Melting Standardized Aluminum Scrap: A Mass Balance Model for Europe

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Although individual aluminum recycling companies have good knowledge of scrap in terms of its characteristic metal yield during melting, an overall view of this industry is still missing. An aluminum mass balance for the aluminum recycling industry in the European Union member states from 1995 to 2004 (EU-15) has been carried out. The objective was to increase the transparency of the complex recycling system and to determine how resource-conservative the industry is when melting aluminum scrap. Results show that in 2002, about 7 million tonnes of purchased, tolled, and internal scrap—with a metal content of 94%—were recycled in the EU-15. By comparing the net metal input to the final product, the study finds a very respectable metal recovery rate of 98%.

INTRODUCTION

Aluminum is one of the youngest industrial metals. Due to properties such as light weight, high corrosion resistance, good formability, and non-toxicity, it has been the fastest-growing metallic material in the past 100 years. With a global primary metal use of 27.4 million tonnes and a recycled aluminum production from purchased and tolled scrap of approximately 13.1 million tonnes (Figure 1) in 2003, it has taken the top position of all the non-ferrous metals.

The 15 European Union member states from 1995 to 2004 (hereafter EU) are, combined, one of the largest aluminum fabricators (e.g., rolling, extrusion, casting) and manufacturers (assembly and production of finished products) worldwide. In view of limited ore mining and energy constraints, the EU is structurally dependent on aluminum recycling for its domestic metal supply. In 2003, 2.6 million tonnes of primary aluminum were produced and a reported 3.9 million tonnes of aluminum were extracted from purchased and tolled scrap. In the past, much has been known about the primary aluminum production chain but comparatively little about recycled aluminum. The aluminum recycling chain comprises the collection of discarded aluminum-containing products and the subsequent treatment and smelting of aluminum scrap. At the moment, the potential for recycled aluminum is unpredictable since future volumes and alloy types of old scrap are unknown. Therefore, strategic thinking in terms of production capacities for scrap melting is difficult. The current stage of knowledge on aluminum scrap flows is best described in Figure 1.[1] This global aluminum flow model aims to better describe the past and to predict the future mix of primary and recycled aluminum metal supplies. The quantitative tool shows a knowledge gap at end-of-life of 3.1 million tonnes aluminum. The European aluminum industry has thus sought to further improve the understanding of anthropogenic aluminum resources (i.e., vehicle stock, infrastructure, and buildings) and the processes of aluminum collection, treatment, and melting needed to produce recycled aluminum. Table I shows the completed and planned projects for 2005 of the European aluminum industry with regards to recycling.

There have been many reports in the literature about life-cycle and material flow analysis of aluminum recycling[4–8] but there has not been a detailed report about the aluminum recycling industry in relation to metal losses. This mass balance model, called the European Scrap Smelting Unit Model (hereafter ESSUM), was developed to improve the transparency of the European alu-

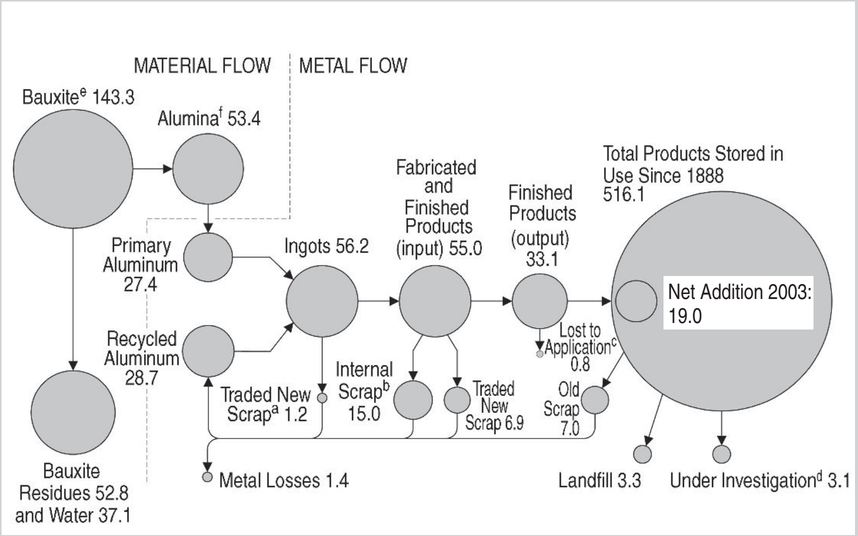

Figure 1. Global aluminum flow.[1] All units measured in million tonnes per year. Values might not add up due to rounding. a–Aluminum in dross; b–not taken into account in statistics; c–such as powder, paste, and deoxidation aluminum (metal property is lost); d–area of current research to identify final aluminum destination (reuse, recycling, or landfilling); e–includes, depending on the ore, between 30% and 50% alumina; f–includes, on a global average, 52% aluminum.

minum recycling industry. It quantifies the internal material flows between the different units (e.g., dross from remelter to refiner or scrap granulate from salt slag processor to refiner), and identifies where and how much aluminum metal is lost during the scrap-melting process. The mass balance has been carried out using empirical data for technical and operational parameters, industry expert estimates, a substance flow model to elaborate the scrap mass flow entering the ESSUM system, and statistical data for quality check. See the sidebar for details on the aluminum recycling industry.

