About the reclamation of Aluminium salt slag / salt cake / black dross

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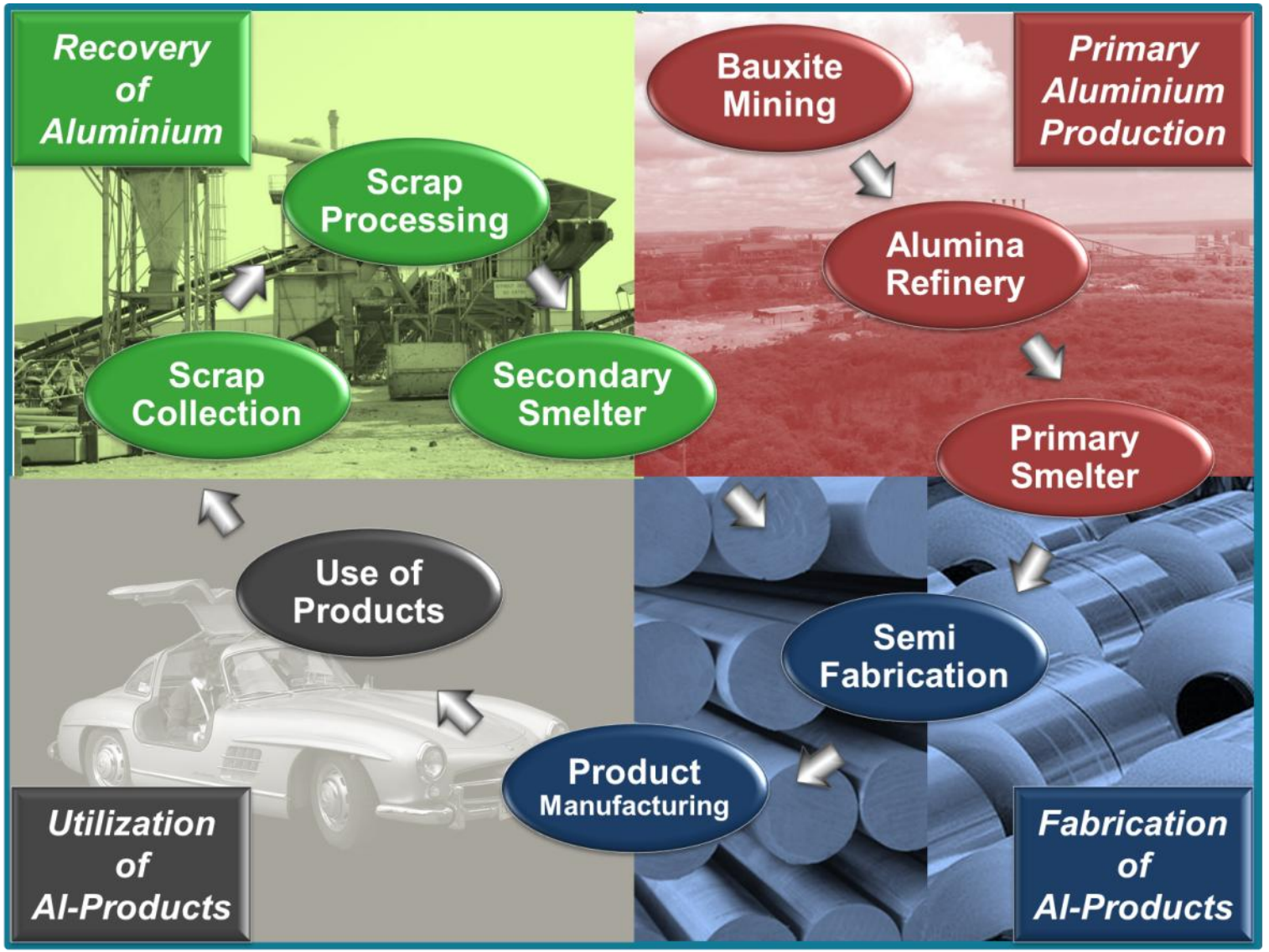
Conference Processing and Recycling 2013, Freiberg UVR-FIA e.V. Freiberg / Helmholtz-Institut Freiberg für Ressourcentechnologie

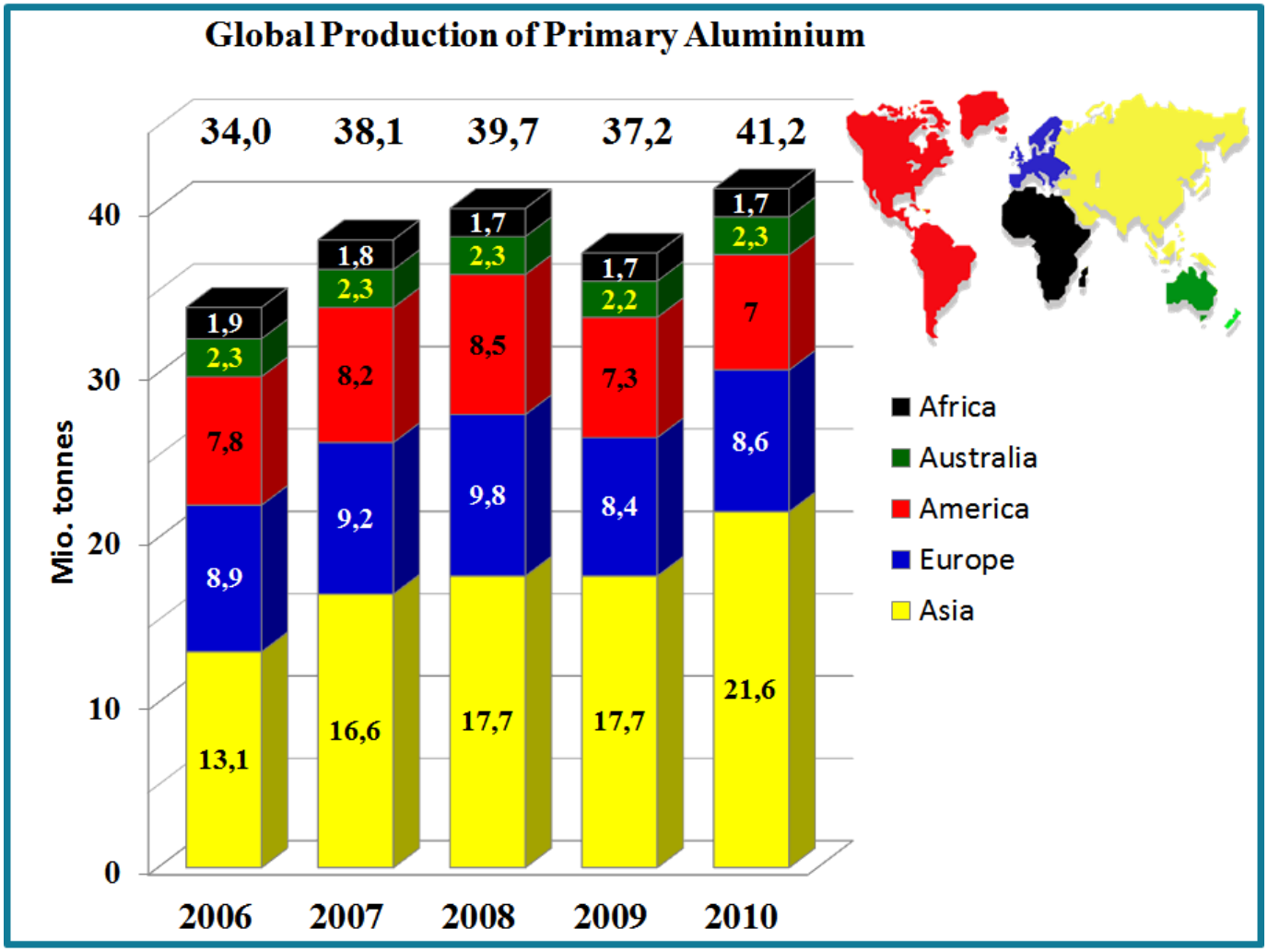
Scope of the presentation

- **Background**
  Aluminium Life Cycle / Statistical Data / Global Aluminium Mass Flow
- **Aluminium Recycling**
  Motivation / Metallurgical Technologies and Process Management /Side-Effects: Residues / Origin and Characterisation of Residues
- **Reclamation of Residues**
  Motivation / Basic Concepts / Nugget Picking / Partial Recycling / Residue-Free Reprocessing / The Oxide Challenge / ScholzAlu Stockach
- **Outlook**
  Future volumes / Global Perspective

