

## **WROUGHT-TO-WROUGHT STRATEGIES: ECONOMIC AND ECOLOGICAL ASPECTS REGARDING ALUMINIUM RECYCLING**

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### **ABSTRACT**

This paper presents a life-cycle management tool comprising costs and environmental impacts for each life cycle phase of a vehicle control arm. A flexible model is developed for the EOL phase describing refining technologies to link any given aluminium scrap fraction of a certain chemical composition with desired wrought alloy purity. This provides a novel link between typical EOL aspects regarding treatment and recyclability, and the material science relevant for product design and production.

### **INTRODUCTION**

High-end products made from wrought aluminium are currently produced from primary aluminium, to meet the high purity requirements. Possibilities of using 75 % recycled aluminium in a vehicle component are investigated within the SuPLight (SuPLight 2013) project, which is financed through the European Commission's 7<sup>th</sup> framework programme.

This paper describes a tool developed to assess the lifecycle environmental performance and the lifecycle costs of a control arm in a vehicle with a lifetime of 200 000 km, including a detailed model for the aluminium scrap treatment processing routes. Within the SuPLight project, 7 generic test components with variable alloy and trace element concentration levels have been tested in regard to formability, mechanical properties and corrosion resistance. These generic test components are the basis for the scrap treatment process route scenarios.

The aluminium market is undergoing a rapid change, and a novel dynamic material flow model for the global vehicle system was developed by Modaresi and Müller (2012). The study predicts an aluminium scrap surplus already in 2018 and reaches a level of 14 million metric tons in 2050. These dynamics will be used as a basis for future predictions of the aluminium market concerning prices and technology penetration. Modaresi and Müller recommend various policy options that can hinder or delay scrap surplus. Two of these are especially relevant for this study; technologies for sorting and refining. Sorting technologies must separate the scrap into castings, wrought aluminium, and different alloy families. Such technologies has been developed (e.g. laser-induced breakdown spectroscopy and colour identification in conjunction with etching), but are currently not economically viable. Refining technologies for separating alloying elements and impurities (e.g. chlorination, fluxing and electrolysis) are currently very costly and have significant environmental drawbacks.

## METHOD

The tool is developed through modeling within SimaPro (PRé Consultants 2012), applying the LCI database ecoinvent v2.2 (Ecoinvent Centre 2010) for the background data. The impact assessment method ILCD (European Commission 2012) combined with cumulative energy demand is used.

The functional unit of the case study presented here is *One vehicle control used in vehicle with a lifetime of 200 000 km*. The recycle content (cut-off) approach is applied, which means that the sorting, remelting and refining of the aluminium scrap is considered as production of raw material as input to the ingot production. In the following this is referred to *Production of recycled aluminium*. The detailed modeling of the production of recycled aluminium links the chemical composition requirements for the product, and hence allows for environmental and economic consequences of both changes in the purity requirements and future policies and market mechanisms.

## THE LIFECYCLE TOOL

An overview of the tool, including the detailed model of EOL is shown in Figure 1.

