RECYCLING RATES OF ALUMINIUM FROM END-OF-LIFE COMMERCIAL VEHICLES
– Four case studies –

FINAL REPORT
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INTRODUCTION

This work followed upon a first study which was realized in 2006 by University of technology of Troyes on behalf of the European Aluminium Association (EAA) and which aimed at understanding the fate, the present and future end-of-life treatment of aluminium parts from trucks and trailers used in EU-25. The main output of that first study has been a European mass flow model of the aluminium scraps coming form end-of-life commercial vehicles and a list of actors involved in the process.

EAA then expressed an interest to observe precisely the current practices of the end-of-life processing through case studies to illustrate:

- The end-of-life treatment processing steps;
- The aluminium losses at each step;
- The total recycling rate

To answer this request, the methodology adopted in this project has consisted of purchasing four end-of-life commercial vehicles in cooperation with important partners[1] to study and establish a mass flow analysis for each process relevant for aluminium.

The field study did not cover the losses during melting of the aluminium scraps since these losses have been taken into account in a previous study.

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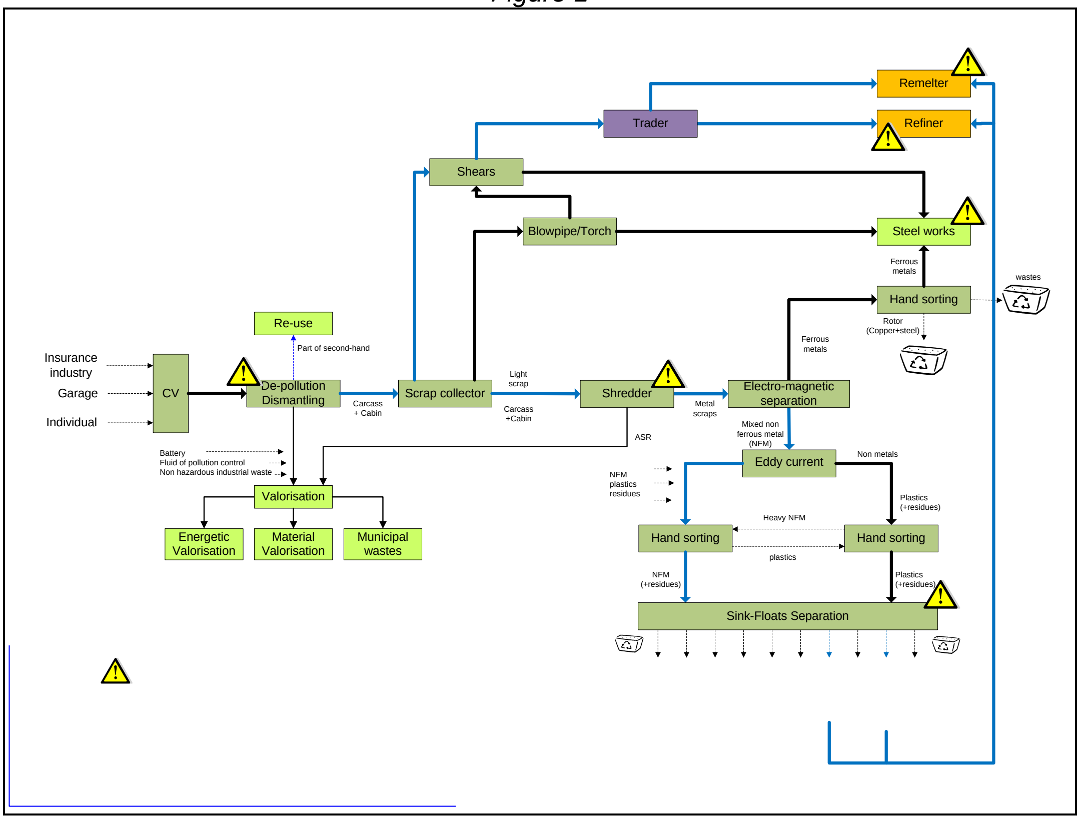
[1] See Annex 1

1. THE END-OF-LIFE CHAIN

The path followed by the end-of-life commercial vehicles (CV) is to a certain extent similar to that of passenger cars. However, for commercial vehicles, the shredding and subsequent separation steps don't always take place and are replaced with either shearing or cutting. Figure 1 illustrates this.

Figure 1



2. ALUMINIUM MELTING[2]

2.1. REFINERS AND REMELTERS

The aluminium melting operation can be done either by refiners or remelters.
Remelters mainly process clean, uncoated and sorted wrought alloy scrap.
Refiners melt all kinds of scrap including multiple alloys, oxidized, coated or soiled scrap.

