport sector every year.

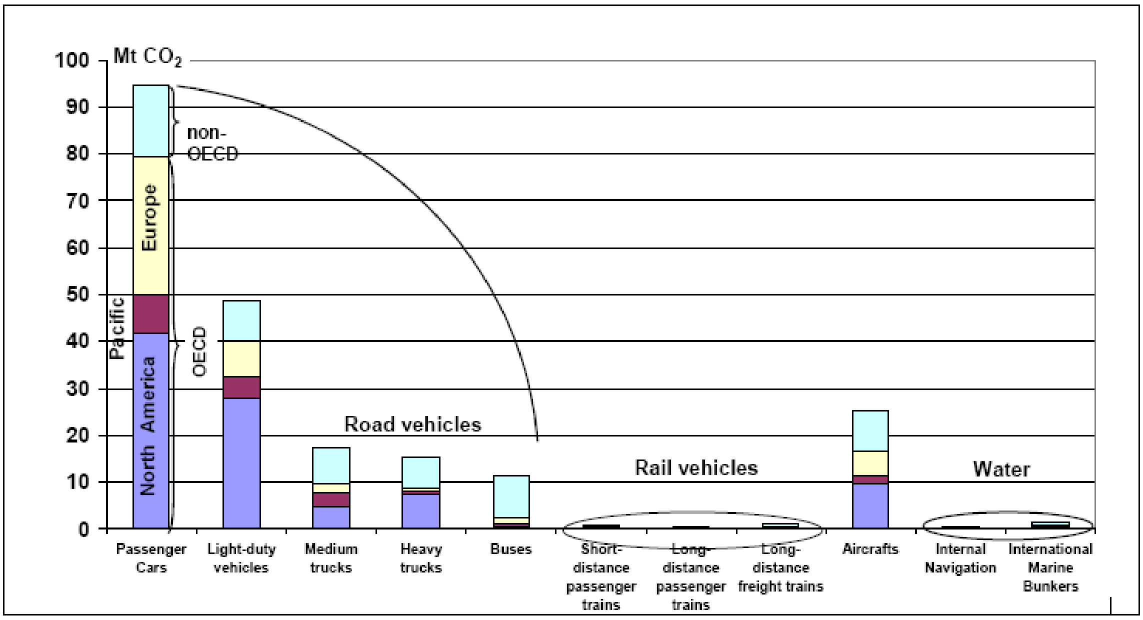

Figure 1: Influence of vehicle fleets to potential annual global greenhouse gas savings

According to International Energy Agency (IEA) research, the transportation sector is responsible for close to 20% of man made greenhouse gas emissions (IEA, 2005[ii]). In 2000, around 7.6 billion tonnes of CO_2 equivalent were emitted through the use of transport. The reduction in the mass of vehicles can significantly improve fuel efficiency, reducing energy consumption and greenhouse gas emissions.

Following on from their findings for individual vehicle types, IFEU considered the potential contribution of light-weighting of whole fleets of vehicles to a reduction in global transport energy consumption and greenhouse gas emissions (Helms and Lambrecht, 2004[iii]; Helms and Lambrecht, 2007[iv]).

Their research concluded that around 660 million tonnes could be avoided if all transport units including road vehicles, nautical vessels, trains and aircrafts were replaced by the same number of vehicles, built according to light-weighting, current design and with the same functional properties.

Consumer demands for increased safety, comfort and convenience, without any sacrifice in overall performance have contributed to a spiralling increase in the mass of road vehicles over the past twenty years. The issue of increasing energy use by and emissions from heavier vehicles is further compounded by the significant increase in the number of cars that will be manufactured to meet growing demand from booming markets in China, India, the Middle East and Latin America. The IEA forecasts that annual car and light truck sales worldwide will grow from approximately 65 million in 2006 to more then 140 million in 2050. As a result, reducing vehicle fuel consumption has become essential to a sustainable transport sector, which is able to meet the twin challenges of climate change and energy security.

The aluminium industry has consistently sought to develop and optimise weight saving components for the transport sector, which can replace heavier materials and thus improve fuel efficiency.

Aluminium is the ideal material for transport applications, because it is light; it can enhance the safety of passengers, other road users and pedestrians; and it retains its value and unique properties even after recycling.

Aluminium scrap from transport applications is part of a well-established recycling system (GARC, 2006[v]). Recycled aluminium can be utilised for almost all applications, preserving raw materials, avoiding emissions and leading to considerable energy savings. The current value of metal scrap (particularly aluminium), driven by high demand for metal products plays an important role in covering the cost of the end-of-life processing of vehicles.