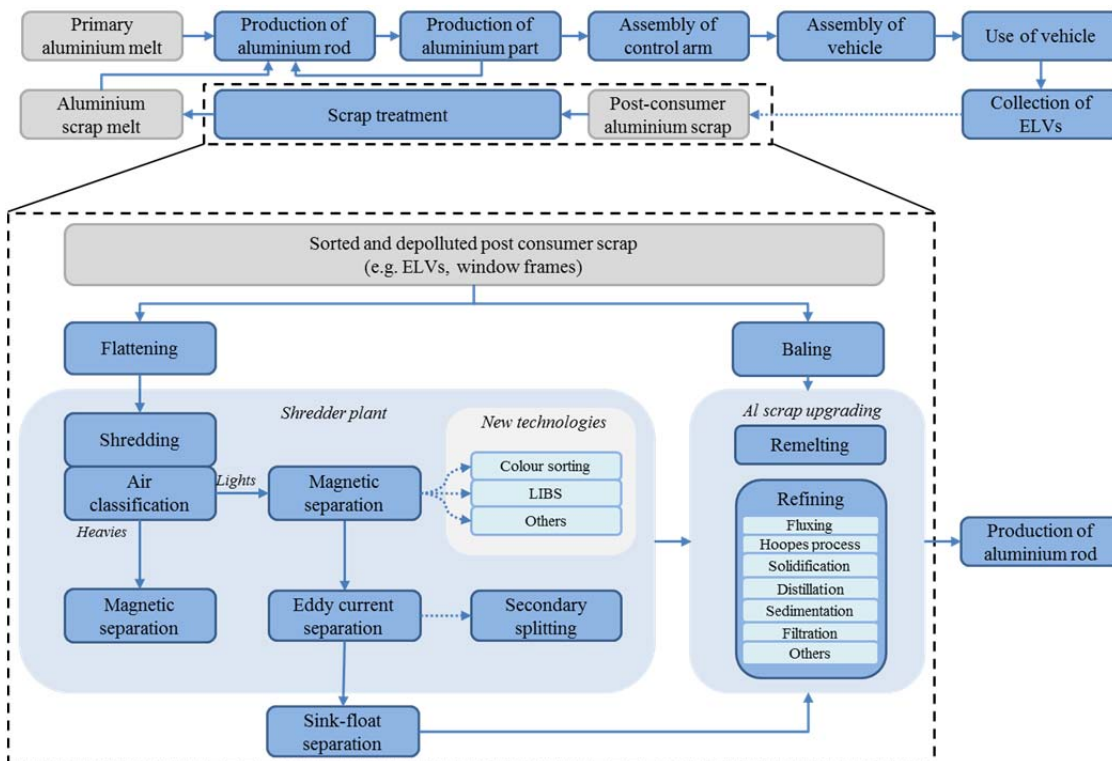


Figure 1: Overview picture of the LCA tool

Lifecycle costs are included in the LCA tool, divided into material costs, production costs and user costs. Material costs include the materials used in the production technology processes from scrap treatment to vehicle assembly. Production costs comprise operation of production facilities and equipment, and labor. User costs include operation and service of the vehicle.

The tool will be applied to compare scenarios with certain variables; chemical composition, scrap treatment technologies, scrap share in production of the component, production process routes and weight of the component. This allows for optimization of the lifecycle environmental impacts and costs, given a set of constraining conditions for the variables. The model will also be flexible regarding future forecasts of price variations for primary aluminium and aluminium scrap fractions undergoing various EOL treatment technologies. A scenario of an equivalent control arm produced from steel is also included as reference.

The purpose of the detailed EOL model is to investigate to what degree material quality, i.e. aluminum purity requirements affect the lifecycle environmental and economic performance of the vehicle control arm. The model is developed based on a vehicle control arm as a case, but can easily be adjusted to fit for other aluminium parts in any other means of transport.

### PRIMARY RESULTS

Results for global warming from the current preliminary lifecycle tool, shows that a control arm produced from primary aluminium (base scenario) gives 12 % less lifecycle CO<sub>2</sub> emissions than a control arm produced from primary steel. For the base scenario 26 % of the emissions are related to production and 74 % to use. For steel, the respective shares are 7 % and 93 %, due to a less emission-intensive production and higher fuel consumption in the use phase. This is because a similar component made from steel will be heavier. These results are shown in Figure 2, including results for more categories.