Selection of the most appropriate furnace type is determined by the oxide content, type and content of foreign material (e.g. organic content), geometry of the scrap (mass to surface ratio), frequency of change in alloy composition and operating conditions.

Scrap is melted in dry hearth, closed-well, electric induction, rotary or tilting rotary furnaces. Refiners most commonly use the rotary furnace, which melts aluminium scrap under a salt layer, while remelters favour the dry hearth furnace.

As a result of contact with the oxygen in air, aluminium is covered with a thin layer of aluminium oxides. This chemical reaction occurs particularly at high temperatures during melting. The generated fine mixture of oxide skins, metal (in equal amounts) and gas on the surface of the melt in the furnace is termed skimmings or aluminium dross. These skimmings have to be removed before the metal is cast. This by-product is collected and recycled into aluminium alloys and aluminium oxides (used in the cement industry) in special refineries.

Using salt during the melting process reduces the amount of oxides generated and removes impurities from the liquid metal. Salt slag is produced and later processed separately.

2.2. METAL LOSSES

The losses during refining and remelting of aluminium scrap from end-of-life commercial vehicles were derived from a study by Boin and Bertram (2005)[3].

The study investigated the average metal and oxide content plus the amount of foreign material (e.g., lacquers, paint, oil, coatings) in the scrap and the losses of metal during melting, dross recycling and salt slag recovery. Within the refiner operation a sub-model for a salt slag processing unit based on ALSA GmbH's process was included. In this process, salt slag is recycled into reusable salt, aluminium granulate, and a reusable non-metallic residue.

Refiners, who usually melt smaller and more contaminated scrap, reach lower melting efficiency than remelters who melt more voluminous and cleaner scrap. For the same reason, refiners use mainly rotary melting furnaces while remelters rely on reverberatory furnaces.

Boin and Bertram (2005) results are summarized in Table 1.

[2] EAA and OEA Brochure "Aluminium Recycling in Europe: The road to high quality products" (2007)
[3] U.M.J. Boin and M. Bertram "Melting Standardized Aluminium Scrap: A Mass Balance Model for Europe," JOM 57 (8) (2005), pp. 26–33.

Table 1

	Remelting	Refining	
		for shredded pieces	for large pieces
Unoxydised metal content (High) [c]	99,6%	96,8%	99,6%
Unoxydised metal content (Low) [c]	99,5%	96,4%	99,5%
Melting Rate [a,b]	99,0%	96,1%	96,1%
Total	98,5%	92,8%	95,6%
=> loss	1,48%	7,17%	4,36%

[a] Reverberatory furnace

[b] Rotary furnace; Including dross/skimmings & salt slag processing

[c] 100% includes aluminium in metallic and in oxidised form. The non-aluminium content is excluded.

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3. RECYCLING RATE AND IDENTIFICATION OF LOSSES

For all vehicles studied, the recycling rate of aluminium will be determined.

$(M_{rec} + M_{reu}) / M_v$

M_{rec} : Mass of aluminium obtained after the remelting or the refining process
M_{reu} : Mass of aluminium contained in parts that are sold for re-use
M_v : Mass of aluminium in the end-of-life vehicle

Standard ISO 22628 “Road vehicles - Recyclability and recoverability - Calculation method”, is generally used to calculate the ability for components and materials to be recycled.
It is not used here because it applies to all materials contained in a vehicle and because it does not incorporate the losses taking place during the various stages of the end-of-life process. Having applied ISO 22628 and having focused on aluminium would have given us a recyclability rate of 100%.

4. CASE STUDIES

4.1. ROAD TRACTOR

4.1.1. Vehicle characteristics

- Tractor brand: Renault
- Type: Premium 420 DCI
- 1st test drive: 18/11/2002
- Mileage: 340,000 km
- General condition: damaged by accident
- Total vehicle mass: 6,918 kg
- Aluminium content: 264.8 kg

4.1.2. Losses during the use-phase

An aluminium part was missing at the time of the entry inspection at the dismantler. The missing element is a piece from one of the step plate support, lost during the accident leading to the end-of-life of the tractor. The aluminium weight of the step plate support has been estimated by the dismantler and confirmed by Renault Trucks to be 1.4 kg.

4.1.3. Depollution

According to the legislation, the vehicle is first decontaminated. Fuel, lubricants, coolants are recovered. Parts containing hazardous substances such as batteries, air bags or catalytic converters are dismantled.

