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Study

Present and future CO_2 reduction potential thanks to aluminium in European articulated trucks

According to the European Commission, Trucks and buses are responsible for about a quarter of CO_2 emissions from road transport and despite some improvements in fuel consumption efficiency in recent years, emissions are still rising, mainly due to increasing road freight traffic.

In May 2014, the European Commission adopted a comprehensive strategy to reduce CO_2 emissions from heavy duty vehicles in both freight and passenger transport. In particular, light-weighting as a means of improving CO_2 emissions is presently under study. In this context, the European Aluminium Association studied the present and future contribution of aluminium for reducing CO_2 emissions of articulated trucks.

This study analyses present and future potential CO_2 savings when using aluminium as light-weighting solution for trucks & trailers. The study concludes that present average articulated vehicles would be 850 kg heavier without aluminium and future ones could potentially be about 2000 kg lighter than today. 1 kg of aluminium in today's articulated trucks saves 26 kg of CO_2 during their whole life-cycle and every additional kg of aluminium in tomorrows articulated trucks would save a minimum of 19 kg of CO_2 during their whole life-cycle.

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Introduction

This document analyses present (2012) and future potential CO_2 savings when using aluminium as light-weighting solution for European articulated trucks.

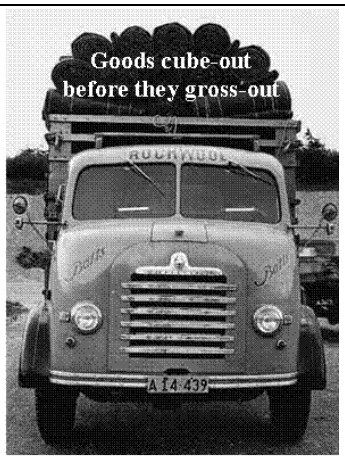
1. CO_2 savings during use-stage

A weight reduction directly reduces the energy consumption because the energy required to move vehicles is, except for the aerodynamic resistance, directly proportional to their weight.

Besides direct energy savings, a weight reduction also permits a higher payload. Indirect energy savings are the result of a lower mileage for the same transport performance. Indeed, increasing payload reduces the necessary kilometres to transport a given tonnage of goods over a given distance.

In the case of volume-limited transport, i.e. low density goods, a reduction of the empty vehicle weight doesn't allow loading more goods, because the full loading space is already occupied. Therefore, only direct energy savings are possible.
In the case of weight-limited transport, i.e. high density goods, a reduction of the empty vehicle weight allows loading more goods. Therefore, indirect energy savings will be achieved.

High density goods
Weight-limited[a]



Low density goods
Volume-limited[b]

[a] Picture source : Benalu
[b] Picture source : Rockwool

For the same light-weighting, energy savings are up to three times higher in the case of weight-limited transport than in the case of volume-limited transport. The reason is that, when kilometres are saved through increased payload, both the mass-related AND the aerodynamic-related fuel consumptions are saved.

In the real life, a vehicle might be used both for weight-limited and for volume-limited transport; however we can distinguish two transport categories:

- For the transport of liquid or solid bulk (i.e. tankers or tippers), the percentage of weight-limited kilometres will be high (e.g. 80%)
- For the transport of conditioned goods, the percentage of weight-limited kilometres will be low (e.g. 20%).

To assess present and future CO_2 savings obtained through light-weighting with aluminium, we need:

- To define the vehicles we will study
- To know the specific fuel economy through reduced weight, in order to calculate direct savings linked to volume-limited transport
- To know the share of weight-limited kilometres for each vehicle type, in order to calculate indirect savings linked to weight-limited transport
- To know the present and future potential weight saving that aluminium can achieve

1.1 Definition of studied vehicle

An articulated truck is composed by a tractor and a semi-trailer, or a rigid truck and a drawbar-trailer. The first combination represents more than 75% of European registrations and will be analysed here.

Across Europe, authorized maximum gross vehicle weight are generally between 40 and 44 tonnes, 40 tonnes being still dominant[cd].
Empty weight of vehicles depends on the kind of transport they are dedicated to, but it is generally accepted that the average European articulated truck consists of a tractor and a semi-trailer weighing about 7 tonnes each, the total empty vehicle weight being 14t.

The total lifetime performance of vehicles is estimated to be 1.200.000 km.

[c] Source : http://ec.europa.eu/transport/facts-fundings/statistics/doc/2012/pocketbook2012.pdf page 23
[d] The present paper deals with the year 2012, but 44 tonnes may become dominant in future revisions since a growing number of countries are allowing 44 tonnes (e.g. France since January 1st 2014 http://www.developpement-durable.gouv.fr/Questions-reponses-sur-la-mise-en,30473.html) and since EU Council Directive 96/53/EC is under revision.