Background - Aluminium Life Cycle

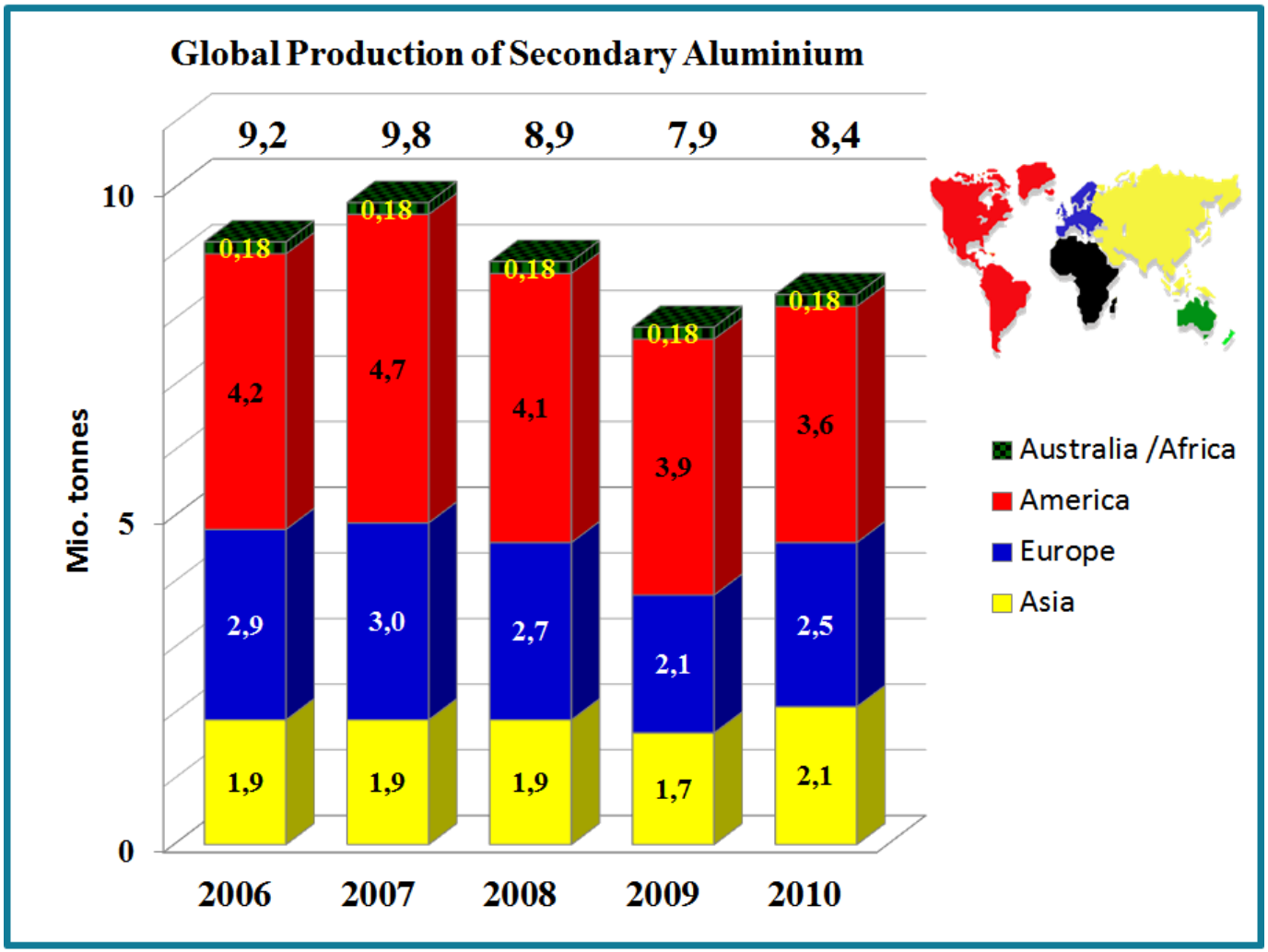


Background - statistical data Primary Aluminium



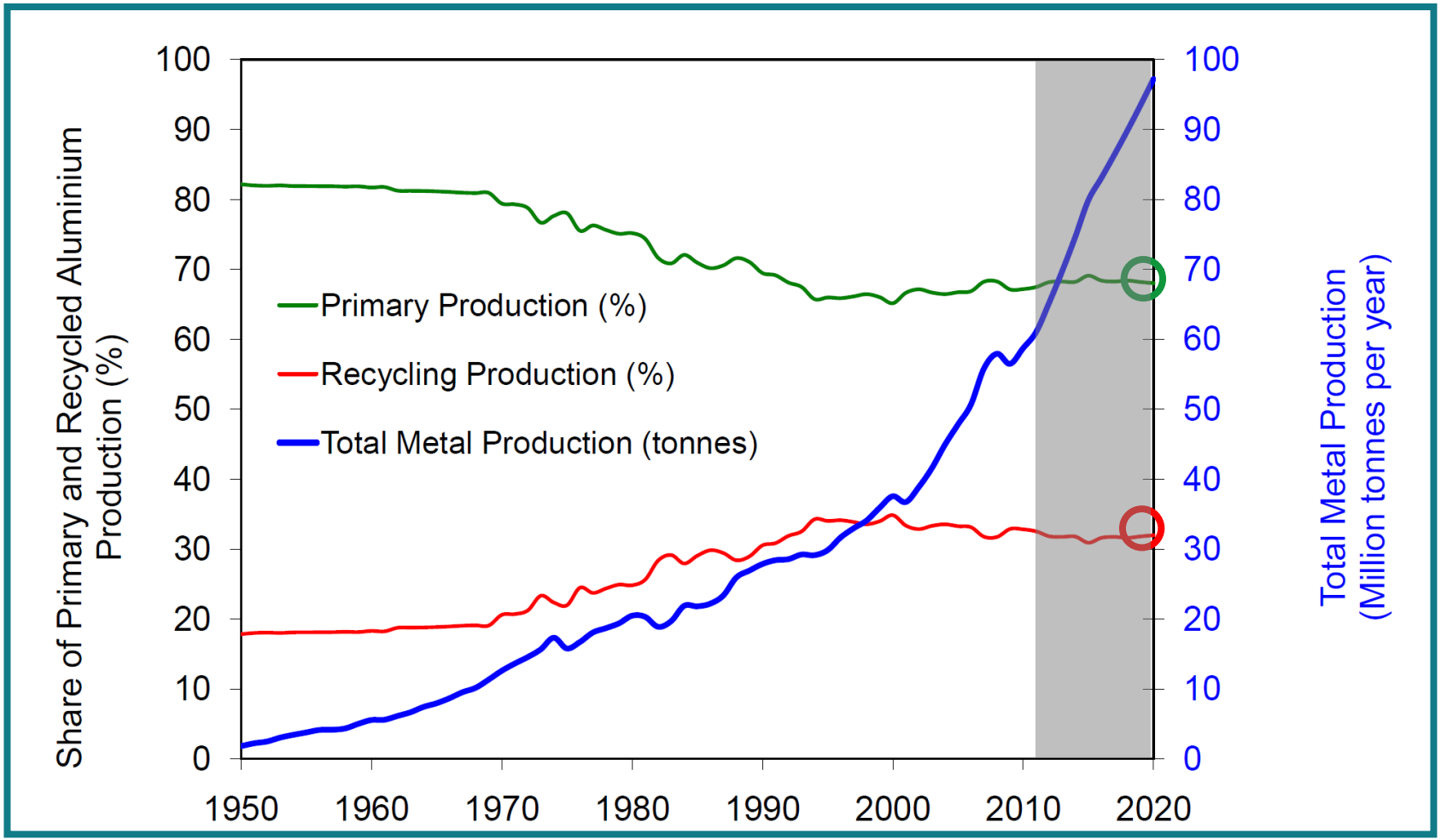
According to: GDA - Gesamtverbands der Aluminiumindustrie (http://www.aluinfo.de/index.php/produktion-weltweit.html)