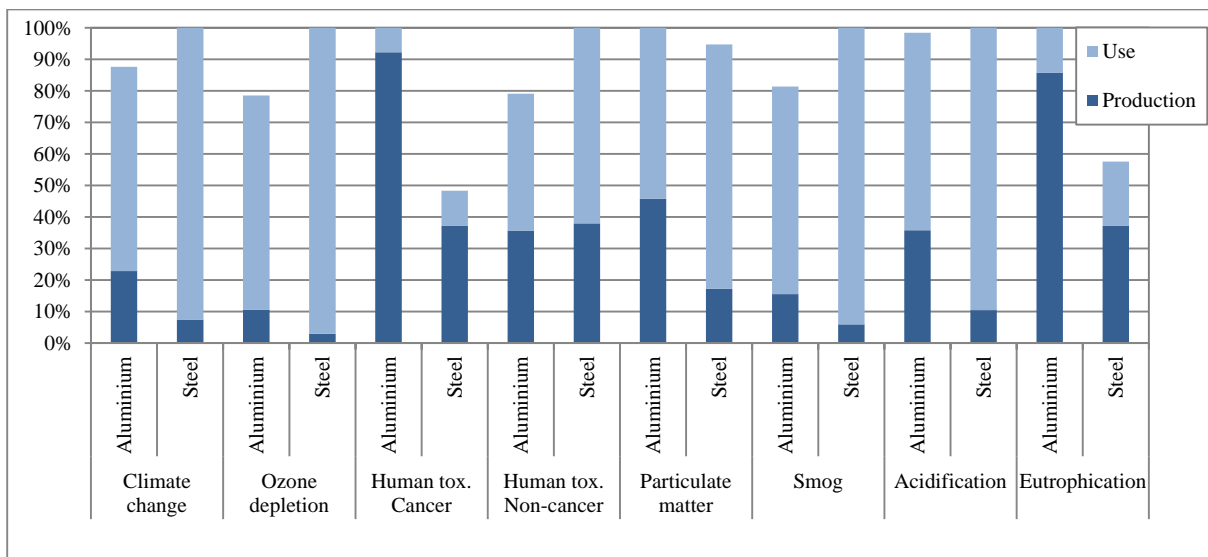


Figure 2: Relative results for aluminium and steel control arm

Three scenarios for the aluminium control arm are compared to the base scenario. The results are given in Figure 3. A share of 25 % and 75 % aluminium scrap gives reductions of 3 % and 9 % respectively in the CO<sub>2</sub> emissions compared to the base scenario. A combination of 75 % recycled aluminium and 1 % increased weight of the control arm gives 36 % higher emissions of CO<sub>2</sub> than the case is for the control arm produced from 100 % primary aluminium.

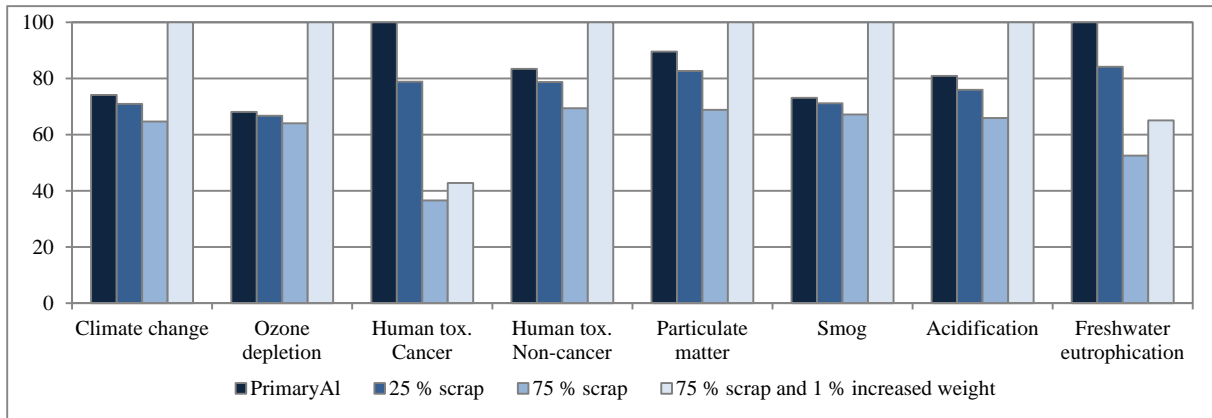


Figure 3: Relative results for various scrap share and weight for aluminium control arm

## CONCLUSIONS AND FURTHER WORK

The preliminary results strongly indicate that the environmental impacts occurring in the use phase outweighs savings related to increased use of scrap in the production. The exceptions are in the impact categories human toxicity (cancer effects) and eutrophication.

Further development of the tool encompasses inclusion of more detailed data, testing and quality checking. The tool shall also be improved by including parameterisation of costs, related to primary aluminium and scrap treatment processes in particular. The lifecycle tool will further be integrated as a plugin to the simulation-based optimisation tool developed within the SuPLight project, including plugins dealing with *Tolerance analysis*, *Metallurgy*, *Mechanical* (including *Material simulation*), *Business models*, *Reverse logistics*, *Eco-design* and *Socio-ethical LCA*.

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