Table I. Completed and Planned Recycling Projects for 2005

End-Use	Collection	Treatment	Melting
Building	92–98%[2]		This work
Trucks	100%[a]	Work in progress	This work
Electrical and Electronic Equipment	Work in progress	Work in progress	This work
Used Beverage Cans	48%[3,b]		This work

[a]High export of second-hand vehicles.
[b]Collection rate for 2003. Data is collected annually.

EU ALUMINUM SCRAP INTAKE

Since 2003, the European standard on aluminum scrap, EN 13920[9], which covers all scrap types, has been considered the norm for scrap classification. Table II shows the 12 scrap categories as used in ESSUM with their average metal and oxide content plus the amount of foreign material (e.g., lacquers, paint, oil, coatings) in the scrap. One of the most important prerequisites for any aluminum recycling mass balance calculation is the knowledge of the metal content of the feed material. Unfortunately, exact figures on metal content as well as metal losses are usually unknown in aluminum recycling smelters. The metal content is replaced within the industry by the so-called metal yield, which is the melting yield of a sampling melt carried out in a small crucible or rotary furnace. A typical sampling furnace has been calibrated resulting in a function "metal content = f(metal yield)," which is used for this model. The percentages for oxide, oil, water, and other impurities in scrap are based on information given in the European scrap standard EN 13920 and industry expertise.

Table II. Selected Scrap Types Listed in European Aluminum Scrap Standard (EN 13920)[8] and Their Average Scrap Compostion

Part	Scrap Description	Aluminum Metal[a] (%)	Oxides[b] (%)	Foreign Material[b] (%)
3	Wire and cable (new scrap)	98.7	1.3	—
	Wire and cable (old scrap)	97.7	1.8	0.5
4	One single wrought alloy	97.2	1.0	1.8
5	Two or more wrought alloys of the same series	97.2	0.8	2.0
6	Two or more wrought alloys	94.0	0.8	5.2
7	Castings	83.4	6.2	10.4
9	Shredded and density separated scrap	84.5	5.4	10.1
10	Used beverage cans	94.0	0.8	5.2
12	Turnings, one single alloy	95.3	3.7	1.0
13	Mixed turnings, two or more alloys	84.0	3.3	12.8
14	Packaging (coated)	71.5	3.8	24.7
15	Packaging (de-coated)	86.1	12.9	1.0
16	Dross	55.7	44.3	—

[a]Based on empirical data.
[b]According to the definitions of the different EN 13920[8] scrap categories and industry knowledge about scrap composition.

2002 was chosen as the exact year of investigation since data on scrap intake flows could be obtained. These were calculated via substance flow analysis, which by definition only tracks the element aluminum and its enclosed alloys. New scrap is generated during the production, fabrication, and manufacturing stages, up to the point where the product is sold to the final user. The amounts of new scrap arising depend on the final product. Old scrap is generated when an aluminum-containing product reaches its end-of-life and is collected and treated for recycling. To calculate the amount of aluminum leaving the use stage, a product residence time model was applied. Considered here are the average lifetime of each of the products in which aluminum is used and the historical tonnage of aluminum in those products. Sources for aluminum scrap comprise new scrap from primary production, fabrication, and manufacturing of products, and old scrap gained from end-of-life vehicles, waste from electrical and electronic equipment, construction and demolition

THE ALUMINUM RECYCLING INDUSTRY

Recycled aluminum is produced by remelters and refiners. Refiners produce casting alloys and deoxidation aluminum (used to remove free oxygen from liquid steel) while remelters produce wrought alloys. Casting alloys have a concentration of alloying elements of up to 20% and wrought alloys of up to 10%. Remelters must select the appropriate quantity and quality of scrap to correlate with the chemical composition of the wrought alloy to be produced. Hence, extra care must be taken to keep the different aluminum alloys separated. The recycling activity of remelters started to gain in importance only in the 1980s. Refiners work under less stringent conditions in terms of alloys. They specialize in melting mixed casting and wrought alloy scrap into standardized aluminum alloys. For refiners it is common practice to mix different alloys to alloy-specific scrap batches before loading the scrap into the furnace. Some scrap is also used in so-called primary cast houses. This flow is included in the European Scrap Smelting Unit Model under remelting.

Recycled aluminum is produced from purchased, tolled, and internal scrap. Tolled scrap describes scrap that stays in the ownership of the customer and is smelted for a fee. Scrap that is generated and smelted in the same company or company group is referred to as internal scrap. Internal scrap is not covered in statistics. With few exceptions, refiners are of small and medium size and only remelters are part of integrated groups (i.e., those companies involved in aluminum production and fabrication). Hence, only remelters produce aluminum from internal scrap.

In this paper, scrap smelting and melting are equally used for the process of extracting aluminum from aluminum scrap in refiners and remelters.

waste, etc. The volumes calculated thus contain the element aluminum and its alloys in scrap. As the volumes originate from a substance flow analysis, they explicitly do not contain any oxygen, oil, water, or impurities that have been coated during the manufacturing or use phase. The parameters used in ESSUM such as the amount of salt used or the oxidation rate originate from practice according to actual scrap. Hence, the quantity of aluminum contained in scrap obtained from the substance flow analysis was converted into the total scrap quantity using the following equation:

$$S = A * \left[\frac{m}{m + \frac{o}{1.89}} + \frac{o}{m + \frac{o}{1.89}} + \frac{f}{m + o} * \left(\frac{m}{m + \frac{o}{1.89}} + \frac{o}{m + \frac{o}{1.89}} \right) \right] \quad (1)$$

with S = scrap (kt/y), A = aluminum in scrap (kt/y) (results from substance flow analysis), m = metal in scrap (%) (Table II), o = oxidized metal in scrap (%) (Table II), and f = foreign materials in scrap (%) (Table II); the 1.89 figure is the conversion factor for aluminum metal into its oxide.

