STIFTUNG ZENTRUM FÜR NACHHALTIGE ABFALL- UND RESSOURCENNUTZUNG

DEVELOPMENT CENTRE FOR SUSTAINABLE MANAGEMENT OF RECYCLABLE WASTE AND RESOURCES

Waste and Resource Management: Innovative, Practical, Economic

Annual Report 2012

Contents

Foreword by the President

Development and Implementation

The name of our foundation says it all: „Development Center for Sustainable Management of Recyclable Waste and Resources“. This places the focus of our development activities clearly on the result, namely on the recovery of various recyclables from waste. In contrast to many research activities that strive to gain new insights, our intention is to resolve a concrete technological problem: how to consolidate various technological sub-processes in a way that enables waste material to be comprehensively broken down into its various recyclables. This intention is clear to all of us and was at the center of our activities during the last year.

We are proud to have developed a comprehensive process for reclaiming metals. However, these activities have a clear internal focus and now need to be expanded through operational and industrial implementation. This calls for more than simply converting our insights into recycling processes within the scope of the new ZAV Recycling AG. The adequate availability of dry bottom ash depends heavily on waste-to-energy processing plants making the necessary investments to create the prerequisites required for dry discharge and the subsequent transport of bottom ash to the processing plant. What is needed is entrepreneurial vision that not only encompasses ecological goals but is also able to justify high investment costs: the three areas of dry bottom ash discharge, transport and processing should be understood and calculated as a single comprehensive system and a holistic decentralized production process.

We and our partners have successfully mastered the transition from development activity to business case; the construction of a comprehensive processing plant in Hinwil will provide the factual proof. We are convinced that the existence of a functional comprehensive system will encourage and motivate other waste-to-energy processing plant operators to decide in favor of a conversion to dry bottom ash.

My sincere thanks go to all employees, the members of the technical council and foundation board and, in particular, to our donators without whose outstanding support our work would not be possible.

Dr. Ueli Büchi
President of the Foundation Board

Activity Report 2012

State of the Art

Bottom ash from incineration plants contains a great deal of non-ferrous metals (NF metals). Significant quantities of scrap iron and non-ferrous metals are separated from wet discharged bottom ash that has been conditioned in accordance with the latest available technology. However, the efficiency of current wet bottom ash conditioning methods in the region of fine bottom ash less than 5 mm is still inadequate, often leaving it unprocessed. However various metals are so highly concentrated in very fine bottom ash that it often contains a greater content than the respective ore. These resources are currently deposited together with the wet bottom ash at reactor waste disposal sites, where they are not only lost but are also responsible for costly post-closure care.

Dry bottom ash discharge has been in place at the Waste-to-Energy Association of the Zurich Oberland region (KEZO) for a number of years. One major advantage of dry discharged bottom ash is the easier access to its metallic content, in particular to fine bottom ash less than 5 mm. The processing method for fine bottom ash of 1.0–5.0 mm already works very efficiently. Today we are able to separate more than 90% of the NF metals in fine bottom ash. An extraction system for very fine bottom ash (0.2–1.0 mm) was added to the existing processing plant to increase the quantity of various reclaimed NF metals and precious metals.

Projects / Results 2012

Very Fine Bottom Ash Processing System Commissioned in 2012

The processing system for very fine bottom ash was taken into operation in March 2012. Its design is analog to the existing fine bottom ash processing system and consists largely of a screen, a magnetic separator, two Eddy Current separators arranged in series and an air separation table.

The NF metals 0.2–1.0 mm separated by the Eddy Current separators are delivered to the separation table. There the aluminum is separated from the other heavy NF metals by means of its different specific density and results in the precious NF fraction, because gold and silver are enriched. Various tests were carried out to increase the quantities of separated fractions and improve quality; these in turn led to a number of conversions and modifications.

Two different types of Eddy Current separator were used during the test phase. One Eddy Current separator was specified by the manufacturer (SGM Gantry S.p.A); the other was specified by ZAR. The two parties jointly determined performance indicators and agreed that the separator with the better performance would become standard. The performance determination tests provided us with the basics of and many valuable insights into the separation of NF metals from very fine bottom ash. Once more we had to realize the different behavior of bottom ash compared to other materials (e.g. plastic, electrical waste etc.). The use of an Eddy Current separator designed specifically for bottom ash is therefore unavoidable if a high level of efficiency is to be achieved. This is why the Eddy Current separator designed by ZAR prevailed in the test, regarding the number of different separated precious metals as well as a very low mineral content. Another very important factor with regard to achieving high process efficiency and reliability for the separation of this very fine fraction 0.2–1.0 mm is the dust extraction.