No aluminium loss is recorded in this operation.

4.1.4. Dismantling

Before starting the dismantling process, the aluminium content of the vehicle is 264.8 kg[4].

The dismantler proceeded as usual, without optimizing aluminium recovery more than in his daily practice. This illustrated the ‘operational’ choices based on economic considerations. The inventory and pictures of dismantled aluminium parts is given in ANNEX II.1.

The amount of parts recovered for re-use mostly depends on the state of the vehicle and market opportunities. In our case, parts for re-use contain 79.2 kg of aluminium. As these parts are detached from the vehicle without cutting or shearing, no metal loss is observed.

Aluminium contained in parts dismantled for further processing amounts to 185.6 kg.
Due to cutting and shearing, a maximum loss of 0.25% is estimated by the dismantler.

The dismantler removed the engine and gearbox and, as usual, didn’t process it further. Engines are usually sold for re-use or, as in our case, sent to a specialised end-of-life engines processing plant.

Finally, after removal of the aluminium pieces and other valuable parts, the cabin is sent to a close shredder plant.

The dismantling of the tractor lasted 35h and was carried out in February 2007.

4.1.5. Treatment by scrap collector

The work of the scrap collector mainly consists in sorting and sizing the scraps in order to optimize their trade value. Since the collected aluminium parts are practically all manufactured from casting alloys and some of them are too large or thick to be sheared, an

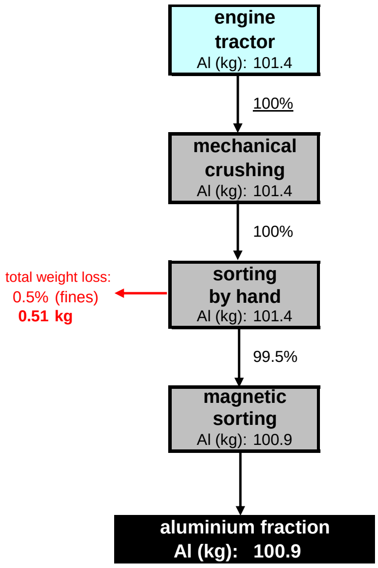
[4] The dismantler weighted all aluminium parts or made estimations of the aluminium content of multi-material parts and reached a total of 280 kg. Based on data kindly supplied by the truck manufacturer, an aluminium content of 264.8 kg was determined. The error made by the dismantler is thus an excess of 5%, which is very good. To be on the conservative side in our flow chart, we have used the data supplied by the truck manufacturer.

oxyacetylene cutting torch is used. The losses in this process do not exceed 0.25% of the input material, i.e. 0.2kg.

4.1.6. Special end-of life process for the engine

At the entrance of the end-of-life engine process, the quantity of aluminium from the studied engine block is 101.4 kg. The processing stages of this engine are described in the chart below.

Figure 2



A loss of 0.5% is recorded.

4.1.7. Aluminium refining

As casting aluminium alloys are dominant in the fractions to be recycled, the refining process (see section 2) is applied.

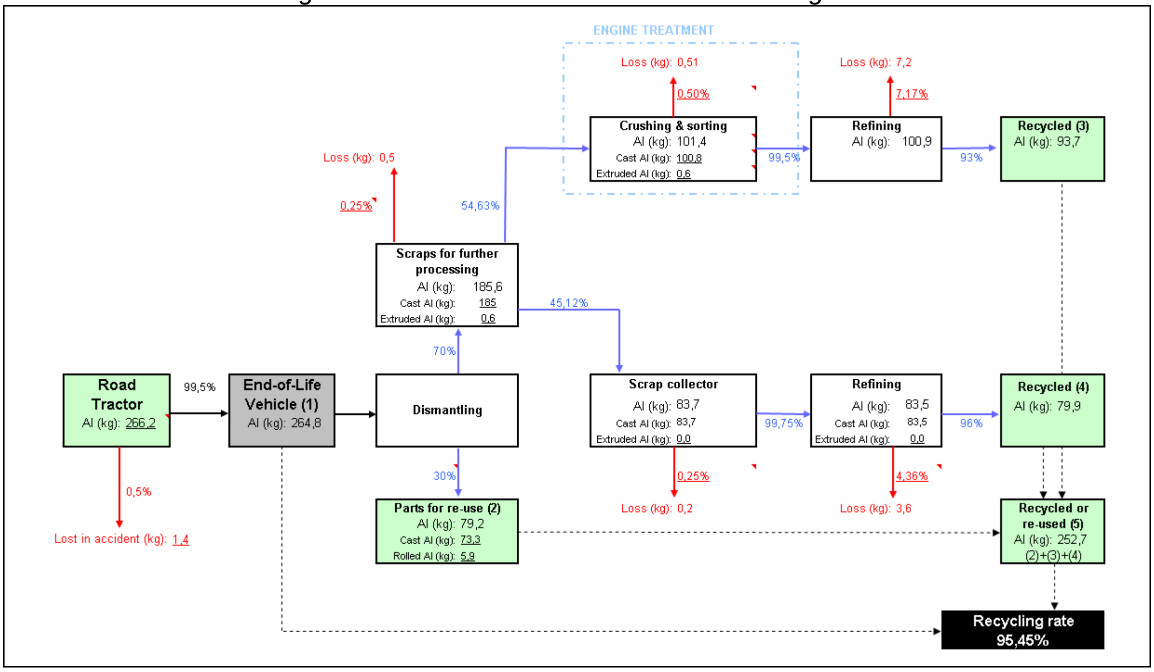
Following Table 1 and because of their small size, we applied 7.17% loss to the aluminium scraps coming from the engine recycling.