The calculated scrap volumes are listed in Table III according to scrap source, presumable mode of melting, and scrap category as defined by the European scrap standard EN 13920. The scrap intake by refiners and remelters according to product changes annually and is statistically unknown. The splits used here have to be regarded as indicative. As a validation check, the total scrap intake to remelters and refiners plus the breakdown of new and old scrap were compared to existing statistics. Based on 2003 statistics for the EU,[10] the tolled and purchased scrap intake, excluding foreign materials, to remelters was 1.6 million tonnes (23% old scrap) and to refiners 2.5 million tonnes (46% old scrap). Since most recycling companies are of small to medium size, it can be assumed that statistics for recycling are incomplete. In Table III, the remelter column is split into two elements: scrap that is offered for sale or tolling and scrap remelted in the same company or integrated company group where the scrap has been generated, without being offered for sale or tolling (i.e., internal). This split is statistically unknown and based on the assumption that all rolling mills and extruders that have a remelt operation melt their own scrap—providing it is suitable for remelting—in-house.

SCRAP MELTING

It is well known that aluminum oxide cannot be reduced by carbon or hydrogen to aluminum metal near its melting temperature. Therefore, the primary production of aluminum has to use an electrolysis process to reduce the metal from its oxide alumina (Al_2O_3). Hence, aluminum recycling is limited to re-melting of the metal content of any aluminum-containing material. Ignoring the alloying elements, this offers a simple method to easily balance aluminum recycling:

$$\text{metal input} = \text{metal output} + \text{oxidized metal output}/1.89 \quad (2)$$

Any oxide or other inorganic nonmetallic component (e.g., paint) of scrap

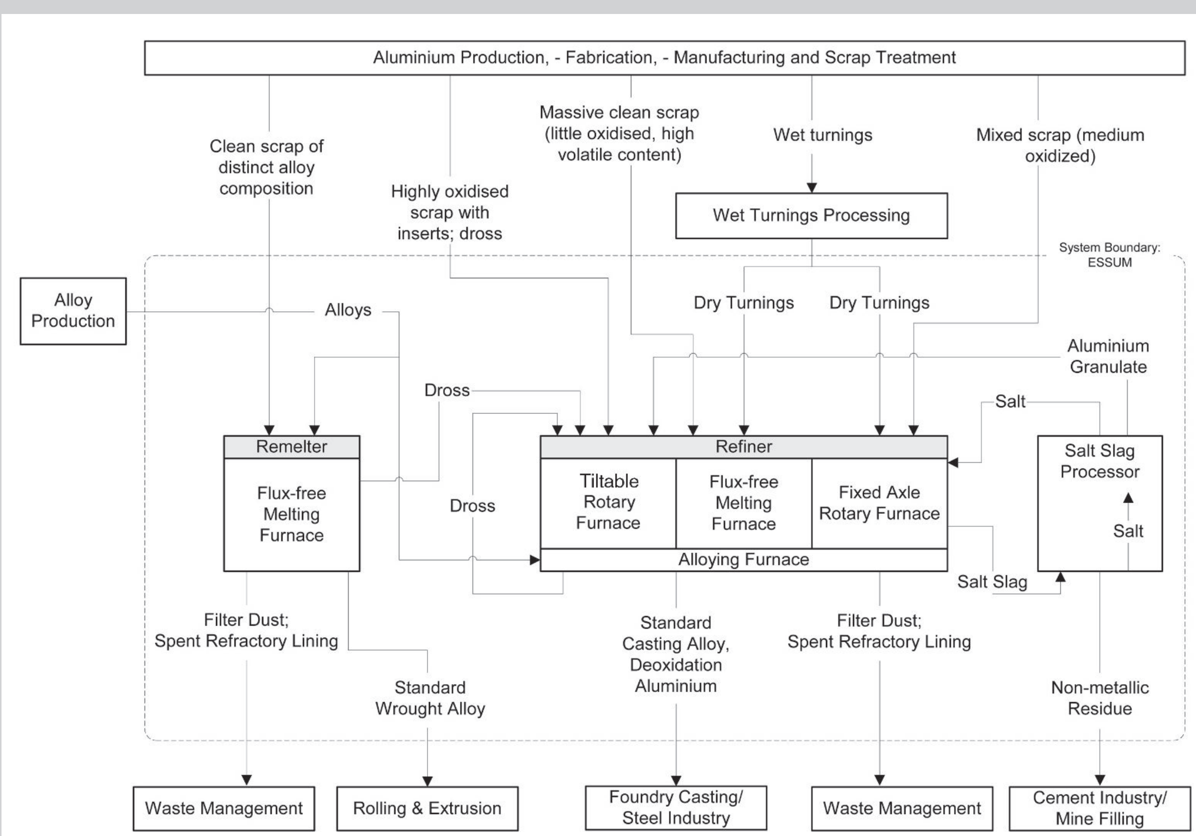

Figure 2. The framework for analysis of material flows into, out of, and within the European aluminum recycling industry.

remains unchanged during melting and is—for mass balance calculations—just a passing-through figure. Salt remains salt, which is mainly needed as the packaging material for inorganic non-metallic components. Oxides are either fed into the system as a part of the scrap or are generated during the melting processes. Volatile organic substances (e.g., oil, lubricants) and moisture leave the recycling system. However, they may carry some components such as salt or oxides.