The separating stage had to be adjusted to guarantee a uniform utilization of both processing lines with fine respectively very fine bottom ash. Tests with different separating stages were carried out: very fine bottom ash will now have a grain size of 0.2–1.0 mm, whilst fine bottom ash will measure 1.0–5.0 mm. This way the throughput can be increased without negative influence on the efficiency. The new separating stage also results in a low dust content in the fraction 1.0–5.0 mm and therefore increases its quality.

Reclaiming Valuable Precious Metals from Very Fine Bottom Ash

Tests to date have shown that very fine bottom ash contains various precious metals alongside aluminum and NF metals and those they can be separated from the bottom ash using the specifically designed separator. These metals can then be recycled and are no longer disposed of along with the rest of the bottom ash. This is all the more advantageous as their active surfaces are responsible for emissions (in the leachate and gas phase) and necessitate costly post-closure care.

Designing a method specifically for processing very fine bottom ash has shown that metals with a grain size of 0.2 mm can be reclaimed from dry discharged bottom ash - a significant advantage over wet discharged bottom ash. This represents a further milestone in thermo-recycling.

Separating the NF Precious Metal Fraction

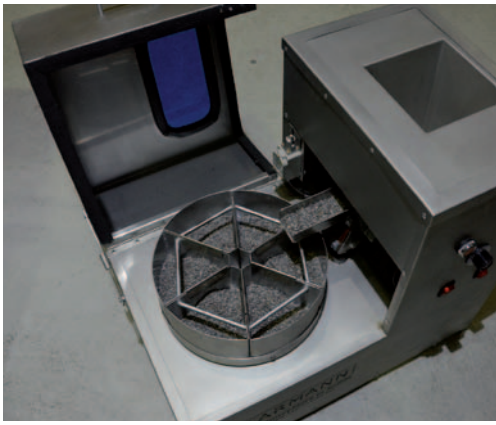
The NF precious metal fraction is very valuable as it contains copper, zinc, lead and various other metals. The fraction can also contain up to 150 g of gold per metric ton, depending on the grain size.

However the question was, whether an additional enrichment of gold would pay economically as well as ecologically. As part of a matriculation project elaborate density sorting trials with a magnetic liquid were undertaken to separate and accumulate the gold from the NF precious metal fraction (LiquiSort® method). The trials showed that separation is possible in principle, but that metals other than gold are also separated; moreover, some of the gold still remains in the copper fraction. These trials were carried out in Holland by Dutch firm Liquisort Metals B.V.

Test results proofed a certain enrichment of gold, but also the separation of other metals. However a certain amount of gold still remained in the other fraction. Discussions with potential consumers for these new fractions have shown neither significant economical nor ecological advantages. Magnetic density sorting will be waived.

Analysis Method for NF Metals

Until now it was not possible to determine the exact composition of the various metals contained in the NF precious metal fraction. Despite the enrichment of precious metals such as gold, the concentrations contained in bottom ash are still very small. Consequentially, the representative sample required for an exact and reproducible analysis has to be very large. The analytical laboratory at Bachema AG and the University of Duisburg-Essen have developed two analytical methods on behalf of AWEL and the ZAR Foundation that enable the exact determination of various precious metal contents.



1. NF metals are ground down to a particle size of less than 0.1 mm and homogenized. This significantly reduces the sample quantity required for acid hydrolysis. The chemically digested samples are then subjected to wet chemical analysis.
2. NF metals are completely melted in a high-temperature furnace. Samples known as lollipops are taken from the smelt and then cool down and solidify very rapidly. The surfaces of these samples are subjected to spark spectrometer analysis after light grinding.

Elaborate trials have shown that both methods produce very reliable and reproducible analysis data. We are therefore now in a position to provide a very exact determination of the precious metal content of the NF metal fractions.