Due to their bigger size, we applied 4.36% loss to the fraction coming from the scrap collector.

4.1.8. Mass flow and recycling rate

Overall, we end with a recycling rate of 95.45%.

Figure 3: Mass flow of road tractor dismantling



4.2. FLATBED SEMI-TRAILER

4.2.1. Vehicle characteristics

- Length: 13.6 m
- Main body brand: Blond Baudouin
- Chassis brand: Benalu
- Aluminium chassis
- Floor: Aluminium omegas + wood
- 1st test drive : 04/01/1995
- General conditions: Curtain and body frame damaged
- Total vehicle mass: 6,090 kg
- Aluminium content: 1,880 kg

4.2.2. Losses during the use-phase

An aluminium rear bumper was lost during the accident that caused the end-of-life of the flatbed semi-trailer. The weight of this element has been estimated by the dismantler to be 13kg.

4.2.3. Dismantling (process, losses)

For the flatbed semi-trailer, the dismantler had to proceed otherwise than usually because of the difficulties encountered at the time of dismantling[6]. The inventory and pictures of dismantled aluminium parts are given in ANNEX II.2.

The front wall, the rails, the roof cross sills, the omegas and the outer rails are in aluminium. The chassis is mainly made from aluminium. Some parts on the axle system have been identified as being aluminium.

The axles being in a good state, they are dismantled from the chassis as a whole to be re-used. Afterwards, the works of the dismantler mainly consists in cutting the omegas and the chassis in order to facilitate their transportation to the scrap collector.
Then, the dismantling of the parts not containing aluminium is carried out.

Before being cut, all the aluminium parts had been taken apart and separately weighted[5], giving a total of 1880.1 kg. The final route of these parts is determined according to the demand from the second-hand market, their nature, the easiness for further dismantling and their general condition.

The proportion of extruded and rolled aluminium parts are 84.5% and 13.5 % respectively.

The losses at the dismantler occur during the cutting operations (chassis, outer rail, omegas…) and are mainly due to the fine chips that are too small to be collected. These chips represent less than 0.25% of the weight of the pieces to be recycled. No loss is allocated to the parts intended for re-use.

The dismantling time required 56 hours[6] instead of the predicted 30h and was carried out in December 2008.

4.2.4. Treatment by scrap collector

The main semi-trailer parts are sold for recycling to the scrap collector. The latter processed with the cutting of the chassis and the sorting of the different types of aluminium (extruded and rolled) because the resale price is not the same for each type of alloy. Then he resells everything, according to the needs of the remelters and refiners through a metal dealer.

[5] The weighing of the chassis ladder frame gave 1280 kg while the weight reported in Benalu archives for similar chassis is 1240 kg. The difference is 3% only, which attests the reliability of weighing made by the dismantler.
[6] This is mainly due to the difficult dismantling of the floor. This type of floor (alu + wood) is no longer produced by Benalu. It has been replaced by a full aluminium floor integrated in the chassis whose end-of-life process will be much easier.

The metal losses observed are due to the shearing of the aluminium elements and consists in uncollected aluminium chips and aluminium particles that. This loss rate does not exceeded 0.25%, and would be closer to 0.1% in reality.

