ANALYSE DE CYCLE DE VIE DU RECYCLAGE DE L'ALUMINIUM : ÉTUDE DE CAS DES CÂBLES

Guilhem GRIMAUD, Marie VUAILLAT, David RAVET, Bertrand LARATTE and Nicolas PERRY

Résumé

Le but de cette étude est de documenter l'impact environnemental d'un procédé de recyclage de l'aluminium, en utilisant la méthodologie d'analyse de cycle de vie (ACV). Aujourd'hui, l'impact environnemental des aluminiums primaires et secondaires est déjà bien défini par l'Association Européenne de l'Aluminium (EAA). Cependant, les processus de recyclage spécifiques ne sont pas disponibles dans la littérature. Dans cette étude, l'évaluation environnementale du traitement et du recyclage des câbles sont examinés. Les données proviennent de l'usine de recyclage MTB Recycling située en France. Le processus spécifique a été développé par les ingénieurs de MTB Recycling et est vendu comme solution de traitement dans les différents pays. La spécificité du procédé MTB repose sur l'absence de fusion pour l'affinage des métaux. Malgré tout, la pureté standard de l'aluminium atteint 99,6 %. Cette performance est obtenue en utilisant uniquement la séparation mécanique et des procédés de tri optique sur les câbles déchiquetés. L'évaluation de l'impact environnemental est effectuée en utilisant la méthode ILCD MidPoint. L'étude compare 3 systèmes : l'aluminium primaire, l'aluminium secondaire affiné par fusion et le processus de recyclage des câbles développé par MTB. D'une part, l'étude démontre les avantages environnementaux de l'aluminium recyclé par rapport à l'aluminium primaire. D'autre part, les résultats font apparaître la forte influence du recyclage à chaud de l'aluminium par comparaison avec le processus MTB de recyclage à froid. L'étude démontre l'intérêt du recyclage par filière vis-à-vis du recyclage en mélange.

Keywords

Analyse de Cycle de Vie, ACV, Aluminium, Recyclage, Affinage des Métaux, Optimisation des Procédés

LIFE CYCLE ASSESSMENT OF ALUMINIUM RECYCLING PROCESS: CASE OF SHREDDER CABLES

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Abstract

Life cycle impact of European generic primary and secondary aluminium are well defined. However specific recycling processes are not available in literature. In this study, the environmental assessment of cable recycling processing is examined. The data come from a recycling plant (MTB Recycling) in France. MTB process relies only on mechanical separation and optical sorting processes on shredder cables. On the one hand, the study demonstrates huge environmental benefits for aluminium recycled in comparison with primary aluminium. On the other hand, the results show the harmful environmental influence of the heat refining by comparison with cold recycling process.

Keywords

Life Cycle Assessment, LCA, recycling, aluminium, metal refining, process optimisation

1. INTRODUCTION

The purpose of this study is to document the environmental impact of a recycling aluminium process, using the Life Cycle Assessment (LCA) methodology, in accordance with the standards of International Organisation for Standardisation (ISO 14,010/44) [1,2]. Today, the life cycle impact of European generic primary and secondary aluminium are well defined through the work of the European Aluminium Association (EAA) [3]. However specific recycling processes are not available in literature. In this study, the environmental assessment of cable recycling processing is examined. The data come from a recycling plant (MTB Recycling) in France. The specific and innovative process was developed by MTB Recycling engineers and is sold as a process solution in different countries. The specificity of MTB process relies on the absence of fusion for metal refining. Nevertheless, it reaches standard aluminium purity up to 99.6%. This performance is obtained using only mechanical separation and optical sorting processes on shredder cables. Environmental impact assessment is done using ILCD Handbook recommendations [4].

Numerous studies were conducted concerning the sustainability of aluminium recycling in comparison with primary aluminium. Outcomes about global and local environmental impacts show decrease up to 90% by using recycled aluminium [5,6]. However, systems modelling always relate to the standard melting solution for recycling aluminium.

The objective of this study is, therefore, to examine the environmental benefits and energy savings of the MTB recycling system.

2. ANALYTICAL FRAMEWORK

2.1. Functional Unit Proposal

As part of this study, the functional unit used is as follows: producing one ton of aluminium intended for end-user applications, with purity above 97% using current industrial technologies (annual inbound processing> 10,000 t) located in Europe. The matching quality of the compared products can meet the same function as a high purity aluminium can be used for producing a large number of alloys without refining. We selected three scenarios that meet all the conditions of the functional unit:

- Scenario 1 or primary: primary aluminium, resulting from mining, data from EAA aggregated in Ecoinvent 3.1 [7–9].
- Scenario 2 or secondary: secondary aluminium from recycling by melting, data from European remelter collected by EAA and aggregated in Ecoinvent 3.1 [10–12].
- Scenario 3 or MTB: MTB Aluminium, from recycling using MTB processes [13].

