Minimizing the carbon footprint of A356 aluminum castings

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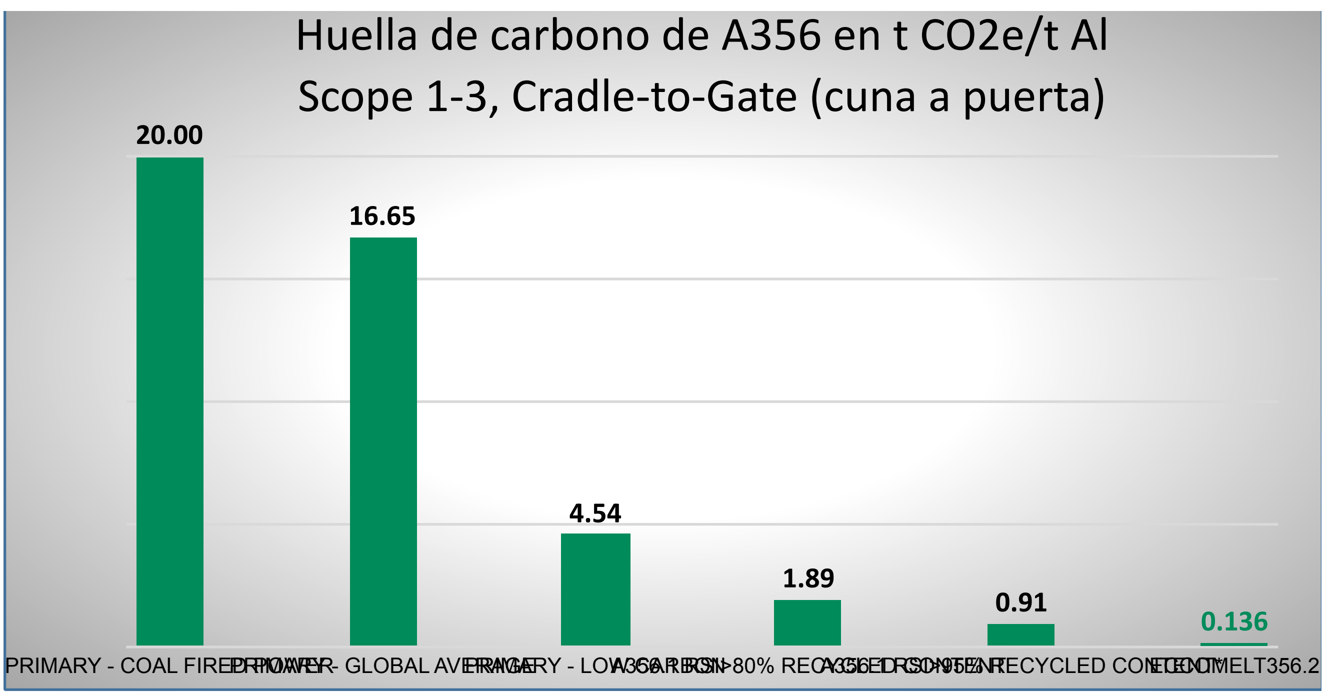
To meet the sustainability and circular economy objectives required by law and society, more and more companies have to calculate (and minimize) their carbon footprint - and that of their products. Foundries are no longer an exception and we even read about the first "carbon neutral recycled wheels" for example from Ronal, which uses recycled wheels from Eccomelt. For A356 castings, the largest source of CO_2 comes from metal, especially if primary aluminum is used. Within the foundry, the process of melting the metal is what contributes the most to the carbon footprint of the castings.

According to the International Aluminum Institute (IAI), the global average carbon footprint of primary aluminum is 16.8 t CO_2e/t Aluminum, but there are large variations. Depending mainly on the type of electrical energy used, its carbon footprint can be more than 20 t CO_2e/t Al if the electricity is produced with coal or only about 4 t CO_2e/t Al if it comes from renewable energy. Recycled content can still lower this figure. A356 ingots produced with 80% recycled content can have less than 2 t CO_2e/t Al, and with 95% recycled content it can even go below 1 t CO_2e/t Al. Recycled wheels (shredded and cleaned) that are recycled directly and without being melted down into ingots have an even lower carbon footprint. In the case of eccomelt356.2, its carbon footprint (cradle-to-gate) is only 0.136 t CO_2e/t Al.



Comparison of the carbon footprint of different types of A356

Therefore, the use of low carbon footprint primary A356.2 ingots and, better yet, high quality recycled metal is key, as is in-house recycling. Regarding the carbon footprint of scrap, we do not yet have a standard or consensus in our industry. For some, pre-consumer scrap should have its original carbon footprint (like the product that has been produced from the same metal). For others (most people in our industry at the moment), only the product should receive the full carbon footprint of all metal used for its production and any scrap metal created during its production should be carbon footprint free. To avoid this rather philosophical question, the simplest thing for a foundry is to recycle its scrap internally. Everyone agrees however that any post-consumer scrap starts back with “zero” carbon footprint in the scrapyard.