4.2.5. Aluminium remelting

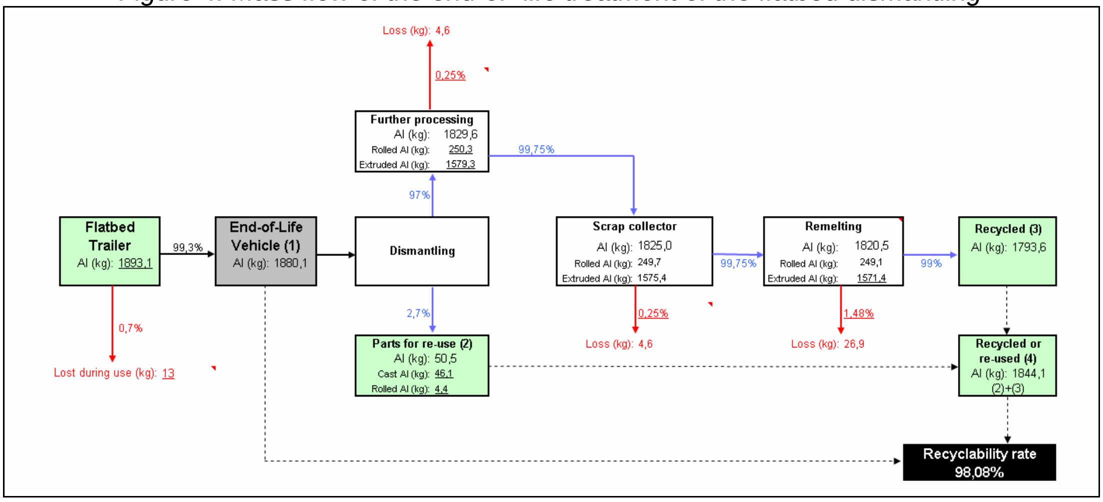
As wrought alloys are dominant in the fractions to be recycled, as aluminium parts are clean and uncoated, the remelting process is applied (see section 2).

Following Table 1 and because of their big size, we applied 1.48% loss to the aluminium scraps.

4.2.6. Mass flow and recycling rate

Overall, the recycling rate of the flatbed trailer is 98.08 %.

Figure 4: Mass flow of the end-of- life treatment of the flatbed dismantling



4.3. SILO SEMI-TRAILER

4.3.1. Vehicle characteristics

- Aluminium silo brand: Filliat
- Steel chassis brand: Fruehauf
- 1st test drive: 1982
- General condition: Very old but still in good shape
- Total vehicle mass: 7,182 kg
- Aluminium content: 1,963 kg (paint layer excluded)
- Type: dry bulk tank body

4.3.2. Losses and addition during the use-phase and paint deduction

Some losses of aluminium on the vehicle occurred during the “use” phase. The first loss concerns one of the 12 fender brackets that was lost and then replaced with a steel bar (3kg). This aluminium loss represents 1kg.

The second loss is due to abrasion of the silo body’s inner surface, generated by the carried materials. In the silo body’s case and according to its use, the loss by abrasion is estimated to be 1%, i.e. 20kg.

Finally, the paint layer weight of the silo body has been estimated at 15 kg and deducted from the initial weight which was 1,978 kg at the time of the entry of inspection at the dismantler.

So, the aluminium content of the tanker retained for this case study will be 1,963 kg.

4.3.3. Dismantling (process, losses)

As for the previous vehicles, the “operational” choices of the dismantler are based on economic considerations. The inventory and pictures of dismantled aluminium parts are given in ANNEX II.3.

In order to obtain the precise aluminium weight in the vehicle, the silo body and chassis part have been separated without aluminium loss. The silo body part is essentially aluminium (1,947 kg) and will be sold to the scrap collector for further recycling.

The chassis contains very little aluminium (16 kg) that will be re-used (valves, wheel cover and fender bracket). As these parts are detached from the chassis without cutting and shearing, no metal loss is observed.

For the silo body that is cut and sheared, a maximum loss of 0.25 % is estimated by the dismantler.

The labour time for the dismantling is 7h and was carried out in June 2008.

4.3.4. Treatment by scrap collector

The steel elements remaining on the silo body are separated from the aluminium elements with the help of an oxyacetylene cutting torch. Then the silo body is sheared to the maximum dimensions of 1.5m x 0.5m x 0.5m in order to satisfy the scrap collector requirements for further refining.

This process lasted 4h and was carried out at the end of July 2008.

Due to the possible errors in sorting the Al and non-Al elements, the oxyacetylene torch cutting and the shearing operations, an aluminium loss of 0.25 % is considered, i.e. 4.9 kg.