2.2. Scenario development

The evaluation is designed by modelling input and output flows that describe different systems of aluminium recycling with the software SimaPro™ 8.04 [14]. All the flows are based on processes from Ecoinvent 3.1 library [15]. The systems are developed according to the local context of Western Europe. To allow comparison all the inventory elements are compiled based on the Ecoinvent database boundaries and data quality check [12,16]. The boundaries include cradle to exit gate stages [17]. Life in use of aluminium in the products are not included in our study scope. The study only focuses on transformation steps of aluminium. Once modelling were done, the characterisation is conducted according to ILCD Handbook recommendations [18,19]. The scenario development for this study is already present in [13]. The data collection method does not allow the use of the results for other cables recycling processes. The results are representative only of recycling solutions developed by MTB.

The Figure 1 presents the main steps taking into account in each scenario for the comparison. For scenarios 1 and 2, the final product is aluminium ingots, while for scenario 3 the final product is aluminium shot. In any case, scenarios meet the functional unit.

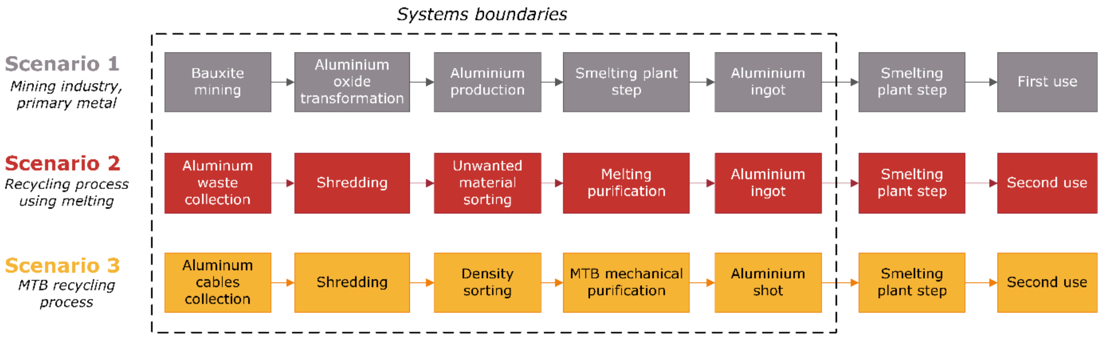

Figure 1 Presentation of the 3 scenarios and main steps of the production process