The carbon footprint of the product caused by the foundry processes (metal melting, casting, heat treatment, machining, etc.) is usually only 0.4 - 1 t CO_2e / t Al, only a few percent of the total carbon foot print of the product, and is mainly due to the metal melting stage, which often accounts for more than half of a foundry's energy consumption and therefore also of the carbon footprint. Minimizing energy consumption and using low carbon energy sources (especially electricity from renewable energy), the latest technologies, best practices to maximize efficiency in all processes, and recycle/reuse everything is a must. But the most efficient way to minimize the carbon footprint of A356 castings (like many others) is by maximizing the recycling content.

Calculating the carbon footprint:

When comparing different carbon footprints of different aluminum producers and their metal or product, it is very important to verify that their numbers are indeed comparable and complete (i.e. the same methods/standards and limits were used):

The most widely used standard is the Greenhouse Gas Protocol Corporate Standard (GHG Protocol Corporate Standard), which is the basis for ISO 14064. It defines 3 scopes: Scope 1 is direct emissions from the company, scope 2 is indirect emissions from purchased energy and scope 3 is all indirect emissions from the entire value chain, including raw materials (and this is the hardest part to calculate for most companies and producers of metals and castings). We already see that just calculating a single scope does not help much, as for example a simple change of the furnace, from gas to electric, simply "moves" the emissions from scope 1 (direct, in the case of gas) to scope 2 (indirect, in the case of electricity for electric furnaces, and depending on the energy used by the power plant it is not necessarily a big improvement).

Many primary aluminum producers instead use the International Aluminum Institute (IAI) Standard which has 3 Levels: Level 1 is emissions from aluminum electrolysis, ingot smelting, anode production, and production of electricity (basically, scopes 1 and 2 of the GHG Protocol of the primary aluminum smelter). Today this is often used to measure and compare primary aluminum ingots (or producers) and define "low carbon aluminum". However, this Level is missing very important elements, only captured in Levels 2 and 3. Level 2 is direct emissions from bauxite mining and alumina refining, electricity, heat generation, and gasoline combustion from those processes. Bauxite mining accounts for a small portion of the total primary aluminum carbon footprint, but alumina refining can create between 0.4 and 6.8 t CO2e/t alumina, with a global average of 1.2 t CO2e/ t of alumina, and about 2 tons of alumina are needed to produce 1 ton of aluminum. Level 3 represents the full cradle-to-gate carbon footprint of primary aluminum ingots, including all transport of raw materials, electricity, heat generation and slag processing. It also includes all the necessary ancillary materials and fuels. The transportation portions can be long and significant as the value chain is often very dispersed.

There are very large variations in the carbon footprint of primary (and secondary) aluminum, and these differences are even larger in A356, as there are equally large variations in silicon (and magnesium), mainly depending on power sources and technologies used.

Traceability across often long, dispersed and frequently changing value chains makes it more difficult. This is why most primary producers will only post Level 1 emissions (Scope 1 and 2 of the smelter). A CRU analysis covers 274 smelters and the average Level 1carbon intensity is 10.64 tons CO2e / t Al with a range of carbon intensity from 1.57 to 19.7 t CO2e / t Al. But without getting the complete numbers of Level 3 (Scope 1-3) for an ingot, these publications are only useful to compare between primary producers (aluminum production), but for a foundry or OEM they have no value. They can also be misleading, so great care must be taken to obtain the appropriate and complete values to calculate the carbon footprint of a foundry. Some producers have begun to address this issue by certifying traceability throughout their value chain and disclosing the full carbon footprint to interested customers.

Currently, several primary aluminum producers are creating special "low carbon primary aluminum" brands such as "RenewAl" (Rio Tinto), "Allow" (Rusal), "Ecolum" (Alcoa) or "Reduxa" (Hydro), and some are even certifying the complete value chain from bauxite mine to smelter. Some companies are working on new technologies (for example, inert anodes) that will further reduce the carbon footprint of primary aluminum, such as Elysis, a joint venture between Rio Tinto and Alcoa. However, we are still a long way from high-volume production on a global scale, but we can already see rising premiums for this type of low-carbon primary aluminum. Some other producers like Hydro with “CIRCAL” or Alcoa with “EcoDura” are integrating recycled content in primary aluminum to reduce the carbon footprint.