4.3.5. Aluminium refining

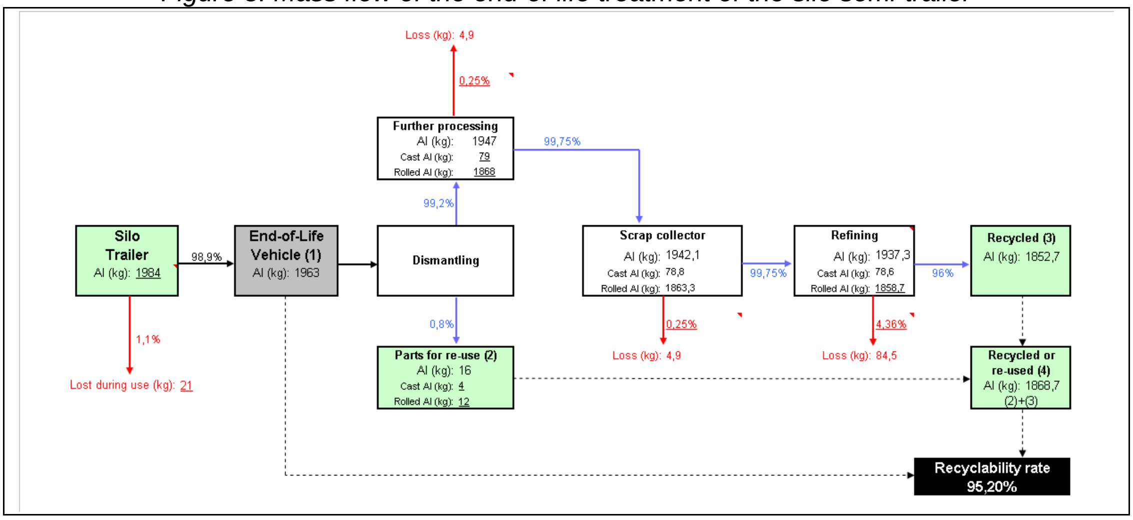
Despite the fact that one single aluminium alloy is dominant (95.8%), the fact that fractions to be recycled contain a lot of impurities (paint layer, grease…) imposes the refining process (see section 2).

Following Table 1, we applied 4.36% loss due to the large size of the fractions coming from the scrap collector.

4.3.6. Mass flow and recycling rate

Overall, we find a recycling rate of 95.20 %.

Figure 5: Mass flow of the end-of life treatment of the silo semi-trailer



4.4. TIPPING BODY

4.4.1. Vehicle characteristics

- External dimensions (L * l * h): 8.7m * 2.5m * 2m
- Internal dimensions (L * l * h): 8.5m * 2.3m * 1.35m
- Bottom plate thickness: 8 mm
- Chassis brand: Fruehauf
- Tipper brand: Benalu
- Type: public works tipper
- 1st test drive: 1999
- General Condition: Tipping body damaged
- Total vehicle mass: 5,340 kg
- Aluminium content: 1977 kg

4.4.2. Losses during the use-phase

Only the tipper body is studied (without its chassis). The body is not painted and does not show any signs of corrosion. Only a small amount of dirt is found under the main body, because it was used mainly for sand transportation to building sites.

The loss during use is due to the abrasion of the body during the repetitive tipping operations. At the most worn place of the tipper, i.e. at the rear end of the bottom plate, a thickness of 3mm is left (5mm lost). No significant wear is observed on the front of the bottom plate. To calculate the loss during use, we assume no loss for the front third of the bottom plate and, for the rear two thirds, a loss between 0 to 5mm at the very end. This corresponds to a loss of 88kg.

4.4.3. Dismantling

The dismantling of the tipping semi-trailer is proceeded as usual and based on economic considerations (see ANNEX II.4). The weight of tipper body is 2000 kg and has been obtained by difference between the complete and the remaining vehicle weight after removal of its tipping body. The tipper body is essentially manufactured in aluminium except some parts like those in galvanized steel. The wrought aluminium alloys present in the tipping body are from two different families, one for the plates and one for the extruded pieces mainly used as stiffeners. The closing door mechanism is manufactured from casting alloys.

The non Al pieces have been removed from the tipper body and their weight is 20.1 kg.

A negligible amount of water and dirt remains on the tipper body after its cleaning. The weight of dirt has been estimated by the dismantler to be 3kg and will thus be subtracted from the recorded weight of the tipper body.

