The Carbon Footprint of Recycled or Secondary Aluminum

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Introduction

Sustainability is one of this decade's most important drivers of aluminum usage. It is a good material for a circular economy as it can be recycled many times if done correctly. Primary aluminum is carbon intensive, mainly due to the energy required for the electrolysis (smelting) process. The aluminum industry has been making significant efforts to reduce the carbon footprint of primary aluminum. Still, there is immense pressure to do more, especially to integrate more recycled/secondary aluminum into products. Recycled aluminum is known to have about 5-8% of the carbon footprint of primary aluminum. However, primary aluminum can have a carbon footprint ranging from less than 4 t CO_2e/t Al (low-carbon primary produced with hydropower) to over 20 t CO_2e/t Al (from electricity produced with coal power).[1] Therefore, the question is when calculating the 5-8% carbon footprint, what number for primary aluminum should be used?

Sometimes 0.5 t CO_2e/t Al is provided as the carbon footprint for recycling or secondary aluminum in literature and presentations,[1] but is this really the correct number? When does aluminum's (or any product's) carbon footprint reset to zero? What is the actual carbon footprint of recycled or secondary aluminum and the products that are made from it?

Calculating Carbon Footprint

When asking a casthouse or foundry what the carbon footprint of their products is, you might get an answer like this: "We are using 40% of internal scrap, 30% recycled aluminum ingots, and 30% low-carbon primary ingots from a hydropower producer. The internal scrap is at zero, the recycled Al ingots at 0.5, and the primary aluminum at 4 t CO_2e/t Al, so with 70% recycling content, the metal in our castings has a carbon footprint of only 1.35 t CO_2e/t Al."

Breaking down the carbon footprint in this way is an oversimplification, and there are three aspects that need to be considered. First, it is important to consider that internal scrap can be calculated in two different ways—though the resulting carbon footprint is identical for both. In one method of calculating the carbon footprint, one must consider that the internal scrap is constantly remelted from one production cycle to the next and never leaves the system boundary (factory). This means that one must then keep the initial carbon footprint of the primary metal on the internal scrap, meaning that the carbon footprint is always carried on to the next production cycle and must be added every time instead of being assumed to be at zero. Therefore, when producing a part, one must account for the primary metal with its carbon footprint and that the process scrap that is being recycled will have the same carbon footprint. As a result, the final piece will also have the same carbon footprint, while the same amount of scrap re-enters the production cycle as initially invested.

Another method of calculating internal scrap is by determining the process scrap to have a zero-carbon footprint, where the scrap then circles through the production system in the same way as previously described. When calculating the carbon footprint of the final product, it will have the same carbon footprint as the primary aluminum, since the process scrap cycles through the production.

For both methods, the CO_2 of the melting processes, etc., are not considered at this stage of the foundry's product carbon footprint calculation (Figure 1). The only way to lower the carbon footprint of the input material is by reducing the carbon footprint of the primary metal.[2]

Second, regarding recycled aluminum, the average carbon footprint for secondary aluminum ingots in North America is about 0.5 t CO_2e/t Al (gate-to-gate), which is what the Aluminum Association has determined is the value for scrap remelting and casting into an ingot. Additionally, scrap collection accounts for an additional 0.1 t CO_2e/t Al, as well as some metal loss, and the logistics from the remelter (secondary smelter) to the foundry.[3,4] If the remelter also needed some primary aluminum to put the chemistry back into specification, the true value can quickly become closer to around 1 t CO_2e/t Al or more (Figure 2). Therefore, calculating the carbon footprint of recycled aluminum is more complex than many assume.

Third, one must remember that the carbon footprint of primary aluminum ingots can have a wide range (as mentioned before). Adding alloying elements like Si and Mg also contributes to the carbon footprint. Aside from that, some primary aluminum producers offer their ingots with a certain recycled content, so it is important that the specific primary aluminum supplier provide as close to the exact carbon footprint as possible, including all of the GHG Protocol Scopes and all International Aluminium Institute (IAI) Levels. If this is not possible, the IAI regional averages can be used.[5]