An important consideration for any motor vehicle is its crash performance. The crash worthiness and crash compatibility of passenger cars was examined in a recent study carried out by Dynamic Research, Inc. (DRI, 2004[vi]) for the Aluminum Association (USA). Results show that decreasing the weight to size ratio of road vehicles provides benefits in terms of reducing impact energies and the severity of injuries. In vehicle-to-vehicle impacts, lighter cars and trucks cause much less damage to the other vehicle and its occupants. The study concluded that the vehicle design, including the use of the superior properties of aluminium for crash energy management, and not the weight is the major factor in safety.

The potential of aluminium as a mass reduction material is clear when looking at its specific mass (2.7 g/cm^3), which is less than half of that of iron (7.6 g/cm^3) and copper (8.5 g/cm^3).

Apart from the direct weight reduction by material substitution, however, there are additional possibilities for light-weighting with aluminium. Aluminium-specific fabrication techniques, such as complex, multi-hollow extrusions or thin-walled, high-strength, vacuum die castings, enable new design solutions.

Furthermore, the reduction of the total vehicle mass also offers the potential for indirect weight savings, such as a smaller engine or fuel tank.

Aluminium is widely used for components such as engines, chassis, driveline, suspension, steering, brakes, closures, heat shields, bumpers, hoods, heat exchangers and radiators. Every vehicle component has different light-weighting gains depending on application-specific design and performance criteria. These criteria are related to specific performance metrics, such as mechanical strength and stiffness, as well as weight. Substituting a cast iron engine block with an aluminium component of equal performance can reduce its mass by more than 50%. Using an aluminium bumper versus a high strength steel bumper can reduce the mass by 45%.

Since its first transport applications, aluminium has contributed to reducing the weight of road, rail, marine and aerospace. The demand for aluminium in transport (as well as all other applications) is continuously increasing. In 2000 the average passenger car contained between 100 and 120 kg of aluminium, while in 2006 this figure had increased to between 110 and 145 kg.

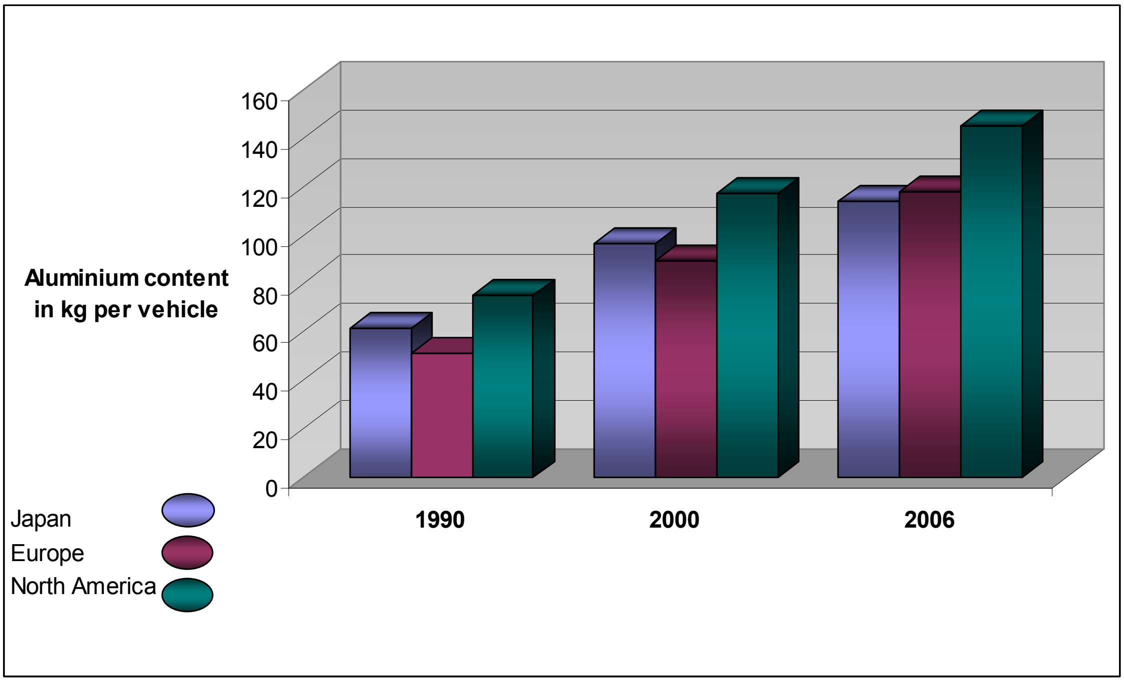

Figure 2: Aluminium content for cars and light trucks in North America, Europe and Japan (Ducker Research, 2005[vii])

As a general indicator, 1 kg of automotive aluminium substituted for a heavier material in a vehicle typically avoids 20 kg of greenhouse gas emissions during its operating life.