No aluminium parts are reused at this stage and all parts go to the scrap collector's. So the aluminium content of tipper body is **1,976.9 kg.**[7]

For the tipper, the dismantler did not perform any cutting or shearing. Thus, there are no losses retained in this dismantling process.

The dismantling of the tipping semi-trailer lasted 5h and was carried out in May 2009

4.4.4. Treatment by scrap collector

As for the other vehicles, an oxyacetylene cutting and shearing of the tipper body are carried out. Then, a sorting and sizing of the scraps are operated in order to optimize their trade value. The scrap collector sends the aluminium pieces to the refiner through a scrap trader.

The main aluminium losses are due to the oxyacetylene cutting and shearing at the scrap collector and do not exceed 0.25%, i.e. 4.9 kg.

4.4.5. Aluminium refining

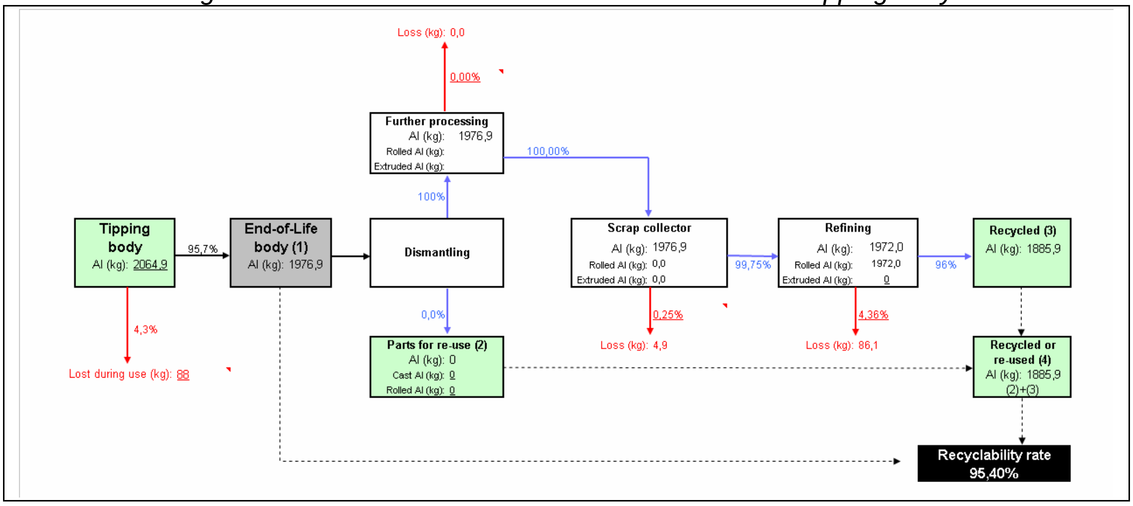
As three different kinds of aluminium alloys are mixed, the refining process is applied.

Following Table 1, we applied 4.36% loss due to the large size of the fractions coming from the scrap collector.

4.4.6. Mass flow and recycling rate

Overall, we end with a recycling rate of 95.40 %

Figure 6: Mass flow of the end-of life treatment of the tipping body



[7] Out of Benalu archives, a similar tipping body with a 10mm thick bottom plate would weight about 2,310kg. For a 8mm thick bottom plate, the weight would therefore be about 2,200kg. If we deduct 88kg lost due to abrasion of the bottom plate, we obtain 2,112 which is 7% more than the 1,976.9 kg obtained in the present study. This may be due to different side plate thickness between the model found in Benalu's archives and the model actually dismantled.

5. CONCLUSION

For the four aluminium commercial vehicles dismantled, a recycling rate of 95% or higher has been demonstrated.

This conclusion is based on real practice taking place during the treatment of “EOL” commercial vehicles. Observation of actors, recognised and transparent calculation methods were used in this study. For each vehicle, a mass flow analysis (MFA) including aluminium losses occurring during each process stage has been made.

Obtaining the feedback from actors involved in the recycling sector is always challenging, reason why a win-win approach has been adopted to motivate them. Nevertheless, we can say that this study sparked the interest of our partners and could emerge in the implementation of a more industrialized process chain.