Since single parameters used for ESSUM are often not measurable, these were obtained from model simulation runs together with measurable control figures such as the metal content in cold dross or salt slag composition. Except for the oxidation rate,[11] none of the used parameters have been published prior to this study.

MODEL STRUCTURE

Mass balances were separately calculated for a remelter that is represented by a typical flux-less operated box-type furnace, and a refiner that comprises a flux-less operated box-type furnace including an electromagnetic pump plus side-well, a fixed axle, and a tiltable rotary furnace. Within the refiner operation a sub-model for a salt slag processing unit based on ALSA GmbH's process[12] was included. In this process, salt slag is recycled into reusable salt, aluminum granulate, and a reusable non-metallic residue. A separate mass balance was established for the treatment of wet turnings, chips, and cuttings. The mass balances for the different smelter sections were calculated from the respective total annual feed. Figure 2 shows the detailed mass flows handled by ESSUM.

REMELTER MODULE

A common feature of remelter operations is the characteristic of its feed: Clean scrap, not oxidized or coated, most of the time of one alloy type is preferably treated by remelters. The metal yield is very high, (i.e., the metal content is between 96% and nearly 100%). Such scrap does not need any melting salt as a packaging medium for inorganic non-metallic components. Little salt is needed as a protective agent against oxidation for the generated dross. Although many furnace types are applied by remelters, for the mass balance a simple box-type, gas-fired hearth furnace was used. Its mass balance reflects the common features of typical remelter furnaces. To allow for the fact that some remelters have to adjust the alloy content according to their customer's request, a 1% alloy

Table III. 2002 EU Aluminum Scrap Intake with Allocation to Scrap Standard EN 13920[8] and Presumable Mode of Melting for Refiners

		Refiner			Remelter (tolled, purchased)		Remelter (internal)	
Life Cycle Stage	Product	kt/y	Standard #	Furnace[a]	kt/y	Standard #	kt/y	Category
Production	Dross[b]	77	16	b, c	0	16	0	16
Fabrication	Extrusion scrap	0	5		489	5	572	4
	Rolling scrap	0	5		0	5	1,144	4
	Foil scrap[c]	0	5		0	5	439	4
	Wire and cable	0	3		39	3	0	3
	Foundry scrap	195	7	c	0	7	0	7
	Dross[b] (foundry)	162	16	b, c	0	16	0	16
	Turnings[d] (extrusion and rolling)	191	13	a, c	0	13	315	12
	Turnings[d] (foil)	26	12	a, c	0	12	52	12
	Turnings[d] (foundry)	297	13	a, c	0	13	0	12
Manufacturing	Building	86	6	a	134	5		
	Transportation	196	6	a	280	6		
	Consumer durables	35	6	a	40	6		
	Cans and rigid packaging	0	6	a	156	15		
	Foil	11	15	c	0	15		
	Cable and wire	45	3	a	0	3		
	Engineering	80	6	a	139	6		
	Other	35	6	a	40	6		
	Turnings[d,e]	99	13	a, c	0	13		
End-of-Life	Building	95	6	a	92	6		
	Automotive	759	9	c	36	6		
	Other transport	60	6	a	58	6		
	Cans and rigid packaging	45	10	c	179	10		
	Foil	60	14	a	0	14		
	Engineering	278	9	c	27	6		
	Consumer durables	95	9	c	0	9		
	Other	37	9	c	0	9		
Trade[f]	New scrap	74	6	a	0	6		
	Dross[b]	–16	16	b, c	0	9		
	Old scrap	–136	9	c	0	16		
Total		**2.886**			**1.709**		**2.522**	

[a]Presumable mode of melting. a = Flux-free melting furnace, b = tiltable rotary furnace, c = fixed-axle rotary furnace.
[b]Also known as skimmings.
[c]Foil fabrication includes rolling into foil stock and final foil.
[d]Representative for turnings, chips, and cuttings.
[e]Turnings generated during manufacturing of various products.
[f]Net imports of aluminium scrap to the EU.

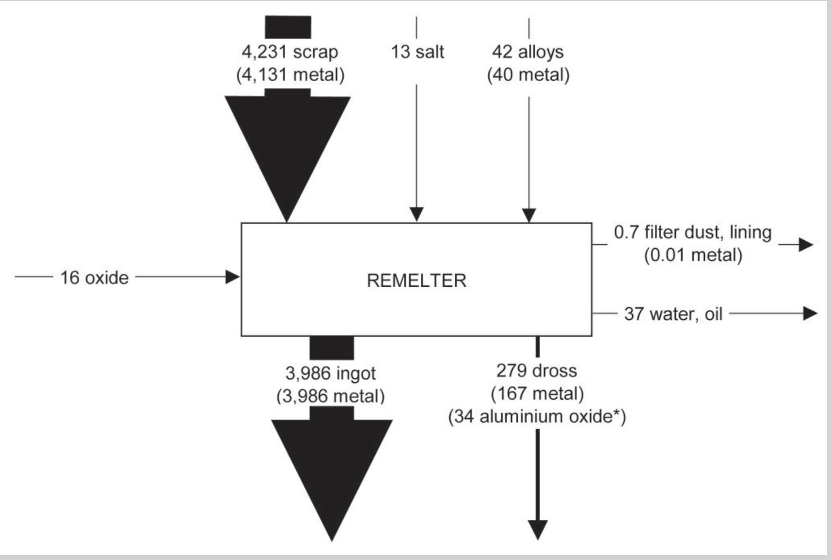

Figure 3. The 2002 EU remelter balance. All units measured in thousand tonnes per year. Quantities shown in parentheses illustrate the content of metal and aluminum oxides within the overall flow. (*Aluminum oxide formed during the process.)