Background - statistical data Secondary Aluminium



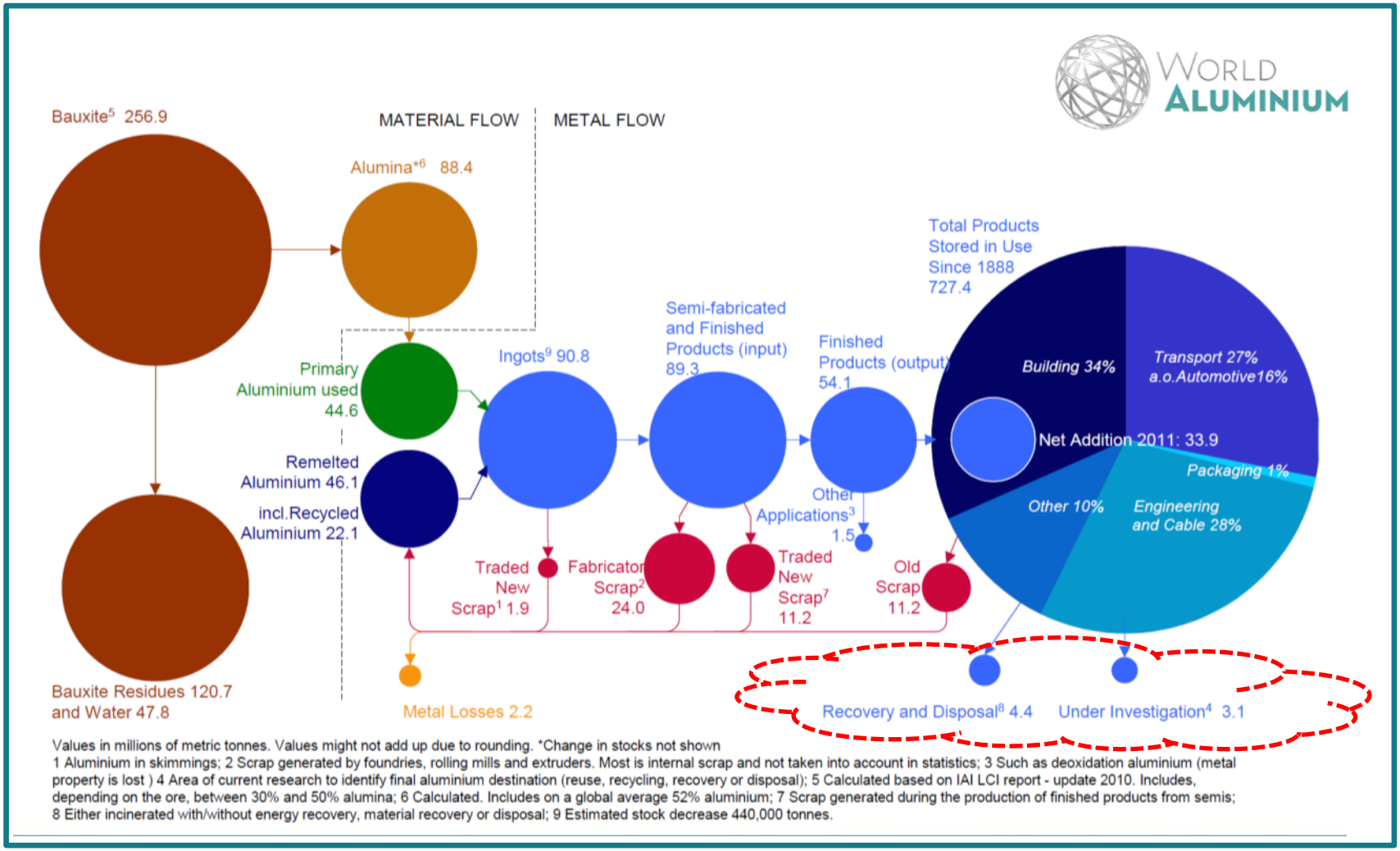
According to: GDA - Gesamtverbands der Aluminiumindustrie (http://www.aluinfo.de/index.php/produktion-weltweit.html)

Background - Primary and Recycled Metal Production



Source: Global Aluminium Recycling: A Cornerstone of Sustainable Development (http://www.world-aluminium.org/media/filer_public/2013/01/15/fl0000181.pdf)

Background - Global Aluminium Mass Flow - 2011



Source: The role of recycling in aluminium sustainability ; Katy Tsesmelis (http://www.world-aluminium.org/media/filer_public/2013/01/15/the_role_of_recycling_in_aluminium_sustainability_1.pdf)

Aluminium Recycling - Motivation: Energy Saving

Bauxite

Al2O3 - Alumina

Al - Aluminium Metall

~ 100 GJ per t Al
~ 28 MWh per t Al

GJ/t Al	GJ/t Al
45	8
55	12

The Aluminium Industry often refers to the max. amount of energy savings in the range of: **95 %**

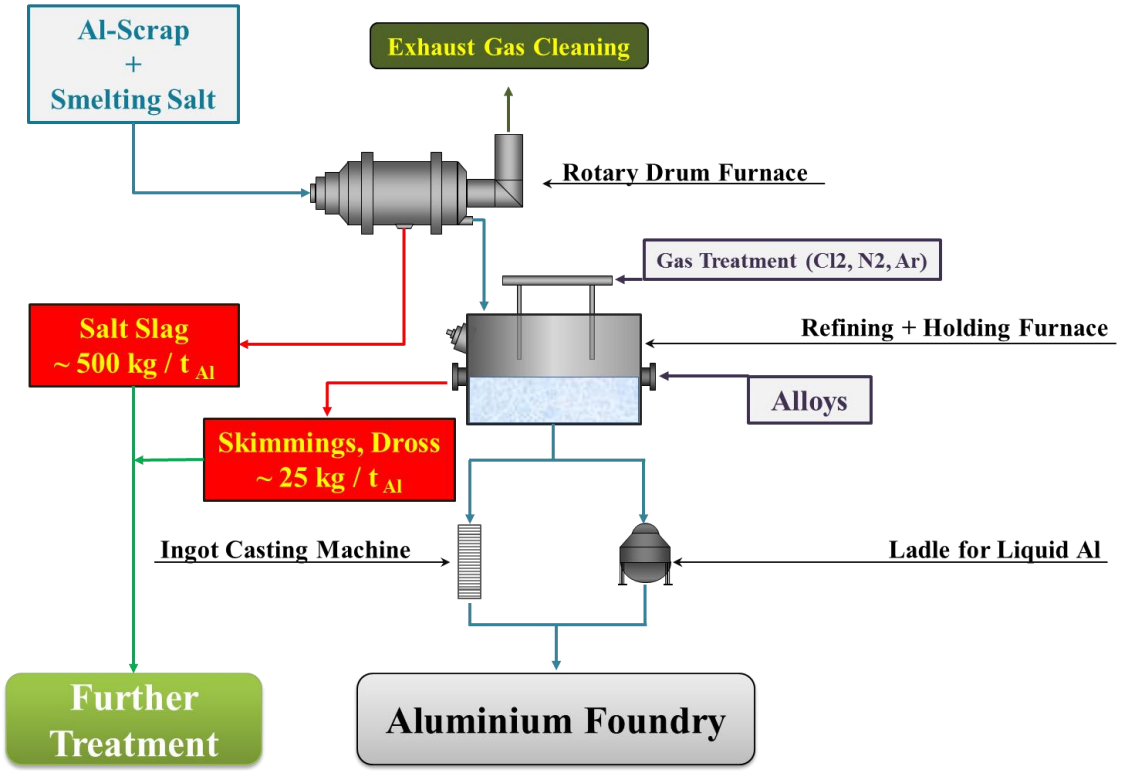
Scrap Mix

Aluminium Scrap

Al - Aluminium Metall

~ 20 GJ per t Al
~ 5,5 MWh per t Al

Aluminium Recycling - Refiner



Rotary melting furnaces are used to melt down the aluminium scrap and other materials containing Al. Typical melting rates vary from 0.5 - 3.0 t/h. The melt process is carried out under a layer of salt, which absorbs the oxides and impurities from the scrap and protects the aluminium melt from oxidation loss (burn-off).

The salt layer consist mainly of NaCl and KCl and some additional cryolite or CaF_2. Typical melting temperatures are around 700 – 750 °C.
Depending on the kind of rotary furnace used and the type of scrap being melted, anything up to 500 kg of salt slag can be generated in the production of one tonne of aluminium metal.