ANNEX 1: PROJECT PARTNERS

MVI: Maire Véhicules Industriels (dismantler)

One of the major participants in this study is MVI. This company specializes in the selling on industrial vehicles and used parts in France and in Europe. This is an SME with 5 employees located near Dijon (200km South East of Paris). MVI is a member of the « Conseil National des Professions de l'Automobile » (CNPA) in the industrial vehicles branch. Mr. Maire (PDG) is involved in providing broken or 'not in use' industrial vehicles (recent tractors, semi-trailers, dumpster trucks…), dismantling them under the usual conditions that come with his profession, (meaning not in an optimal way), and to list and photograph the extracted parts in a way that still allows their weight and composition to be defined. These parts remain his property and are resold at the old parts market. Then we buy the carcasses of these vehicles from him so the participants can treat them in the downstream course to their end of life. MVI's company assures the transportation of these carcasses towards the places in which they will be treated.

SARL Gaudillière (scrap collector & separation)

Industrial demolition and metal and iron recuperator enterprise. This enterprise is also located close to Dijon.
As a general rule, MVI's company sells the vehicles' carcasses to their scrap collector, Mr GAUDILLIERE, who, after having carefully sorted the materials and conditioning them, normally resells them to a metal trader or from time to time to a smelter. His main work tools are a shear, a handling shovel and a 'weighbridge' that is using as the weighing device.

Groupe GALLOO Recycling (scrap collector, shredder & separation)

The Galloo Recycling Group is an enterprise that recuperates ferrous and non-ferrous metals. They employ 400 people with an annual turnover of €400 million.
Galloo has an industrial machining process that recovers consumer goods or worn industrialists (vehicles, electronic and electric equipment, ships…).
This organization has several recycling sites in Halluin, France (59), specializing in the shredding and treatment of shredded residues. M. FRANCOIS (in charge of all environmental affairs) and M. VAN HEUVERSWIJN (commercial manager, non-ferrous metal specialist) have been our interlocutors at this heart of this study.
This organization has 3 shredders/crushers, 1 press, 1 flotation unit and 5 shears and, thus, intervenes in the study and, according to methodology chosen, is responsible for the crushing of the vehicles.

Renault Trucks (manufacturer)

We have chosen to honor the vehicles with the brand Renault (The Volvo organization whose turnover in the heavy lorries division reached €19,7 billion in 2007 and sold 79,442 'Renault Trucks' vehicles) for the choice in tractors. Our interest in contacting Renault lay in their will to collaborate in this study by providing the data they have about their vehicle composition and to thus precisely locate the position of each aluminium part and its corresponding mass.

Our main contact at the head office of Renault Trucks at Saint Priest (69) has been Mme ODJIAN (in charge of everything environmental) who knew how to motivate the design team in order to collect the necessary information.

SOREMO (engine crusher & refiner)

SOREMO is a shredder and refiner of engine blocks Company in Chaumont (52) to approximately 80 km in the North-East from MVI. SOREMO treats vehicle engines (cars, small trucks…) and industrial vehicle engines.
Its main production tool is a dry hearth furnace with 30 tons/year holding furnace (European largest facility), a tilting rotary furnace (rated at tons of aluminium per hour), a special engines block crushing system with washing trommel and a shredder.
Moreover, SOREMO produces Secondary aluminium ingots (Alloys: AS9U3, DIN226, 5075, 5076) for 8,000 tons per year.
Hence, SOREMO are involved with all tractor engine recycling stages in the study. Our main contact within this company is M. P. SANTINI, the Production manager.

BENALU (Trailer manufacturer)

BENALU, is a pioneer and the European leader in the manufacturing of dry bulk vehicles made of aluminium. Since the company made the very first model of aluminium semi-trailer, its fame is now recognized with an unequalled know-how and a creativity regarding weight saving. Established since its creation in 1967 in the Pas-de-Calais, BENALU is located in Liévin.

Thanks to Mr C.Gressier, the original aluminium content of the vehicles could be retrieved in the archive of the company. This allowed the project team to cross-check and to validate the data obtained after dismantling and weighing.

EAA (European Aluminium Association)

The European Aluminium Association (EAA) represents the aluminium industry in Europe. The EAA was founded in 1981. Its members are the European primary aluminium producers, the national associations representing the manufacturers of rolled and extruded products in 18 European countries, the Organisation of European Aluminium Remelters and Refiners (OEA) and the European Aluminium Foil Association (EAFA). The overall objective of the EAA is to secure sustainable growth of aluminium in its markets and to maintain and improve the image of the aluminium industry towards target audiences (source EAA).
EAA is represented for this study by Bernard Gilmont, Automotive and Transport Director and Marlen Bertram, who was working for EAA and OEA at the beginning of the study.

ANNEX 2: END-OF-LIFE PROCESSING AND ALUMINIUM INVENTORY

See separate document.