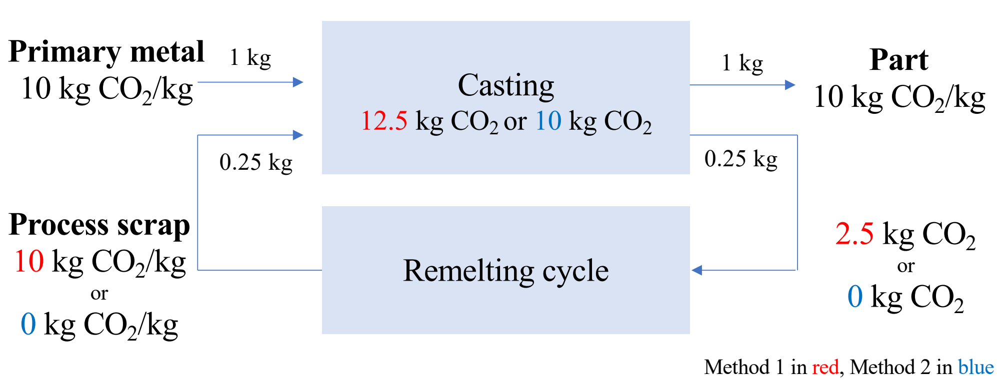

Figure 1: Overview of internal scrap carbon footprint calculation methods.[2]

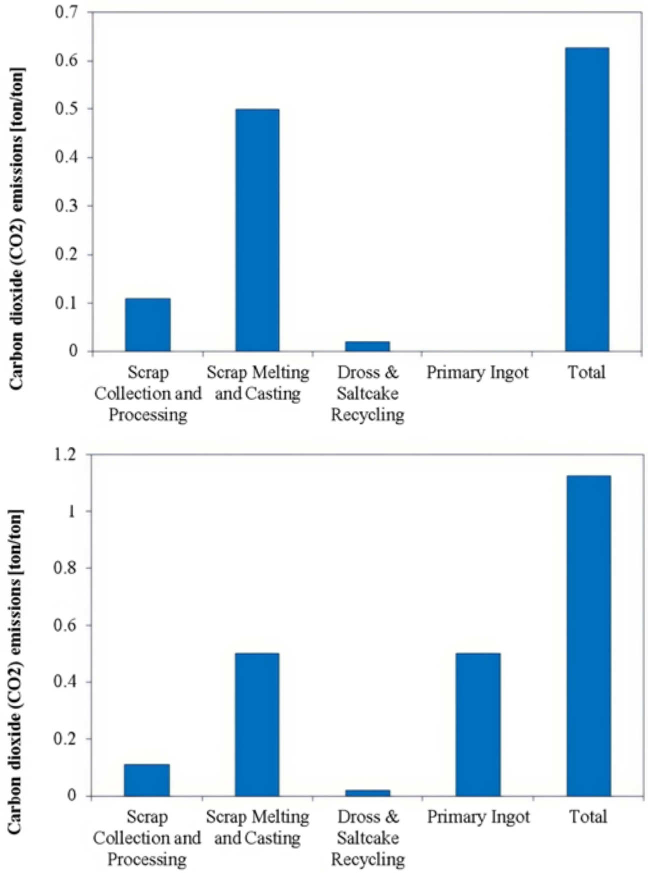

Figure 2. The carbon footprint of recycled aluminum (cradle-to-gate), representing 1,000 kg of recycled aluminum (top) and representing 1,000 kg of a secondary aluminum ingot with some primary content (bottom).[3,4]

Returning to the foundry's initial statement regarding the carbon footprint of their castings, a more accurate calculation would be as follows: the internal scrap has the average carbon footprint of the recycled and primary aluminum ingots. Assuming the ingot producers provide this information, the recycled ingots would more likely have a carbon footprint of 0.9 t CO_2e/t Al delivered to the casthouse, and the primary aluminum ingots (including alloy ingredients and freight) might be closer to 4.5 t CO_2e/t Al. Therefore, the average melt and the product (casting) would have a carbon footprint of 2.7 t CO_2e/t Al.

The Carbon Footprint of Recycled Aluminum

The next question is, of course, is all recycled aluminum equal? The answer is definitively *no*. Different industry associations categorize scrap differently. In the aluminum industry, the IAI has published a draft "Reference document on how to treat scrap flows in carbon footprint calculations for aluminum products."[5] Following this, the industry must first distinguish between *pre-consumer scrap (*or in-process scrap) and *post-consumer scrap*. An important difference is that post-consumer scrap arises after a product is used. In contrast, pre-consumer or process scrap originates from production and is immediately transferred to another production without being used as a product.