Today, the superstructures of most tankers and silo semi-trailers are composed almost entirely of aluminium. The metal is also frequently used for vans, tipping and self-discharging bodies. In an average articulated truck aluminium components can reduce the weight of a trailer by up to 2 tonnes. With this weight advantage, an aluminium-intensive truck can carry heavier loads without exceeding statutory weight limits. This increase in the load capacity of vehicles also means fewer trips are necessary, which contributes to additional reductions in greenhouse emissions and to less wear and tear of road surfaces.

In North America, aluminium hoppers and gondolas have displaced steel cars in coal-hauling trains. In many cases the investment by rail hauliers in new aluminium rolling stock is recovered in under two years. In the 1980s, aluminium emerged as the metal of choice for suburban transportation and high-speed trains, which benefited from lower running costs and improved acceleration. In 1996, the double-decker TGV Duplex train was introduced, combining the concept of high speed with that of optimal capacity, transporting 40% more passengers while weighing 12% less than the single deck version, all thanks to its aluminium structure. Today, aluminium metros and trams operate in many countries. Canada's LRC and Japan's Hikari Rail Star, the newest version of the Shinkansen Bullet train, as well as France's TGV Duplex trains, all utilise large amounts of aluminium. One thousand high-speed passenger ships are currently in service, most of which have a structure and superstructure made of aluminium. Cruise ship superstructures continue to be made of aluminium, while over half of all yachts have aluminium hulls. These ships take full advantage of the metal's low density and strength, as well as its corrosion-resistance, another indispensable property for marine environments, significantly reducing maintenance costs.

Latest research by the International Aluminium Institute (IAI), European Aluminium Association (EAA) and Aluminum Association (AA) on vehicle light-weighting goes beyond the theoretical studies of IFEU, to look at specific examples, where aluminium components have been utilised and where such applications can be built into the design of new vehicles (IAI, 2007[viii]). In this research the full life cycle of the vehicle component was investigated, including fabrication and manufacturing, vehicle use and material production (recycling and primary). For each component a sensitivity analysis was conducted to determine the impact of critical parameters such as lifetime driving distances on primary energy and greenhouse gas savings. Results of these analyses showed that in automotive applications each kilogram of aluminium replacing mild steel, cast iron or high strength steel saved between 13 and 20 kilograms of greenhouse gas emissions depending on the component (bumper and motor block of a compact car, front hood of a large family car, body-in white of a luxury car). Today about 40% of automotive aluminium used is in the form of engine components. The case for such replacements in metro/subway cars indicated avoided emissions of approximately 26 kilograms (operating in Europe) and 51 kilograms (operating in the USA) of greenhouse gas emissions.

Component	CO_2eq savings (kg CO2eq/kg Al)	Primary energy savings (MJ/kg Al)
Bumper* (aluminium – mild steel)	16	210
Bumper* (aluminium – high strength steel)	15	190
Front hood* (aluminium – high strength steel)	13	170
Engine block (aluminium – cast iron)	20	280
Body-in-white (aluminium – mild steel)	15	190

Table 1: Life cycle greenhouse gas and primary energy savings per kg of aluminium for a lifetime driving distance of 200,000 km
*No indirect weight savings included

The IAI study also compared aluminium to high strength steels in two applications: a bumper beam on two similar European-made cars (one using high strength steel the other aluminium) and a hood on a US-made family sedan. In both applications, aluminium achieved significant energy and emissions savings over the high strength steels. The aluminium bumper beam was lighter than the high strength steel component by 2.6 kilograms. Over a 200,000 kilometre driving cycle the aluminium component was found to avoid 15 kilograms of CO_2 equivalent emissions per kilogram of aluminium, or 48 kilograms for the whole bumper. The aluminium hood on the registered a 42% direct weight reduction over high-strength steel. Over the 200,000 kilometre driving cycle of this vehicle, the hood was found to avoid 131 kilograms CO_2 equivalent emissions. When the secondary weight savings of the bumper and hood are included in the model, the CO_2 equivalent emissions reductions increase to 61 and 161 kilograms, respectively.

The use of 7 million tonnes of aluminium for passenger car components manufactured in 2006, instead of heavier materials, will result in potential global savings of approximately 140 million tonnes of CO_2 equivalent greenhouse gas emissions and to energy savings equivalent to about 55 billion litres of crude oil over the life of these vehicles.

The transport life cycle model, developed by IAI Sustainable Aluminium Working Group in cooperation with the European Aluminium Association (EAA) and the Aluminum Association (AA), focuses on the environmental aspects of light-weighting in transport and the resulting savings of fuel and electricity. It quantifies the primary energy and greenhouse gas savings realised from the light-weighting of specific vehicle components based on life cycle assessment methodology. The developed model is based on the ISO 14044 life cycle assessment methodology and covers the whole life cycle of a vehicle including production, use and end-of-life (collection, recovery and recycling). It can be used to assess future scenarios and applications.