Aluminium Recycling - Metallurgical Process Management

The amount of dross and slag generated during the metallurgical process of Secondary Aluminium Production depends on:

- The type of scrap, resulting in different amounts of oxides and contaminants !
- The type of furnace in use !
- The metallurgical process management itself !

There are several ways to minimise the formation of these waste streams during the process and in addition, there some processes known, to recover the metallic aluminium content of dross or salt slag in-house. This can be done with hot or with cold material. For example:

Hot Treatment	Cold Treatment
• ALTEK Dross Processing Press	• Rotary Tumbler, DIDION
• ECOCENT/Focon Process	

But !

There will always be a residue, with less aluminium, but with oxides, salt, a.s.o.
The problem is smaller, but still **a l i v e** !

Aluminium Recycling - Furnace Design

The type of furnace used, depends on the type of charge material and the type of aluminium to be produced.

				RF convent.	RF Stirrer	RF LEAM	RTF	HF Single Chamber	HF Multi Chamber
Impurities	oxidic				X	X	X		
	organic	low		X	X	X		X	
		medium, max.10%		X	X	X			X
		high							X
	Input	GAS	[m³/t]	90-120	65		35	70-90	70
		O2	[m³/t]		120		70		
		Salt Factor	[-]	1,6	1,3		0,4		
		Operation time per Charge	[h]	7	5		4		

RF: Rotary Furnace, stationary / RTF: Rotary Tilting Furnace / HF: Hearth Furnace

Aluminium Recycling - Side-Effect: Residues

Residues of Aluminium Production		
	Primary	**Secondary**
Skimmings, Dross	**~ 20 kg/t Al**	**~ 25 kg/t Al**
Spent Pot Lining	**~ 25 kg/t Al**	
Spent Refractory Lining		**~ 2 kg/t Al**
Filter Dust	**~ 5 kg/t Al**	**~ 25 kg/t Al**
Salt Slag		**~ 500 kg/t Al**

Source: Integrated Pollution Prevention and Control (IPPC) – Reference Document on Best Available Techniques in the Non Ferrous Metals Industry ; December 2001 (http://eippcb.jrc.ec.europa.eu/reference/BREF/nfm_bref_1201.pdf)

Aluminium Recycling – Side-Effect: Residues

Global Amount of Residues (2011)		
	Primary	Recycling (old scrap)
Production (Mio. t)	79,5	11,2
Skimmings, Dross	~ 1,6 Mio. t	~ 0,3 Mio. t
Spent Pot Lining	~ 2 Mio. t	
Spent Refractory Lining		~ 20.000 t
Filter Dust	~ 0,4 Mio. t	~ 0,3 Mio. t
Salt Slag		~ 5,6 Mio. t

Aluminium Recycling - Definition of Terms

Skimmings:
residue of primary and secondary smelters with a content of :
> 45 wt.-% $Al_{met.}$

Salt cake / salt slag:
"non-metallic" residues generated from scrap/dross smelting operations:
4–10 wt.-% $Al_{met.}$
22 – 55 wt.-% salt (NaCl; KCl;…)
35 – 75 wt.-% oxide

Dross:
residue of secondary smelters with a content of:
< 45 wt.-% $Al_{met.}$

"white dross" :
Originates from Primary Smelters
20 – 45 wt.-% $Al_{met.}$

"black dross":
Originates from Secondary Smelters.
10 – 20 wt.-% $Al_{met.}$
40 -45 wt.-% salt ;

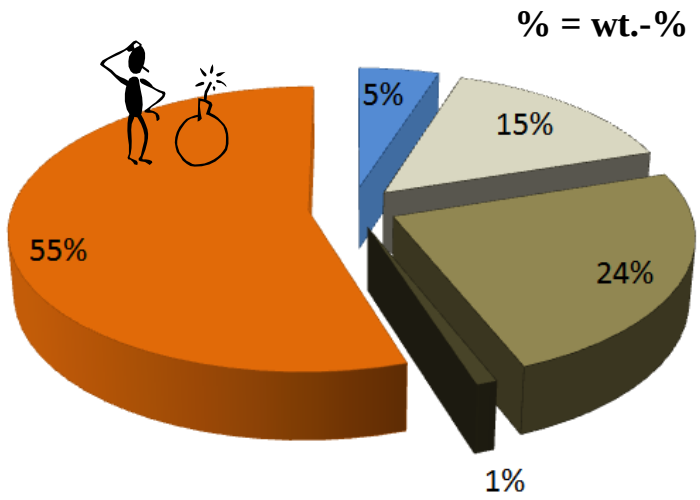
Reclamation of Residues - Motivation

According to the European Catalogue for Hazardous Wastes, **Salt Slag** is classified as toxic and hazardous waste. The disposal of salt slag is prohibited in Germany and many other countries of the EU.

A major problem of the disposal is the **high reactivity with water** or even humidity in air, leading to the formation of toxic, harmful, explosive, poisonous and unpleasant odorous gases, such as NH_3, CH_4, PH_3, H_2 and H_2S.

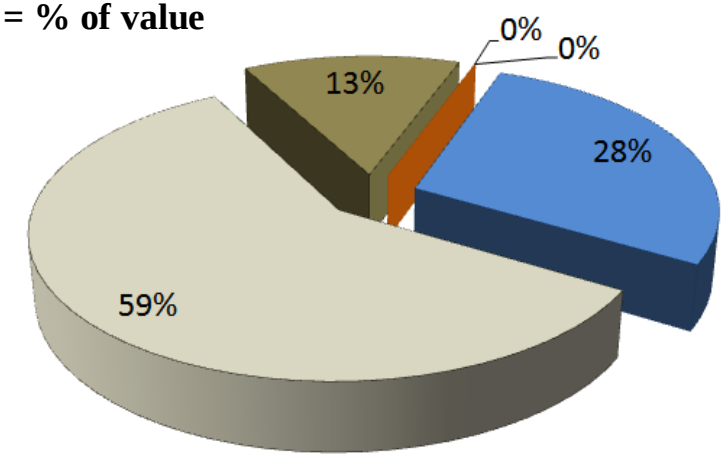
Therefor it has to be considered as highly flammable, irritant, harmful and leachable. Globally, the (often improper) disposal of salt slag is a growing problem which attracts public recognition.

Reclamation of residues - Composition of Salt Slag (average)



Without any value adding treatment, the commercial value of the oxides are zero !

Substance	Value per tonne	
	of subst.	of salt slag
Al $_{Granules}$	500 €	25 €
KCl	350 €	53 €
NaCl	50 €	12 €



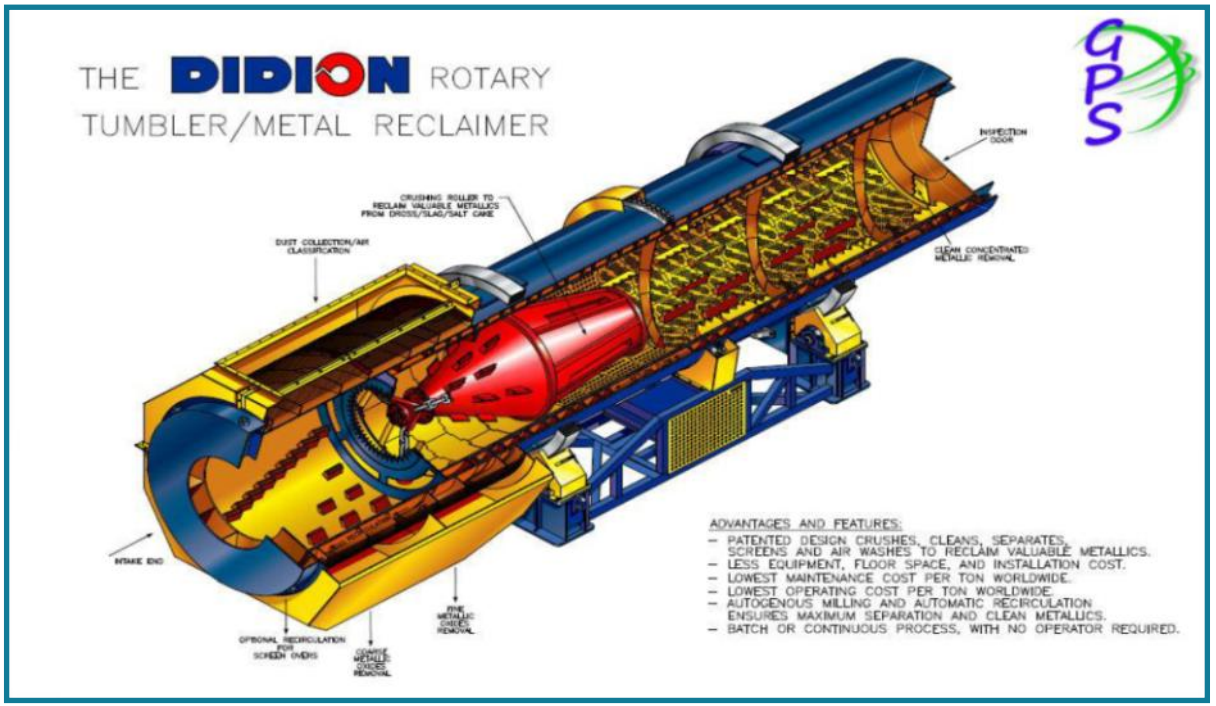
Reclamation of Residues - Basic concepts