3. RESULTS

3.1. Comparison of the 3 Scenario

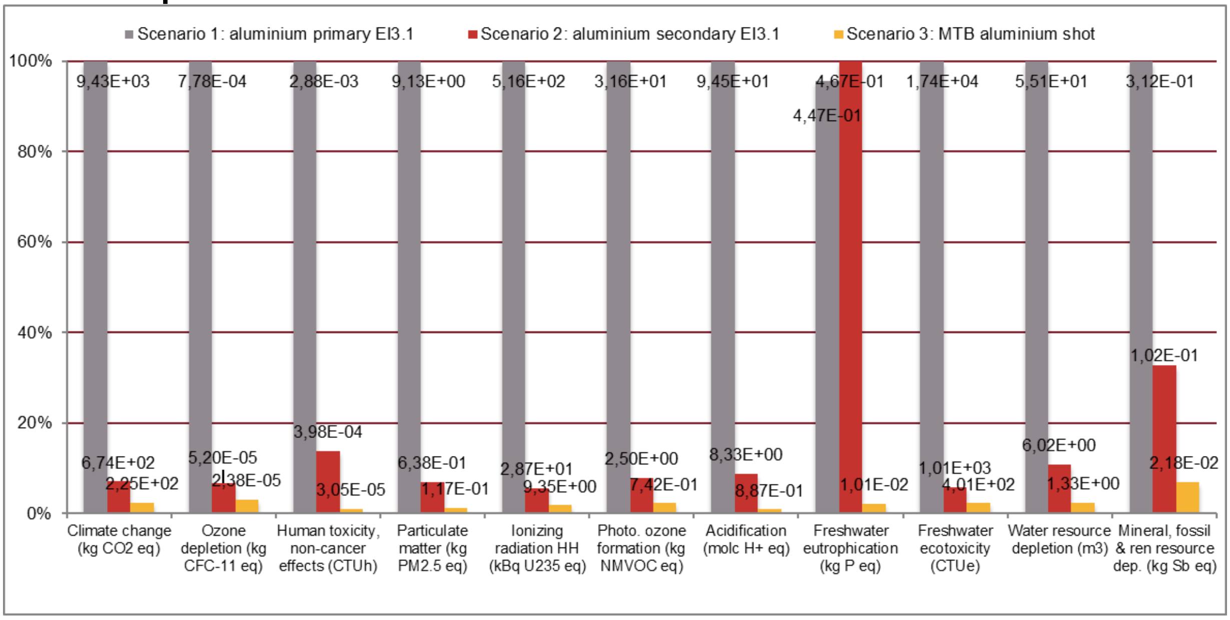

Figure 2 Characterisation of the 3 scenarios with specific electricity mix

The Figure 2 draw the comparison for the three scenarios. The calculations were made using the specific electricity mix for each scenario. As expected the scenario 1 emerges as far more significant on all indicators with the exception of freshwater eutrophication where recycling aluminium (scenario 2) takes the lead. The scenario 2 (secondary aluminium) has the highest impact, even higher than primary aluminium (scenario 1) on the freshwater eutrophication impact category as can be seen in Figure 2, because it requires the addition of alloying metals to aluminium production. The addition of alloying elements is required to supply the market with aluminium alloys that meet the market constraints. Copper is the principal alloying element modelled in Ecoinvent 3.1, indeed production chain requires sulphuric tailing representing 96.4% of the impact on the freshwater eutrophication impact category. This result seems to be a modelling error into Ecoinvent 3.1. The study does not account this result from LCA to draw conclusions.

Average secondary aluminium reaches approximately 10% of the impact of the primary aluminium scenario. And MTB aluminium shot is close to 5% of the primary aluminium impact on all the set of indicators. Those results correspondent to evaluation already done and meet the values given by the Bureau of International Recycling (BIR) for aluminium recycling benefits [20].

The primary aluminium production is used as a reference for guidance on the quality of production. Foremost, our analysis is intended to compare methods of recycling. Comparison with scenario 1 should help translate environmental benefits of recycling.

3.2. Recycling Scenario Comparison

In previous characterisation, the difference between scenarios 2 and 3 are not clearly shown on the representation. The Figure 3 gives the opportunity to compare more specifically the two recycling scenarios, the impacts are still presented using the specific electricity mix for the 2 recycling scenarios.

On the set of indicators, the impact of scenario 3 does not exceed the impact of scenario 2. In addition, the impact of MTB recycling scenario represents between 2% and 46% of the impact of recycling by melting. The average impact of the solution is halved. Nevertheless MTB has launched an approach to reducing impacts by working on different subjects (blades, plastics processing, shredding steps, etc.) [32].

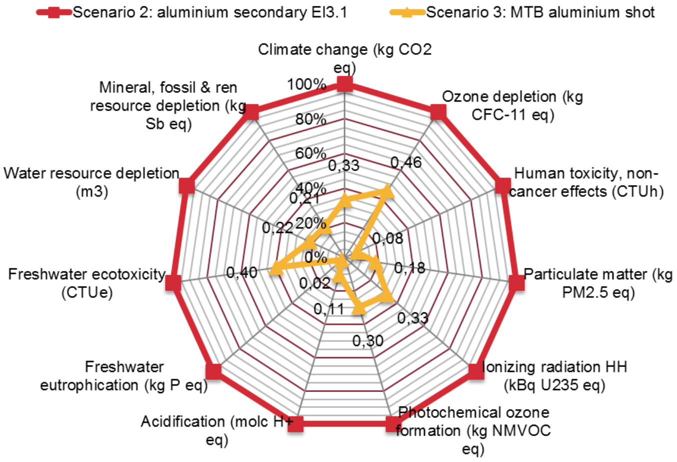

Figure 3 Comparison of the characterisation of the 2 recycled scenarios, equivalent electricity mix

3.3. Uncertainty Analysis for Recycling Scenarios

An uncertainty analysis was conducted between the three scenarios. With the specific electricity mix, the uncertainty between scenarios 2 and 3 do not exceed 5% on all the indicators. Except human toxicity indicators (8%) and the water resource depletion indicator (45%). With equivalent electricity mix, the uncertainty exceeds 5% on 3 indicators: ozone depletion (11%), human toxicity, non-cancer effects (9%) and water resource depletion (45%). The conclusions of the study are strong with respect to the weak uncertainties on the characterisations.

4. CONCLUSION

This study allows us to establish an environmental hierarchy between recycling solutions for aluminium cables. Whatever the electricity mix used by the recycling plant, the MTB mechanical recycling process is the most environmentally friendly. Additionally, LCA was conducted in order to help the company to highlight environmental hotspots of the system and try to design new solutions to decrease environmental impact of aluminium produced [21].

On the one hand, the study demonstrates huge environmental benefits for aluminium recycled in comparison with primary aluminium. On the other hand, the results show the harmful environmental influence of the melting refining in comparison with mechanical recycling process. The LCA revealed that the closed product loop option (considering aluminium cables) has lower environmental impact over the other recycling scenario using mixed aluminium scraps. This performance has already been demonstrated for aluminium cans [22]. To conclude, recycling when driven without loss of quality is a relevant alternative to mining.

Acknowledgements

This work was performed within the financial support from French Agency for Environment and Energy Efficiency (ADEME).

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