addition, which has a metal content of 95%, is applied. About 0.15% of the total metal in the feed material is converted to oxides. The hot dross skimmed from the bath contains 70% metal, mostly entrapped. The dross is stored in a steel box, where it is covered by a shovel of salt (equals 5% of the hot skimming) to prevent most metal from oxidizing. The final metal content of the cooled dross is assumed to reach 60%. This product is delivered to refiners and there melted under salt.

Figure 3 illustrates the mass balance for the EU remelter industry. In 2002, approximately 34,000 tonnes of aluminum oxides were created, which corresponds to a metal loss of 18,000 tonnes. The cold dross contained 167,000 tonnes of metal which is recycled by refiners. On average, per tonne of produced ingot, 3 kg salt were needed.

REFINER MODULE

For simplicity, ESSUM assumes that only three types of melting furnaces are used in the EU. This does not represent reality but it was assessed that, at present, the scrap intake to other furnaces is comparatively small.

The furnace equipment of refiners is dominated by conventional rotary furnaces (Figure 4a) to melt all kinds of oxidized, coated, or otherwise soiled scrap under salt. The traditional rotary furnaces with a fixed axis of rotation generate conventional liquid salt slag, containing an average of 50% salt. A salt factor (added salt per quantity oxide contained in scrap) of 1.3% is used for this model. About 5% of inorganic non-metallic components in the scrap are assumed to be carried over with the off-gas, a figure that well reflects single- and double-pass fired operations. The amount of evaporated salt is derived from numerous sample measurements at 4.5 kg of salt per tonne charge. From simulation runs and empirical data an average oxidation rate of 3% of the metal content in the feed material is used. The metal content of salt slag is set to 8.5% at the moment of tapping.

Some refiners operate flux-free box-type hearth furnaces—often multi-chamber furnaces for material with high organic contamination—for continuous melting of uniform alloy type scrap. It is assumed that the flux-free melting furnace (Figure 4b) is equipped with a vortex-generating electro-magnetic metal pump suitable for submerged melting of dry turnings. It is further assumed that due to the continuous operation of such furnaces, turnings consisting of only a single alloy are fed to this operation. About 0.2% of the total metal in the scrap is oxidized during melting. The generated dross is skimmed off with 70% metal content and cooled down in dross boxes. During cooling, the metal content in the dross is reduced to 60%. Process data from field observations show that 3% of the inorganic non-metallic components contained in the scrap feed exit the system via filter dust.

An increasing number of refiners use tiltable rotary furnaces shown in Figure 4c. These represent the most resource-efficient furnaces for melting dross. The volume of dross to be processed in the EU is much higher than the existing melting capacity of tiltable rotary furnaces. Therefore, the model contains a switch that distributes the dross between tiltable and conventional rotary furnaces, according to the current melting capacity of tiltable rotary furnaces. The switching criterion used for the 2002 balance is 17 tiltable rotary furnaces with a total melting capacity of about 310,000 tonnes of feed per year. A salt factor (added salt per quantity of oxide contained in scrap) of 0.4% is used, leading to a salt slag with a salt content of 27%, typically. About 7% of the inorganic non-metallic components in the scrap are assumed to be carried over with the off-gas into the gas-cleaning system, dragging along about 0.04% of the metal in the feed. From simulation model runs combined with empirical data, an oxidation rate of 3.5% is used. In the salt slag at the very moment of tapping, a value of 12.5% entrapped metal is used.

It is common refiner practice to tap metal from melting furnaces via launders into so-called holding furnaces (Figure 4d). There, the metal is degassed, sometimes further treated, and the alloy composition is corrected by the addition and dissolution of alloying elements, predominately elemental silicon. Here again dross is generated, skimmed off, and returned to the tiltable or fixed-axle rotary furnace. An addition of 7% alloying elements is assumed. The alloying elements to be added to the tapped molten metal are assumed to have a metal content of 95%. This figure is an average of process data from field observations of technical alloying elements like silicon, magnesium and copper scrap, manganese, and titanium metal. The mass of frozen metal in the tapping launders is dependent upon their length. As a mean figure, 40 kg of launder residues per 12 tonnes liquid metal tap are assumed, containing about 0.8% newly formed aluminum oxides. Based on measurements, about 0.05% of the metal flowing through the launders is oxidized by air. The resulting oxides are carried into the holding furnace and exit the system as a part of dross. The oxidation rate of the holding operation is set to 0.25%. Hot dross contains 70% liquid metal, which cools down by the addition of 10% salt, resulting in a final metal content of typically 55%. The holding furnaces are tapped and the liquid metal flows to casting or to a transportation ladle filling station. It is assessed that here 20 kg of launder residue per 25 tonnes of tapped metal is generated with about 0.8% newly formed aluminum oxides included. All launder residues are returned to the fixed-axle rotary furnace.