In the last four (4) decades, basically three (3) different types of dross and salt slag processing concepts have been established:

- **Nugget Picking**
  Recycling of coarse metallic aluminium particles by dry processes
- **Partial Reclaiming**
  Recycling of the metallic aluminium and a part of the salt and/or oxides
- **Residue-free Reprocessing**
  Multi stage dry and wet processes for the complete reclamation of included materials

Reclamation of Residues - Nugget Picking

Mainly dross, but sometimes also coarse aluminium from salt slag is recycled in-house mechanically. For example – the DIDION RT Metal/Dross Reclaimer System.

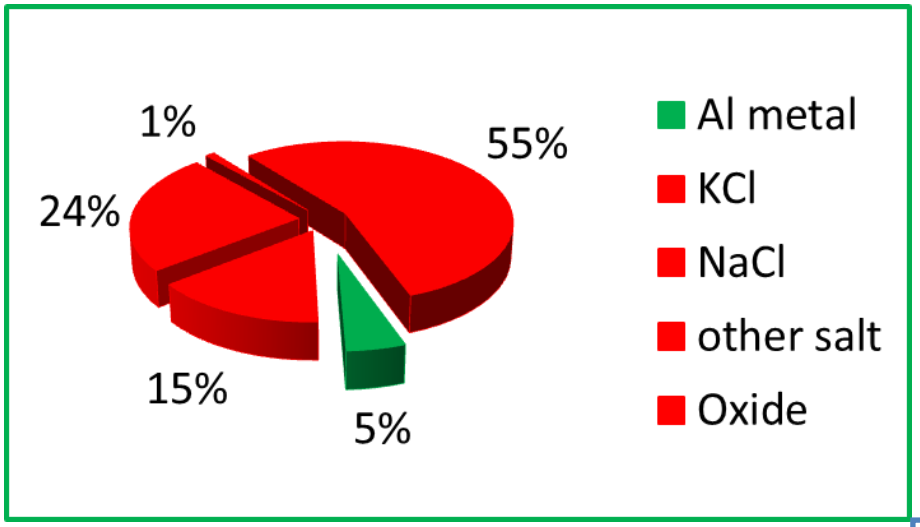


From a processing point of view, it should be more accurate to use different types of equipment for crushing, scrubbing and classification, like:

Impact crusher, dry double deck screen to achieve a higher recovery and less dust !

Source: „The Latest Steps in Mechanical Processing and Recovery of Aluminium Drosses“; David J Roth
http://www.spectrumtechnical.co.za/documents/gps/5-latest-steps-in-mechanical-dross-processing/file

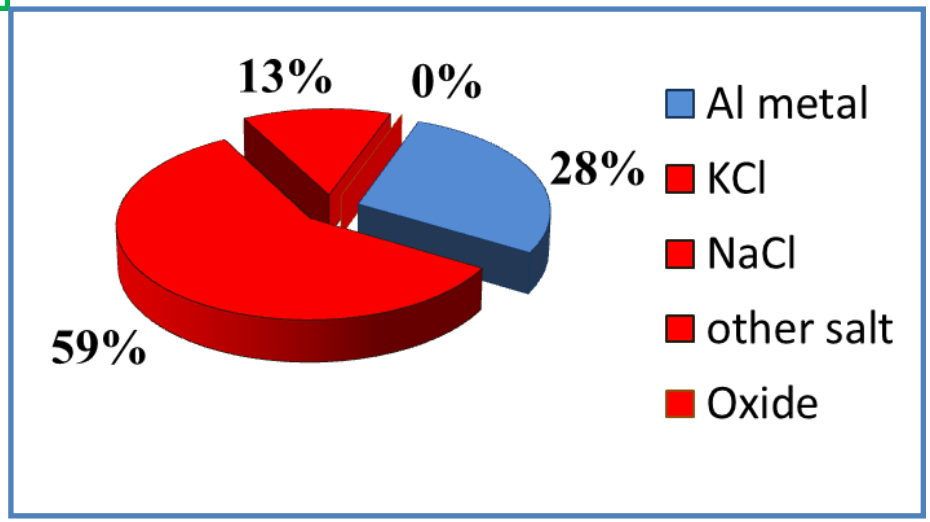
Reclamation of Residues - Nugget Picking



Nugget Picking *(Cherry picking)*

Just about 5 Wt.-% of the Input (salt slag) can be recycled.
For 95 Wt.-% environmental friendly routes for reprocessing or proper landfill have to be executed.

But, about 25 % of the value (28% less losses), can be recovered.



Reclamation of Residues - Partial Reclaiming

REKAL – **RE**cycling of **K**alium and **A**lmuninium, K+S

Recycling – ecologically meaningful

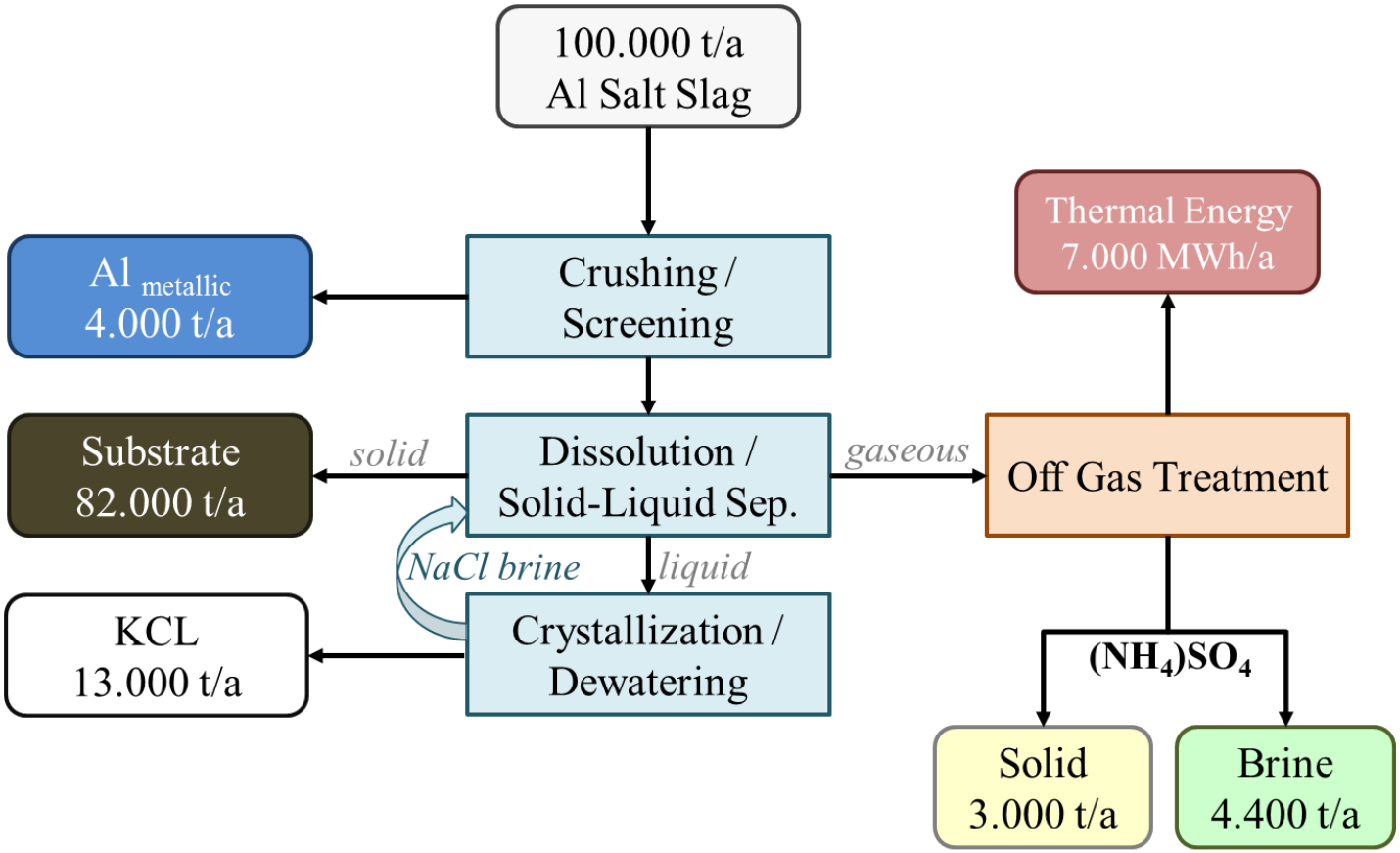
Moreover, the business segment markets high-quality smelting salts from potash production that optimise yields for smelting aluminium waste. We take back the salt slag produced during the process and completely recycle it in our REKAL® facility. The aluminium granulate extracted from the salt slag is then introduced into the substance cycle. In a further plant, soil and construction waste are processed. A large part of the material is used for the recultivation of a potash tailings pile, where it forms the basis for growing plants. Additionally, secondary building material is created for road construction and civil engineering projects.