Recycled aluminum is said to use only 5% of the energy of primary aluminum and the Aluminum Association calculated its carbon footprint (of an A356 ingot made from 95% recycled aluminum) from cradle to gate at 0.91 t CO2 e/t Al, a level that will not be achievable with primary aluminum (at least not in the short term), so the big push now is to increase recycling, improve separation and maximize recycling content in products. It is normally not possible to produce A356.2 (0.12% Fe max) from 100% recycled metal, but if a foundry can accept at least some of its metal with a maximum of 0.15% Fe, a significant recycling content is possible.

The main driver of the carbon footprint in recycled aluminum is of course the melting part and the melt loss (especially due to dirty scrap). Therefore, Eccomelt LLC has developed a non-thermal recycling and cleaning process for A356 wheels. Their product, “eccomelt356.2” – a very clean A356, with a maximum of 0.15% Fe has a cradle-to-gate carbon footprint of just 0.136 t CO2/t Al, the lowest carbon footprint found anywhere in the industry, which is why it is being used by more and more foundries to minimize the carbon footprint of their castings.

Therefore, A356 foundries are increasingly optimizing their metal mix with the aim of maximizing recycling content to minimize their carbon footprint. Of course, internal recycling is a must, as is optimizing furnace efficiency and, where possible, switching to renewable energy sources (e.g. switching to electric furnaces). Table 1 shows that a gas-fired tower melter has a lower carbon footprint than reverberatory furnaces and especially crucible furnaces. But in crucible furnaces the CO2 reduction is very large already from oil to gas, and especially to an electric one – especially if the electricity comes from a renewable source.

Tipo de horno de fusión		Perdida de metal			Eficiencia energetica			Energía para la fusión en kWh/mt			Huella de carbono en t CO2e/t Al		
		baja	media	alta	baja	media	alta	alta	media	baja	alta	media	baja
Reverbero	Gas	2.0%	3.3%	5.0%	30.0%	34.0%	40.0%	1155	1002.6176	841.5	0.2333	**0.2025**	0.1700
Torrefusora	Gas	0.5%	2.0%	5.0%	40.0%	48.0%	60.0%	866.25	701.25	552.75	0.1750	**0.1417**	0.1117
Crisol	Gas	1.0%	2.0%	4.0%	7.0%	13.0%	20.0%	4902.857	2589.231	1666.5	0.9904	**0.5230**	0.3366
Crisol	Propano	1.0%	2.0%	4.0%	7.0%	13.0%	20.0%	4902.857	2589.231	1666.5	1.1179	0.5903	0.3800
Crisol	Petroleo	1.0%	2.0%	4.0%	7.0%	13.0%	20.0%	4902.857	2589.231	1666.5	1.3581	0.7172	0.4616
Criso-eléctrico	Carbón	0.5%	1.0%	2.0%	55.0%	57.0%	60.0%	612.000	584.737	552.75	0.1818	**0.1737**	0.1642
Criso-eléctrico	Gas	0.5%	1.0%	2.0%	55.0%	57.0%	60.0%	612.000	584.737	552.75	0.1236	**0.1181**	0.1117
Criso-eléctrico	Revovable	0.5%	1.0%	2.0%	55.0%	57.0%	60.0%	612.000	584.737	552.75	0.0061	**0.0058**	0.0055
Reverbero-eléctrico	Carbón	1.0%	2.0%	5.0%	60.0%	67.5%	75.0%	577.5	498.667	444.4	0.1715	0.1481	0.1320
	Gas	1.0%	2.0%	5.0%	60.0%	67.5%	75.0%	577.5	498.667	444.4	0.1167	0.1007	0.0898
	Renovable	1.0%	2.0%	5.0%	60.0%	67.5%	75.0%	577.5	498.667	444.4	0.0058	0.0050	0.0044
Crisol - Inducción	Carbón	0.5%	1.0%	3.0%	60.0%	70.0%	75.0%	566.5	476.143	442.2	0.1683	0.1414	0.1313
Crisol - Inducción	Gas	0.5%	1.0%	3.0%	60.0%	70.0%	75.0%	566.5	476.143	442.2	0.1144	0.0962	0.0893
Crisol - Inducción	Renovable	0.5%	1.0%	3.0%	60.0%	70.0%	75.0%	566.5	476.143	442.2	0.0057	0.0048	0.0044

Table 1: Comparison of different furnace types with respect to their carbon footprint