To estimate present CO_2 savings obtained thanks to aluminium, different types of trailers will be analysed separately:

- General cargo trailers (Commonly named “curtainsiders”)
- Closed trailers (Insulated or not)
- High volume tipping and moving floor trailers
- Public works tipping trailers
- Powder tankers
- Fuel tankers
- Chemical and food tankers

To estimate future CO_2 savings, weight saving potential will be analysed for each trailer category, but an *average trailer* will be defined before making CO_2 calculations.

Last but not least, present and future CO_2 savings obtained through tractors and wheels light-weighting will be analysed separately.

When loaded up to the maximum allowed gross vehicle weight of 40 tonnes, vehicles are estimated to consume 36 litre of diesel fuel per 100km[e].
When the gross vehicle weight is 27 tonnes, which is the European average, vehicles are estimated to consume 29 litre of diesel fuel per 100 km.
Last but not least, from well-to-wheel, 1 litre of diesel fuel is equivalent to 2.98 kg of CO_2.

1.2 Specific fuel economy through reduced weight

As no universally agreed figure for specific fuel saving through light-weighting for European articulated trucks could be found in the literature, the European Aluminium Association commissioned a study to the Institut für Energie- und Umweltforschung (IFEU) in the year 2005[f].

IFEU concluded that 100 kg saved on an average European articulated truck allowed the saving of 0.06 litre of fuel per 100 km. The full study is available upon request.

Since the overall fuel efficiency of trucks has improved since 2005, we corrected the above value downwards by 10%, leading to a saving of 0.054 litre of fuel per 100 km & per 100kg saved.

[e] Source: Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy http://ec.europa.eu/clima/policies/transport/vehicles/docs/ec_hdv_ghg_strategy_en.pdf , page 187 Ricardo 2010 data

[f] IFEU 2005, Hinrich Helms, Udo Lambrecht (In cooperation with TU Graz): Energy savings by light-weighting for European articulated trucks

1.3 Share of weight-limited kilometres for each vehicle type

The share of weight limited-kilometres of different vehicle types has been estimated based on interviews with leading trailer manufacturers, transport companies and studies made by the British "Department for Transport".
Empty or partly loaded trips have been treated as volume-limited kilometres.

Semi-trailers - Today

- General cargo trailers: 15%
- Closed trailers: 15%
- High volume tipping and moving floor trailers: 50%
- Public works tipping trailers: 80%
- Powder tankers: 90%
- Fuel tankers: 80%
- Chemical and food tankers: 80%

Semi-trailers – Future

- *Average semi-trailer (see 1.1 §5)*: 15%, because future potential light-weighting could mainly occur on general cargo and closed trailers

Tractors:

- Presently: 27%, which is the weighted average for the different types of semi-trailers pulled by the tractors
- Future: To simplify calculations, we will use a very conservative 15%, i.e. the value taken for our average semi-trailer.

Wheels:

- Presently: 80%, because they are mainly used for bulk transport today
- Future: 15%, because future potential light-weighting could mainly occur on general cargo and closed trailers

1.4 Present and future weight savings

The present and future weight saving potential has been estimated based on interviews with leading trailer manufacturers and has been cross checked with aluminium statistics. As the market has been rather unstable during the period 2008-2012, average registration figures[g] across that period served as basis to estimate the market shares of the various semi-trailer types.

[g] Sources: CLCCR, CLEAR and The European Truck-Trailer Report – Sixth Edition, published by Truck & Bus Builder Reports Ltd

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Table 1

Semi-trailers	Weight saving (kg)		Market
	Achieved	Potential	Share
General cargo	255	1245	62%
Refrigerated	289	841	16%
High cube tippers	2805	195	8%
Public works tippers	900	900	8%
Powder tanks	2254	46	3%
Fuel tanks	622	779	2%
Chemical tanks	15	285	2%
Weighted average	570	1009	100%

Tractors	Weight saving (kg)		Market
	Achieved	Potential	Share
	220	765	100%

Wheels	Weight saving (kg)		Market
	Achieved	Potential	Share
	63	188	100%

FULL VEHICLE	Weight saving (kg)		Market
	Achieved	Potential	Share
	853	1962	

In other words, **present average articulated vehicles would be about 850 kg heavier without aluminium and future ones could potentially be 1960 kg lighter than today.**