Figure 4 shows the mass balance for the EU refiner industry. In 2002, about 151,000 tonnes of aluminum oxides were created, which corresponds to a total metal loss for the refining operation of 80,000 tonnes. Per tonne of produced ingot, 230 kg of salt were necessary and 490 kg of salt slag were generated.

DRYING OF TURNINGS

Turnings (here representative of turnings, chips, and cuttings) used by refiners are commonly contaminated with cutting and cooling liquids, which are basically emulsions of water and various organic liquids. Turnings from manufacturing moreover contain sizeable amounts of free iron. Due to their enormous surface-to-mass ratio of more than 1,000 m² per tonne and the high content of potentially oxidizing liquids, turnings must be dried and subsequently cleaned from free iron. In a separate balance module, all turnings are processed, including drying and separation of free iron and dust. The separated material contains 84% organic liquids, 14% metals (predominantly iron), and 1% oxides. The product of this module is used for further melting of turnings.

SALT SLAG PROCESSING

Salt slag from tiltable and fixed-axle rotary furnaces is collectively treated in processing units. The mass balance considers a separation step for metal granulate, a leaching step where residual metal is converted into oxide, a solid-liquid separation step where the final non-metallic residue is discharged almost salt-free, and eventually a crystallization step where clean melting salt is produced. The frozen entrapped metal is screened out after wet or dry crushing and grinding. The average metal content of the separated granulate is assumed to be 80%, the remaining 20% is split 50:50 between salt and inorganic non-metallic components. The metal recovery is assessed at 75%. The remaining 25%

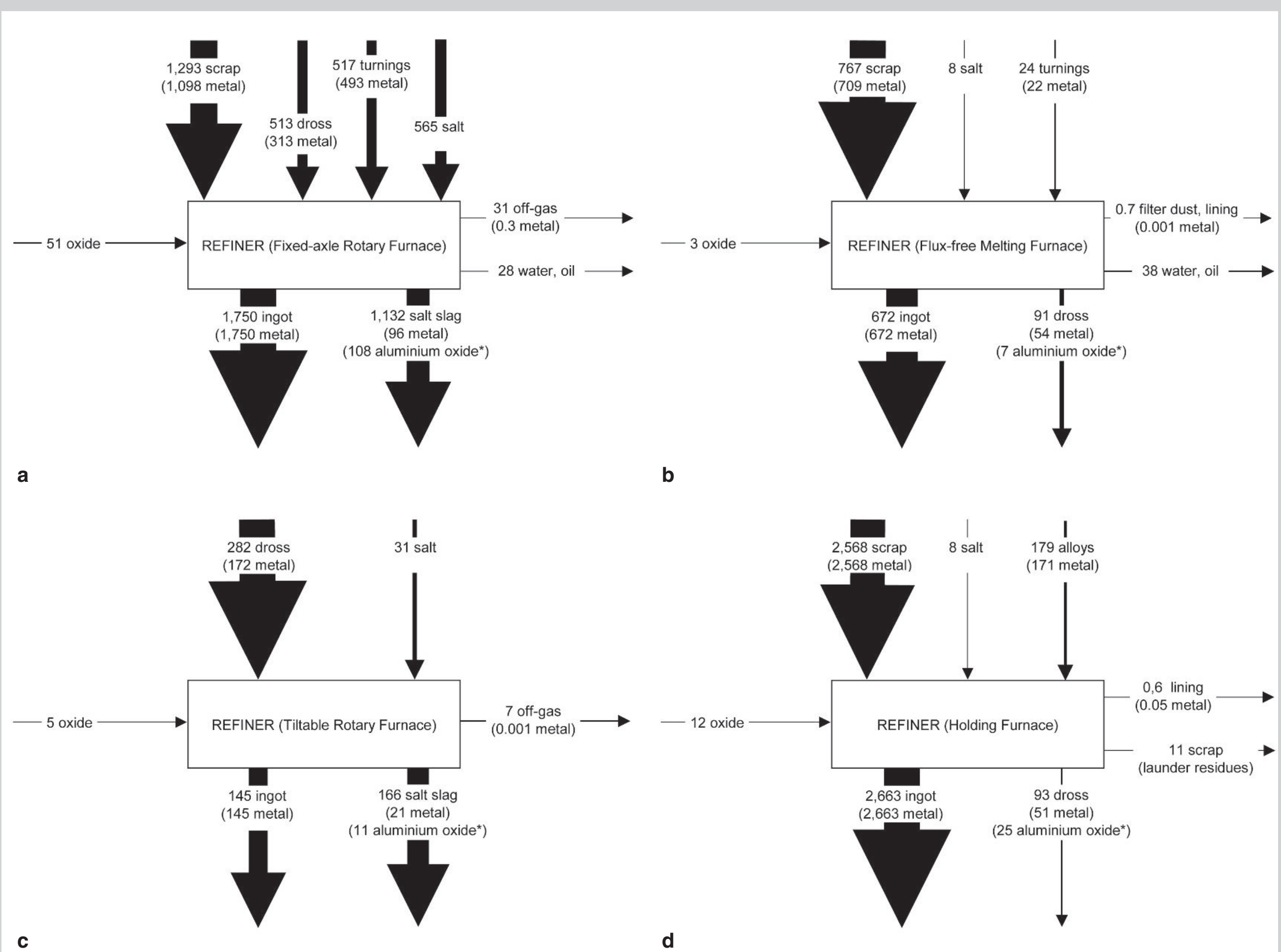

Figure 4. The 2002 EU refiner balance. All units measured in thousand tonnes per year. Quantities shown in parentheses illustrate the content of metal and aluminum oxides within the overall flow. (*Aluminum oxide formed during the process.) Figures (a) to (c) show the investigated melting furnaces. Figure (d) is the holding and alloying furnace that follows the melting furnaces.