The use of the oxidic "residue" as a material for recultivation is highly controversial and under legal dispute !

Source: „Genuine Substance - Corporate Sustainability Report 2009"; K+S AG

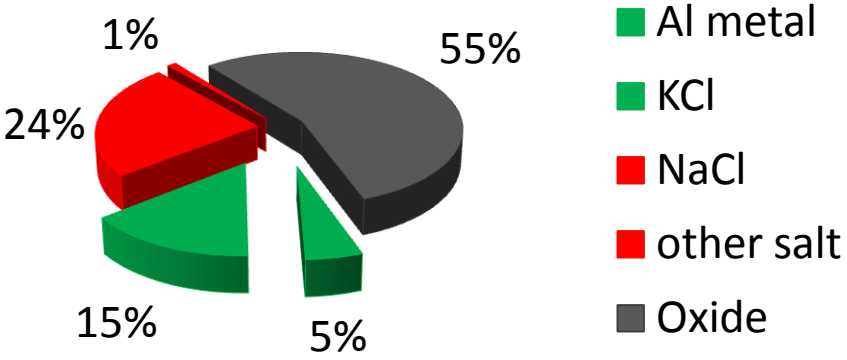
Reclamation of Residues - Partial Reclaiming

REKAL – Flowsheet (simplified)



According to: „Aufbereitete Aluminium-Salzschlacke als Rekultivierungsmaterial“; Volko Wöhler; 1999 Dissertation Universität Gesamthochschule Kassel, Fachgebiet Bodenkunde

Reclamation of Residues - Partial Reclaiming



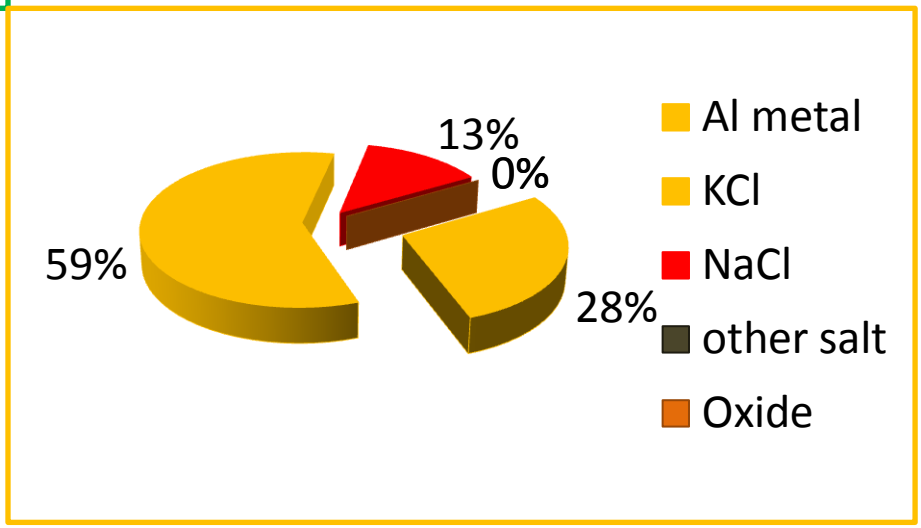
Partial Reclaiming

About 20 Wt.-% of the Input are recycled,

and about additional 55 Wt.-% of the Input are used in a “meaningful” way.

In addition about 87 % (less losses) of the value of the substances of content can be recovered.

This remarkable economical and ecological result is just possible due to special locational advantages (K+S etc.) and not possible for most locations.



Reclamation of Residues - Residue-Free Reprocessing

A couple of plants are operated, which abide the basic concept of the idea of a "closed substance cycle and waste management" ⇒ total recycling.

The processes are designed for a residue-free reprocessing of salt slag and other waste materials from the secondary aluminium industry.

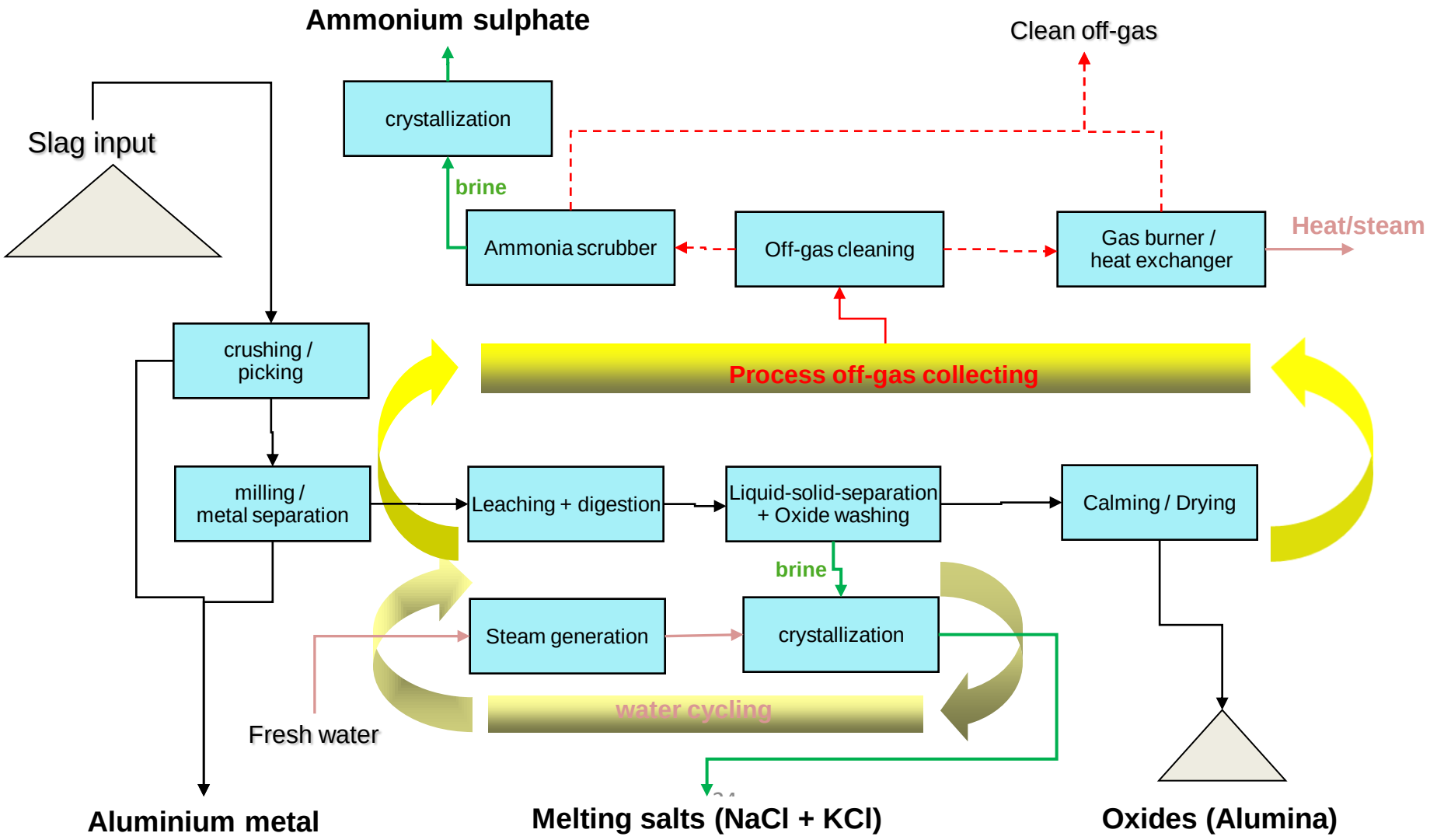
Examples of plants operating residue-free: ScholzAlu Stockach, BEFESA Salzschlacke GmBH (Lünen, Hannover, Vallodolid , Whitchurch), Vedani metalli Milano, RVA Les Islettes)