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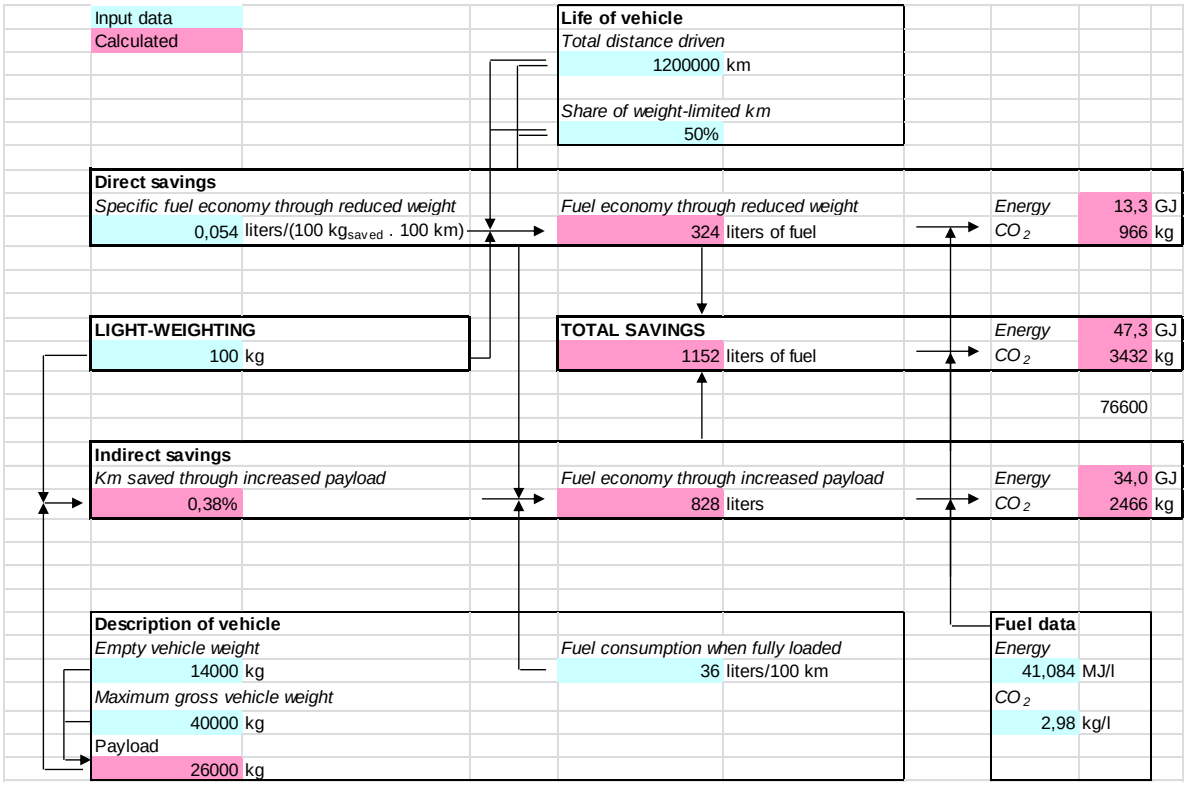
1.5 Calculations

1.5.1 The model

The model used is illustrated below, taking the example of a 100kg light-weighting and a vehicle making 50% weight-limited kilometres.



1.5.2 CO_2 reduction thanks to present light-weighting

Using the above-described model, CO_2 reductions can easily be calculated for each semi-trailer type, as well as for tractors and wheels.

Table 2

Semi-trailers	Present light weighting (kg)	Weight sensitivity	Savings/unit CO_2 (kg)	Market Share
Gen cargo & refrig	255	15%	6061	62%
Refrigerated	289	15%	6866	16%
High cube tipper	2805	50%	89764	8%
Public works tipper	900	80%	37933	8%
Powder tank	2254	90%	96783	3%
Fuel tank	622	80%	26444	2%
Chemical tank	15	80%	652	2%
Weighted average	570		**18141**	100%
Tractor	220	27%	**6049**	100%
Wheels	63	80%	**2733**	100%
FULL VEHICLE	**853**		**26923**	

Assuming that 1 kg weight saving is obtained with 1,2 kg of aluminium, an average vehicle contains 1023 kg of aluminium, leading to a CO_2 saving of 26.923 kg during the use stage.

In other words, **1 kg of aluminium in today's articulated trucks saves 26,3 kg of CO_2 during their use phase.**

1.5.3 Potential CO_2 reduction thanks to future light-weighting

The same model used on the potential future vehicle, 1962 kg lighter than today and supposed to be 15% weight-limited, results in a CO_2 saving of 45.752 kg.

Assuming that 1 kg weight saving is obtained with 1,2 kg of aluminium; a future average articulated truck would contain 2354 additional kg of aluminium.

In other words, **1 additional kg of aluminium in tomorrows articulated trucks would save a minimum of 19.4 kg of CO_2 during their use phase.**

2. Production and recycling

As all metals are characterised by their ability to maintain their inherent properties after recycling, contrary to wood, paper, concrete or plastics, their live cycle is not "cradle-to-grave" but rather "cradle-to-cradle". This means that the life cycle of a metallic product usually ends when the recycled metal is rendered in a re-usable form, e.g. as an ingot. Consequently, only the environmental burdens of the production of the lost metal have to be charged to the system under study, together with the burdens of the recovery operations.