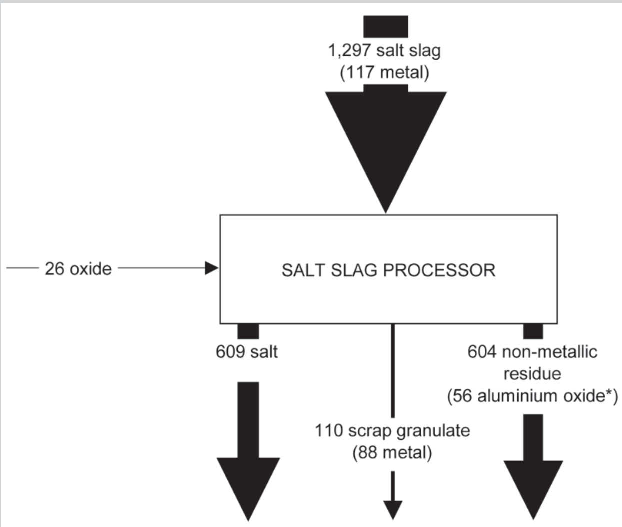

Figure 5. The EU 2002 salt slag processing balance. All units measured in thousand tonnes per year. Quantities shown in parentheses illustrate the content of metal and aluminum oxides within the overall flow. (*Aluminum oxide formed during the process.)

of the metal inventory is completely converted into oxide, although most of the oxidized metal ends up in slightly differing chemical compositions. The whole non-metallic residue is filtered and washed to a final salt content of 0.2%, reflecting target values of the cement industry that apply to this oxide blend product. A salt balance is used to determine the amount of additional salt needed by refiners and remelters.

As llustrated in Figure 5, more than 56,000 tonnes of aluminum oxides were generated in 2002, corresponding to a metal loss of approximately 29,000 tonnes. Just about 84 kg of aluminum granulate were produced per tonne of salt slag. The 604,000 tonnes of non-metallic residue from the salt scrap processing unit were used in a variety of applications, such as the production of cement.

CONNECTIONS BETWEEN PROCESSING UNITS

Remelter dross is processed by a refiner unit. This means that a sizeable fraction of the salt used by refiners is needed to envelop the remelter's non-metallic components and to discharge it as salt slag. The refiner's salt slag is processed by salt slag treatment units which return scrap granulate and melting salt to the melting unit. The granulate carries back some non-metallic components that again require some salt for proper separation into slag. Within the melting units there are internal material flow cycles such as launder residues and dross from holding furnaces. Some residues, like filter dust and spent refractory lining, leave the system, representing a small outlet predominantly for salt and inorganic non-metallic components. Such interconnected material flows and cycles, their respective salt demand, and resulting metal losses make the aluminum recycling system rather complex.

RESULTS

Figures 3–5 show the input and output flows for each process within the EU aluminum recycling industry, and Figure 6 collects this information to provide a comprehensive view of the interconnections within this industry. About 7 million tonnes of scrap plus 222,000 tonnes of alloys were converted into approximately 4 million tonnes of wrought alloys and about 2.7 million tonnes of casting alloys and deoxidation aluminum. In addition to the 223,000 tonnes of dross from external sources, the industry produces 463,000 tonnes of dross internally. Per tonne of wrought alloy produced, 41 kg of casting alloys are created simultaneously because of the recycling of remelter dross by the refiner unit. The ingot production from scrap in the EU requires 625,000 tonnes of salt and generates 1.3 million tonnes of salt slag. The salt slag is then recycled in the salt slag processing industry into 609,000 tonnes of dry salt and 110,000 tonnes of aluminum granulate, which serves as an input material for the aluminum recycling industry. The 604,000 tonnes of non-metallic residue from the salt scrap processing unit is used in applications such as the production of cement.

Metal can be oxidized during initial fabrication and manufacturing, use, and scrap treatment, or during the smelting procedure. The total amount of irretrievably lost metal from the EU aluminum cycle amounts to approximately 270,000 tonnes per year, more than 50% occurring prior to smelting (see values in parentheses in Figure 6). Related to the huge volume of more than 6.6 million tonnes of recycled metal produced in the EU, this loss is reduced to an impressively low figure of 4%.

Illustrated in Table IV, the salt needed for production varies depending on the scrap type from 40 kg to 280 kg per tonne of product. The metal yields represent the total metal production related to the total volume of external scrap and alloy feed. This is on average 91.5% for the EU. The recovery figures compare the net metal input to the total metal production. The found total metal recovery of more than 98% stands any comparison with other secondary base metal smelting.

Each parameter can be separately varied to study its influence on the results. Running the model, for example, with a doubled oxidation rate for both remelter and refiner, the metal recovery rate reduces to 96.7%. Salt consumption rises to 670,000 tonnes, salt-slag generation to 1.5 million tonnes, and total metal losses to 360,000 tonnes.