Along with the maximum external recycling content, the pressure is on best practices for melting and melt treatment. With the right technologies and knowledge, a foundry can manage this very well and reduce its carbon footprint and that of its castings by a significant percentage at very reasonable costs (or even cost savings - as recycled metal can be considerably cheaper than the primary metal (especially low carbon primary). The following examples illustrate this: If a casting were made from 100% “global average” primary A356.2 ingots with process yield 70% and without internal recycling, those castings would have a carbon footprint of 24.29 t CO2e / t Al. By simply recycling internally (and thus replacing 30% of the primary ingots), the carbon footprint is reduced by about a quarter to 17.14 t CO2e / t Al. Now, by replacing 20% of the primary ingots with eccomelt356.2, the carbon footprint is reduced to only half of the original value, that is only 12.4 t CO2e/t Al. If low carbon A356.2 primary ingots are used, the values are much lower, but the carbon footprint reduction through internal recycling and use of eccomelt356.2 to replace primary ingots has the same effect of cutting the carbon footprint of castings in half:

	huella de carbono		huella de carbono
	t CO2e / t Al	%	t CO2e / t Al
Lingotes de aluminio primario (promedio global)	16.65	**100%**	23.79
Rendimiento de proceso		70%	
Retornos internos	0.00	30%	0.00
Fusión del metal	0.28	100%	0.28
Colada, mecanizado, etc. (resto de la fundición)	0.22	100%	0.22
Huella de carbono por pieza fundida en kg CO2e / kg Al			**24.29**
	t CO2e / t Al	%	t CO2e / t Al
Lingotes de aluminio primario (promedio global)	16.65	**70%**	16.65
Rendimiento de proceso		70%	
Retornos internos	0.00	**30%**	0.00
Fusión del metal	0.27	100%	0.27
Colada, mecanizado, etc. (resto de la fundición)	0.22	100%	0.22
Huella de carbono por pieza fundida en kg CO2e / kg Al			**17.14**
	t CO2e / t Al	%	t CO2e / t Al
Lingotes de aluminio primario (promedio global)	16.65	**50%**	11.89
eccomelt356.2	0.136	**20%**	0.04
Rendimiento de proceso		70%	
Retornos internos	0.00	**30%**	0.00
Fusión del metal	0.25	100%	0.25
Colada, mecanizado, etc. (resto de la fundición)	0.22	100%	0.22
Huella de carbono por pieza fundida en kg CO2e / kg Al			**12.40**

	huella de carbono		huella de carbono
	t CO2e / t Al	%	t CO2e / t Al
Lingotes de aluminio primario (bajo de carbono)	4.54	**100%**	6.49
Rendimiento de proceso		70%	
Retornos internos	0.00	0%	0.00
Fusión del metal	0.28	100%	0.28
Colada, mecanizado, etc. (resto de la fundición)	0.22	100%	0.22
Huella de carbono por pieza fundida en kg CO2e / kg Al			**6.99**
	t CO2e / t Al	%	t CO2e / t Al
Lingotes de aluminio primario (bajo de carbono)	4.54	**70%**	4.54
Rendimiento de proceso		70%	
Retornos internos	0.00	**30%**	0.00
Fusión del metal	0.27	100%	0.27
Colada, mecanizado, etc. (resto de la fundición)	0.22	100%	0.22
Huella de carbono por pieza fundida en kg CO2e / kg Al			**5.03**
	t CO2e / t Al	%	t CO2e / t Al
Lingotes de aluminio primario (bajo de carbono)	4.54	**50%**	3.24
eccomelt356.2	0.136	**20%**	0.04
Rendimiento de proceso		70%	
Retornos internos	0.00	**30%**	0.00
Fusión del metal	0.25	100%	0.25
Colada, mecanizado, etc. (resto de la fundición)	0.22	100%	0.22
Huella de carbono por pieza fundida en kg CO2e / kg Al			**3.75**

Table 2: Examples of carbon footprint calculations with different metal mixes.

As well as reducing the carbon footprint directly, recycling content (especially, for example, the small pieces of regrind material like eccomelt356.2) in a furnace can help foundries increase charge density and thus the melting/furnace efficiency, as it is a clean material, it is also reducing the melt loss and the emission of fumes generated by the melting compared to unclean material, which also (indirectly) contributes to reducing the carbon footprint of the castings.

Conclusion

Foundries now increasingly need to calculate and reduce the carbon footprint of their castings. The contribution of a foundry with melting the metal, casting the part, heat treatment, machining, etc. is very small compared to the carbon footprint of the purchased metal used to make the castings. Primary ingots can have a carbon footprint of up to 20 t CO2e/t Al, and even “low carbon primary” A356 ingots have around 4 t CO2e/t Al. Recycling is therefore very important, as it replaces the amount of primary metal with a material with a much lower carbon footprint. As we have seen in our example, internal recycling alone can reduce the carbon footprint of castings by a quarter. Replacing another 20% of the primary ingots with recycled material (as in our example with eccomelt356.2) can help cut the carbon footprint in half (compared to casting made with 100% primary ingots). Additionally, recycled aluminum in small pieces (such as eccomelt356.2) helps increase melting efficiency and lower costs. In the foundry, the melting furnace is what creates the majority of the plant's carbon footprint. Selecting the most suitable furnace (with the best technologies) and the best practices for melting, treating and transferring metal are extremely important.