All these plants have following basic unit operations in common:

pls see next page

Reclamation of Residues - Residue-Free Reprocessing

Simplified example of a general flow sheet of a total reclamation process with optional gas cleaning ways



Residue-Free Reprocessing – Exampel of ScholzAlu Stockach

At ScholzAlu Stockach, the salt slag produced during melting and refining of aluminium scrap is fully recycled in the own slag and water treatment plant.

ScholzAlu Stockach has continuously enhanced and optimised this process.

The present day plant runs at such high capacity that SchozAlu Stockach does not only recycle all of its own slag (about 40.000 t/a), but offer this environmental service to other smelting works as well (about 20.000 t/a).

From this plant, four products are obtained:

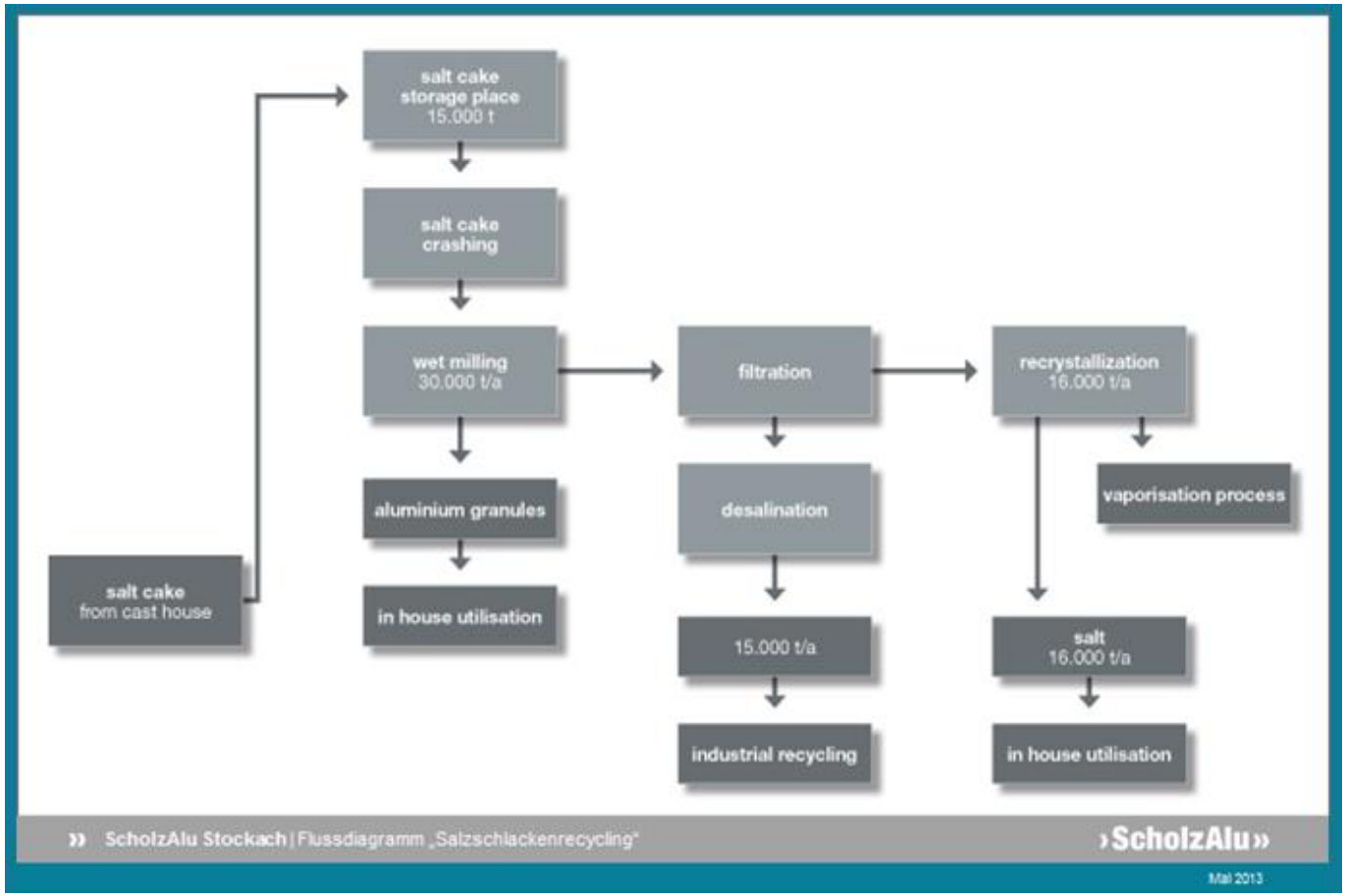
- Aluminium granules, which are fed back into the aluminium resource cycle;
- Salt flux for reuse in the melting process;
- Aluminium oxide regenerated as raw material substitute for bauxite;
- Clean water for cooling purposes.

The different aluminium oxide products are used in the cement, refractory,

steel, mineral fibre and ceramics industries, and are available as lumpy or screened bulk material at original water content or dried silo ware.

Residue-Free Reprocessing – Exampel of ScholzAlu Stockach

Capacity: **max. 58.000 t/a Input**
Aluminium Salt Slag from other Remelters: max. 15.000 t/a
Magnesium Salt Slag: max. 1.500 t/a



Residue-Free Reprocessing – Exampel of ScholzAlu Stockach

Reclamation of Residues - The Oxide Challenge

For all companies which operate this full recycling type of plant, it can be stated:

- the metallic Aluminium Product,
- the Ammonium Sulphate Product (off gas treatment),
- the KCL/NaCL product (Salt Flux),

do have a high and constant quality and are "*easy*" to market.

The Oxide Product, which is even at a dry basis the most important Product, concerning the quantity, is a different story and a crucial point in terms of the cost benefit analysis of salt slag processing projects.

Therefor it is important to actively market this Product and even to develop new ways of utilization by further upgrading.