Table IV. Results of Aluminum Scrap Melting from End-of-Life and Total

Scrap Type	Metal Recovery (%)	Metal Yield (%)	Salt Use (kg/t Product)	Salt Slag Generation (kg/t Product)
Building Scrap	99	94.7	40	70
Transport Scrap	96.1	83.5	230	460
Foil Scrap	96.1	69.8	220	450
Used Beverage Cans	98.5	92.6	50	110
Engineering Scrap	95.8	82.5	250	500
Scrap from Consumer Durables	95.4	81.2	280	550
Total Old Scrap	96.6	85	190	380
Total Scrap	98.1	91.5	90	200

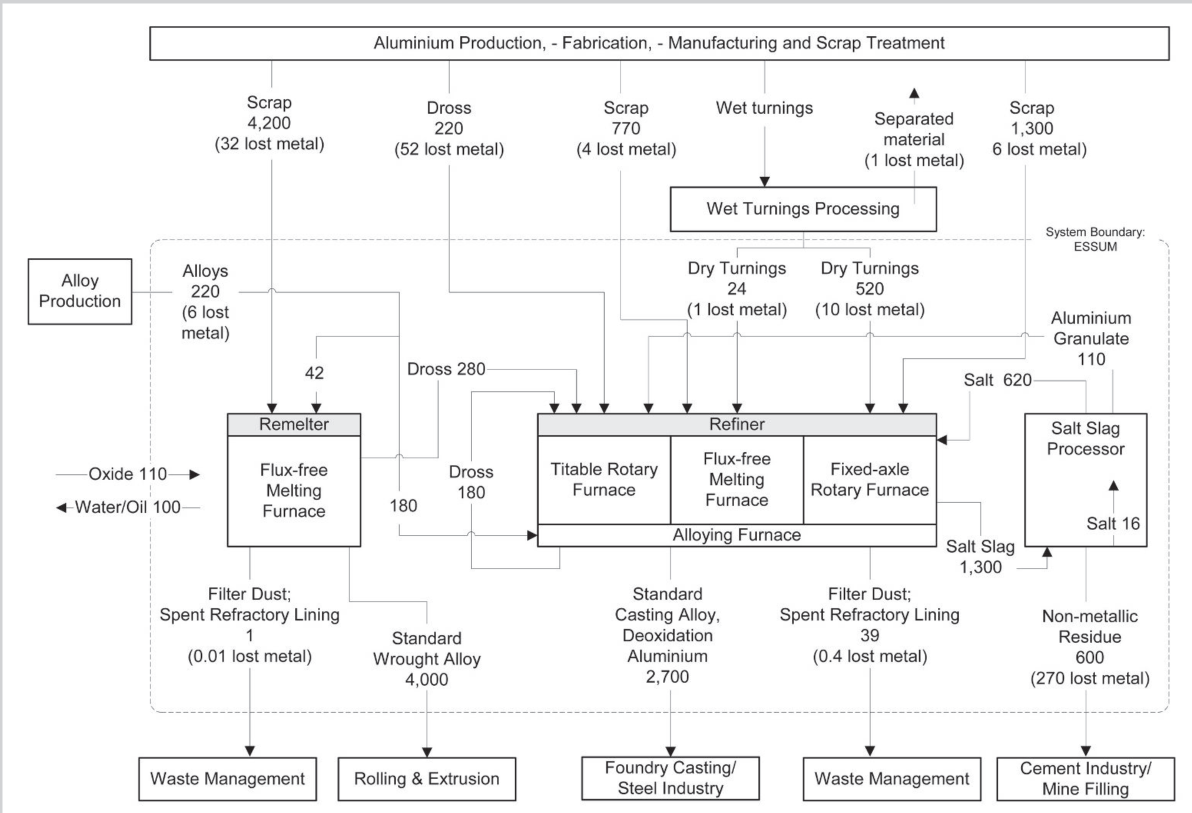

Figure 6. The material flows into, out of, and within the EU aluminum recycling industry. All units measured in thousand tonnes per year. Values in parentheses represent the amount of metallic aluminum lost due to oxidation. Spent refractory lining does not include any furnace material.

CONCLUSION

The core business of the aluminum recycling industry is to melt scrap into aluminum alloys that can be reabsorbed into the aluminum life cycle. The market for recycled aluminum in the EU cannot be overstated in an aluminum recycling industry that has been steadily growing from about 1.2 million tonnes in 1980[13] to 3.9 million tonnes in 2003. With a recycling rate of 98% and an internal recycling cycle for salt slag, the EU aluminum recycling industry shows that it has not only the knowledge to produce a valuable material but is also safeguarding energy and material resources to an exceptionally high level.

Most of the parameters used in this model are widely distributed and often not even numerically known. It goes without saying that any of the assumed parameters could become the subject of disputes, since individual European recycling smelters may have different experiences, data, and measurements. However, the figures used are deliberately part of a data set that represents a base-case scenario that is equivalent to the most likely one. With new data arising, this scrap smelting model will be updated frequently and hence will further tend toward reality.

Lifetimes for aluminum-containing products as well as collection and treatment rates for end-of-life aluminum are in some cases not known. This fact results in a high uncertainty in scrap intake, and additional analysis is in progress.

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