If we assume that 100 kg of light-weighting is obtained with 120 kg of aluminium, we have to compare CO_2 emissions for production and recycling of 120 kg of aluminium versus 220 kg of steel[h].

If we assume a recycling rate of 90%[i] both for steel and aluminium, we calculated that the production and recycling of 120 kg of aluminium represents 36 kg of $CO_{2\text{-eq}}$ more than 220 kg of steel.

3. CO_2 savings during whole life-cycle

3.1 CO_2 reduction thanks to present light-weighting

Table 2 can now be corrected taking production and 90% recycling into account, still assuming that 1 kg weight saving is obtained with 1,2 kg of aluminium.

Table 3

Semi-trailers	Present light weighting (kg)	Weight sensitivity	Savings/unit CO_2 (kg)	Market Share
Gen cargo & refrig	255	15%	5969	62%
Refrigerated	289	15%	6762	16%
High cube tipper	2805	50%	88748	8%
Public works tipper	900	80%	37607	8%
Powder tank	2254	90%	95967	3%
Fuel tank	622	80%	26219	2%
Chemical tank	15	80%	646	2%
Weighted average	570		**17935**	100%
Tractor	220	27%	**5969**	100%
Wheels	63	80%	**2710**	100%
FULL VEHICLE	**853**		**26614**	

An average vehicle contains 1023 kg of aluminium (853 x 1,2) and leads to a CO_2 saving of 26.614 kg during its whole life cycle.

In other words, **1 kg of aluminium in today's articulated trucks saves 26 kg of CO_2 during their whole life-cycle.**

[h] Aluminium data from "Environmental Profile Report for the European Aluminium Industry (April 2013 - Data for the year 2010); Steel data from Worldautosteel

[i] To be on the conservative side, since the case studies made in cooperation with the Université de Technologie de Troyes (F) obtained recycling rates in excess of 95%, http://www.alueurope.eu/transport-recycling/

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3.2 Potential CO_2 reduction thanks to future light-weighting

Taking production and recycling into account and still assuming that 1 kg weight saving is obtained with 1,2 kg of aluminium, a future average articulated truck could contain 2354 kg of aluminium (1962 x 1,2) and save 45,041 t of CO_2.

In other words, **1 additional kg of aluminium in tomorrows articulated trucks could save a minimum of 19,1 kg of CO_2 during their whole life-cycle.**

4. The influence of weight-limited kilometres

To calculate the potential CO_2 reduction thanks to future light weighting in section 1.5.3 (use stage) and 3.2 (full life cycle), we used a very conservative 15% as share of weight-limited kilometres.

However, 2002 statistics from the British Department for Transport indicated that 29% of tonne-kilometres performed by articulated vehicles (over 33t) are weight-limited. If we dilute that figure to take empty trips into account, we obtain 24%.

We consequently found interesting to calculate the impact of using 25% weight-limited kilometres instead of 15%.

Our findings are an improvement of 2.23 kg of CO_2 saving per extra kilo of aluminium used in future vehicles.

5. Conclusion

Present average articulated vehicles would be 850 kg heavier without aluminium and future ones could potentially be 1960 kg lighter than today.

1 kg of aluminium in today's articulated trucks saves 26,3 kg of CO_2 during their use phase and 26 kg of CO_2 during their whole life-cycle.

1 additional kg of aluminium in tomorrows articulated trucks would save a minimum of 19,4 kg of CO_2 during their use phase & a minimum of 19,1 kg of CO_2 during their whole life-cycle.

These last figures are based on an estimated 15% share of weight-limited kilometres for vehicles were aluminium penetration could be further increased.
Every 10% increment of weight-limited km (e.g. jumping from 15 to 25%) would represent 12% improvement of CO_2 savings.

Non-articulated trucks were not part of this study, but maximised light-weighting of these vehicles could also lead to significant CO_2 savings, as they represent about 40% to 50% of new motorised commercial vehicles registrations.

This study is based on best available data. When data was missing, estimates have been made, but always on the conservative side for aluminium. We therefore expect that better data precision would reinforce our conclusions.

Brussels, 31 July 2014 (Revision 1, based on 2012 data)

About the European Aluminium Association:
The European Aluminium Association, founded in 1981, represents the whole value chain of the aluminium industry in Europe, from alumina and primary production to semi-finished, end-use products and recycling. The European aluminium industry directly employs about 255,000 people and yields an annual turnover of 36.8 billion €. *For information, please visit www.alueurope.eu*

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