Reclamation of Residues - The Oxide Challenge

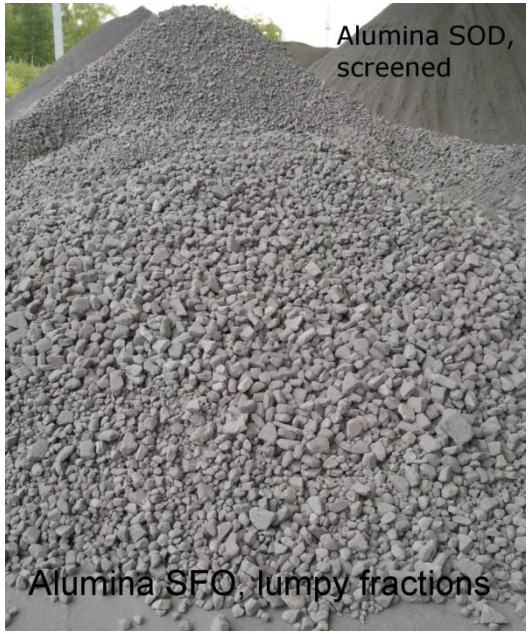
Selected figures of saleable secondary alumina from salt slag			
Country	Facility	estimated tonnage [mtpy]	
		Oxides dry	Al_2O_3
Germany	ScholzAlu	20,000	14,000
	others	150,000	100,000
France		40,000	27,000
Italy		50,000	35,000
Spain		60,000	40,000
UK		~ 30,000	~ 20,000
Norway		~ 15,000	~ 10,000
Brasil		~ 50,000	~ 33,000
U.S.A.		~ 40,000	~ 25,000
Middle East		~ 20,000	~ 15,000

Source: „News from ALSA's secondary Alumina", Gerhard Merker; 14th Bauxite and Alumina seminar, Miami March 2008

Reclamation of Residues - The Oxide Challenge

Typical characteristics of selected alumina products,
(chemical composition % by dry mass)

Characteristic	Raw bauxite /2,6,7,8,11,12,13/	Example of a centralized type oxide sort (/1,9,10/)	selected ScholzAlumina sorts from pre-sorted slag SFO	SMG	S
Al_2O_3	40 - 80	66	74	63	68
CaO	0,1 - 2	3	1,5	1,5	2
Fe_2O_3	1 - 30	1,5	0,8	0,7	1,2
MgO	?	7	3	13	5,5
SiO_2	1 - 25	9	4	4	7,5
TiO2	1 - 8	0,6	0,9	0,9	0,6
Cu	?	0,32	0,04	0,06	0,2
Cr	?	0,06	0,015	0,025	0,03
Na_2O+K_2O	< 1	1,5	1	0,6	1,1
Cl+F	?	1,5	0,8	0,75	0,75
Loss of Ignition	11 - 30	11	14	16	14
moisture %	?	26-30	20-25	20-25	28-32
Silo ware moisture	< 2	< 5	< 5	< 5	< 5
Original size mm	?	max 1	max 150	max 100	max. 150
Grain size as supplied, mm	max 250, customized	max. 1	customized, fractions 1-100	customized, fractions 1-100	customized, fractions 1-100



Reclamation of Residues - The Oxide Challenge

Selected grades of ScholzAlumina calcinate in comparison to calcined Bauxite, typical characteristics

	calcined Bauxite /6/7/8/12/	ScholzAlumina calcines SFO-K fines	SFO-K lumps	SMG-K	S-K
Al_2O_3	60 - 90	85	86	74	80
CaO	0,1 - 0,8	1,6	1,6	2,5	2,4
Fe_2O_3	1 - 7	0,8	1	0,8	1,2
MgO	0,2 - 0,6	4	3,5	15	5
SiO_2	5 - 35	5	4	5	9
TiO_2	2 - 4,5	1,1	1,1	1	0,7
Cr	?	0,017	0,017	0,03	0,04
Na_2O+K_2O	0,3 - 0,7	0,9	1	0,7	1,2
Cl+F	?	0,25	0,25	0,25	0,25
Loss of Ignition	< 0,9	< 0,5	< 0,5	< 0,5	< 0,5
grain size mm	max 250	max 1	1-30	max 50	max. 50
main mineral phase	α-Alumina	α-Alumina	α-Alumina	α-Alumina	α-Alumina

Reclamation of Residues - The Oxide Challenge

Product development:
Selected market lines suitable for secondary Alumina sorts of Scholzalu

Sort	markets					
	P cement	special cements	mineral wool	refractory ceramics	steel slags	bauxite blend
SFO	+	+	+	+	+	0
S	+	0	+	-	0	-
SMG	0	-	+	-	-	-
SFO-K	+	+	+	+	+	+
S-K	+	0	+	0	+	0

legend:		
	suited	+
	limited use	0
	no use	-

Outlook - Future Trends for Dross / Salt Cake

Technical Development

The Metallurgy of Aluminium (Remelter, Refiner) will be positively developed !

⇒ Less residues per kg of recycled Aluminium metal with normal impurities

Social and Political Development

The Recycling Rate of Aluminium containing products and waste streams will be increased steadily !

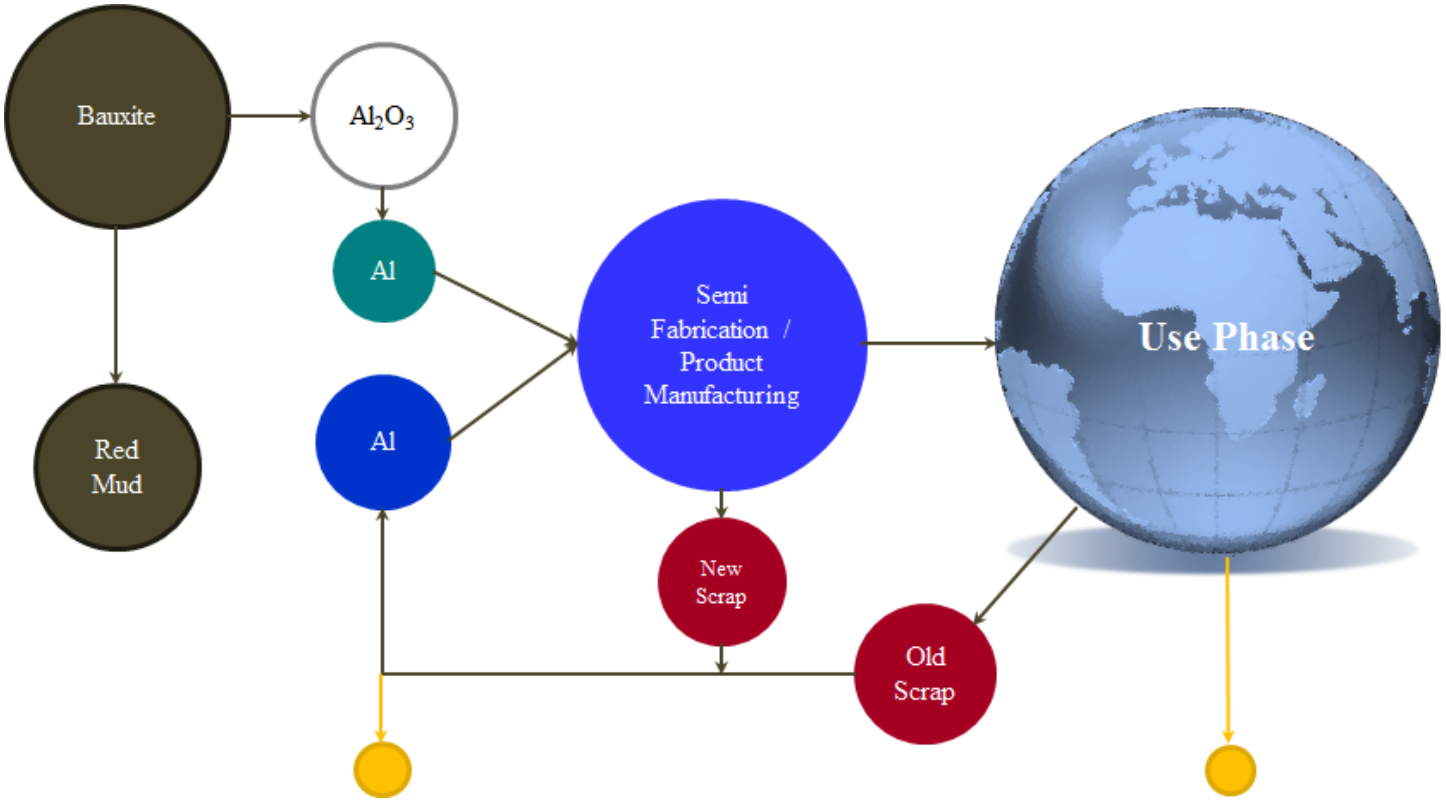
⇒ More scrap with more impurities

⇒ More residues per kg of recycled Aluminium metal

Growing environmental requirements will ban landfill, or increase costs of landfill in more and more countries !

⇒ Better economical situation for residue-free reclamation plants

Outlook – Future Massflow



The share of recycled aluminium metal will increase steadily. The amount of Aluminium "stored" in use, will not increase (no net addition). The Primary Al, will just be used to equal the losses during collecting, processing and refining of old scrap and collecting and re-melting of new scrap. To avoid environmental damages, the residue free reclamation of the growing amount of residues has to be implemented all over the world.

Thank You for your kind attention !

Your Triangle of Contact for
Reclamation of Process Residues from Aluminium Recycling

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