Substitutions by aluminium are made component by component in different vehicle series. Each component is subjected to individual life cycle assessment, which provides a detailed profile of the energy and greenhouse gas savings. A life cycle model developed by the aluminium industry can be used for these component specific calculations for all types of vehicles, including automotive, trucks, trains and ships.

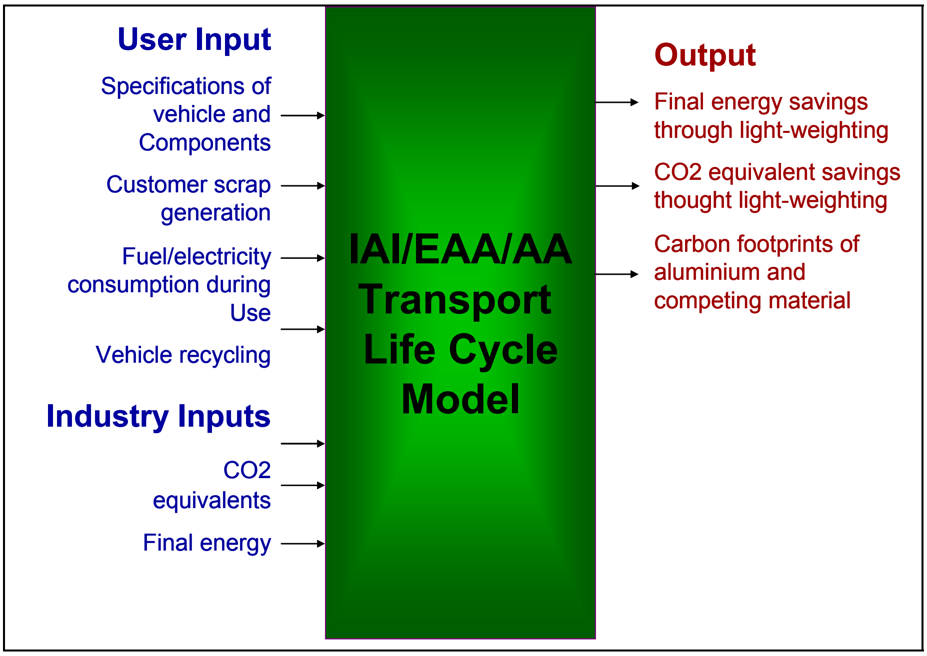

Figure 3: Inputs to and outputs from the aluminium in transport life cycle model

The specific case studies can be ordered from the International Aluminium Institute (iai@world-aluminium.org and the full report can be found on http://www.world-aluminium.org.

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[i] Helms, H., U. Lambrecht & U Höpfner, 2003. *Energy Savings by Lightweighting*. IFEU – Institute for Energy and Environmental Research, Heidelberg. http://www.world-aluminium.org/cache/fl0000125.pdf

[ii] IEA, 2005. *CO2 Emissions from Fuel Combustion, Data Services* . International Energy Agency, Paris.

[iii] Helms H. & U. Lambrecht, 2004. *Energy Savings by Light-weighting II*. IFEU – Institute for Energy and Environmental Research, Heidelberg. http://www.world-aluminium.org/cache/fl0000126.pdf

[iv] Helms H. & U. Lambrecht, 2007. *The Potential Contribution of Light-Weighting to Reduce Transport Energy Consumption*. In International Journal of Life Cycle Assessment, Special Issue Vol. 12, No. 1, pp58−64. http://www.ifeu.org/verkehrundumwelt/pdf/lca2006.07.258.pdf

[v] GARC, 2006. *Global Aluminium Recycling: A Cornerstone of Sustainable Development*. Global Aluminium Recycling Committee – Organisation of European Aluminium Refiners & Remelters; European Aluminium Association; International Aluminium Institute, London. http://www.world-aluminium.org/cache/fl0000153.pdf

[vi] Dynamic Research, Inc.2004. *An analysis of the effects of SUV weight and length on SUV Crashworthiness and compatibility using systems modelling and risk-benefit analysis.* California, USA.

[vii] Ducker Research, 2005. *Aluminum Content for Light Non Commercial Vehicles to be Assembled in North America, Japan and the European Union in 2006*.

[viii] IAI, 2007. *Improving Sustainability in the Transport Sector Through Weight Reduction and the Application of Aluminium*. International Aluminium Institute, London. http://www.world-aluminium.org/cache/fl0000124.pdf