A number of other terms are also used to distinguish scrap types. *New scrap* is what arises throughout the production stages, and similarly, *internal scrap* (sometimes called *run-around scrap*) is scrap from the same source—both of which are remelted by the same company that generated it. Aside from that, there is *old scrap*, which is the same as post-consumer scrap. Then there is *traded scrap*, which is scrap sold or traded between companies, which can be either old or new scrap.[5] All of these scrap types are treated differently regarding their carbon footprint calculation, depending on the method applied.

Another question arises: when (if ever) is the carbon footprint of scrap reset to zero? Some primary aluminum producers have an extreme position about this: they say it is never reset, and every recycling loop will add to the original carbon footprint. Some aluminum industry participants consider this to be correct but impractical. This position only works if every product had a perfectly traceable history regarding carbon footprint (which no product has). It also implies that a product would be more sustainable (i.e., have a lower carbon footprint) if it were made from low-carbon primary without any recycled content and that all aluminum at the end of a product's life is put into landfills (and replaced with "cleaner" primary aluminum).

As such, the idea that scrap is never reset to zero could potentially incentivize very negative behavior for the environment. The industry agrees, therefore, that as soon as a product has reached the end of its life cycle and reaches a scrap yard, its carbon footprint is reset to zero—simply because the alternative to recycling would be landfill, which means the raw material (and the energy used to produce it) would be lost. Indeed, in all cradle-to-gate product carbon footprint (PCF) calculations, post-consumer scrap is considered burden-free (i.e., reset to zero carbon footprint). This concept works somewhat similarly to the internal scrap recycling concept described previously, just on a macro level over the full life cycle of a product.

Any scrap generated during the production of a product requires more in-depth consideration: If a piece of scrap is post-consumer, similarly to a part that has served its function, the carbon footprint is typically reset to zero. Some companies may use other approaches, such as resetting process scrap to zero, although it is important to note that IAI does not support this. If the scrap is internal, it would typically follow the previous steps.

Additionally, the IAI outlines three general approaches for calculating scrap's full life cycle carbon footprint and gives extensive examples. The first one is *Co-Product Allocation*, where any waste generated during production must carry the same carbon footprint as the final product from which it was produced. The second option is the *Cut-Off Approach*, in which case, the scrap generated during the production of a product has no emissions (burden-free). Instead, the final product will have the carbon footprint of all raw materials used to produce it, including all scrap generated during its production process. The third option is the *Substitution Approach* (also known as *avoided burden*), where credit is added to process waste when created, which is then transferred to the scrap when used in another product. The Co-Product and Substitution approaches require traceability in scrap flows and a complex calculation; however, they incentivize a clearer differentiation between pre- and post-consumer scrap.

It is important to note that there are various relevant standards on this topic, such as ISO14021:2016 (Environmental labels and declarations), ISO14044:2006 (Environmental management – LCA), and ISO14067:2018 (Greenhouse gases – Carbon footprint of products), as well as many sector-specific standards. Aluminum scrap definitions (and hence their treatment regarding carbon footprint) in ISO standards leave room for interpretation. ISO standards offer calculation methods for process scrap in cradle-to-grave assessments (LCAs), but not for product carbon footprint (cradle-to-gate) calculations, which are most often done for secondary aluminum or semi-finished products. For this reason, the IAI has tried to offer a general industry guideline that should help all industry players in their quest to calculate the correct carbon footprints of recycled/secondary aluminum and products made from it.[5]

Conclusion

Calculating the carbon footprint of a product can be complex and challenging. For most aluminum products, the raw material represents the lion's share of its carbon footprint, especially if it is made from (a high percentage of) primary aluminum. Secondary aluminum has a lower carbon footprint. Still, not all recycled aluminum is the same, and sometimes complex calculations with many differentiations between different recycled aluminum types are necessary. The IAI has recently released documents that should help calculate the correct carbon footprint of scrap, recycled, or secondary aluminum. Transparency and consistency along the supply chain are key to avoiding leakage and double counting. When sources and exact contents of scrap types are unavailable, the IAI offers "averages" typical to product forms and regions.

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