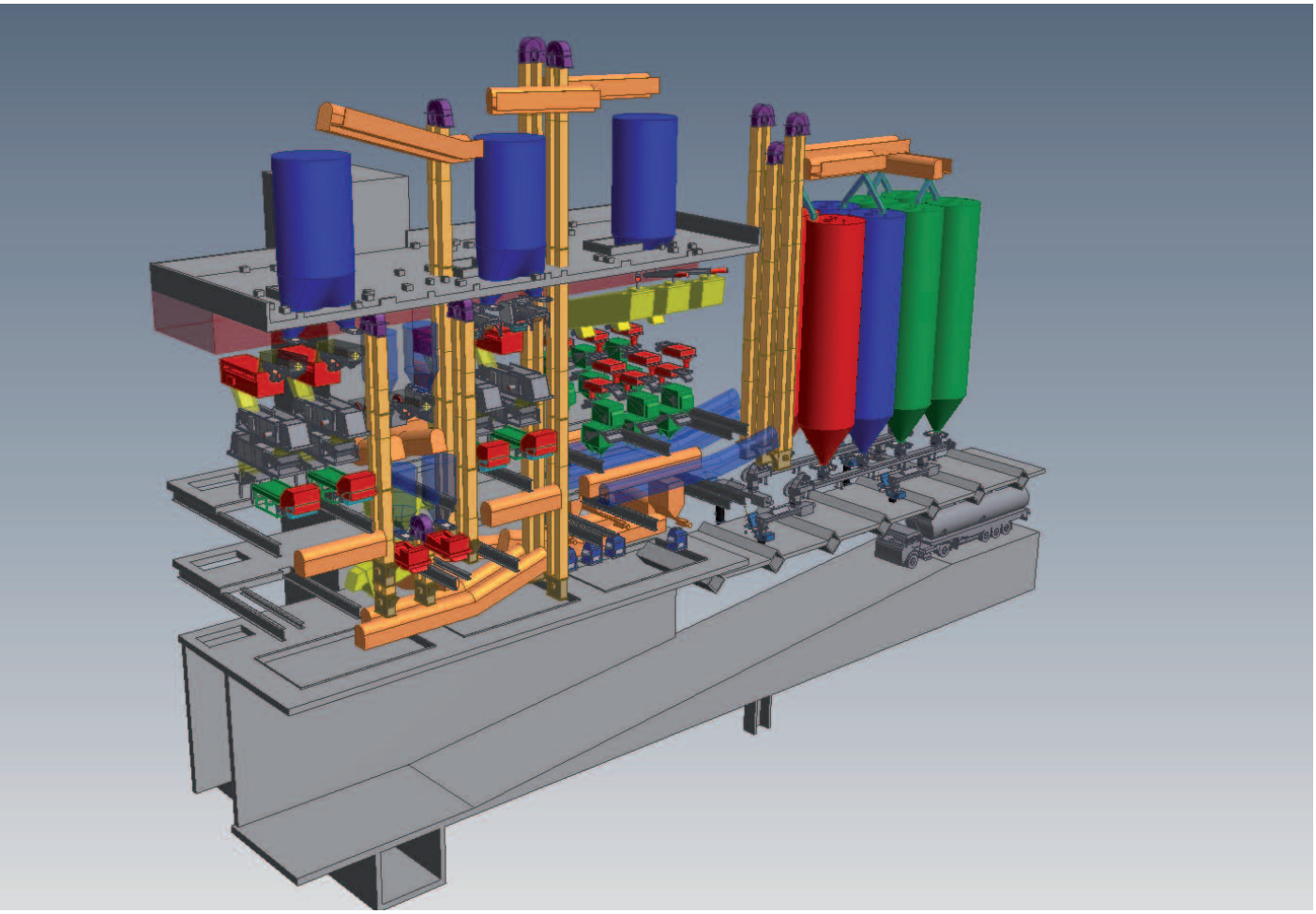
Course Bottom Ash Processing – ZAV Recycling AG

We have now spent some considerable time planning the course bottom ash processing plant in Hinwil that will be taken into operation at the end of 2013 / beginning 2014. The processing plant - which is able to process dry discharged bottom ash only - will be constructed and operated by a new company, ZAV Recycling AG, as yet to be established. Together with KEZO three other municipal waste-to-energy plants in the canton of Zurich (KVA Dietikon, KVA Horgen and KVA Zürich Hagenholz) will participate in the corporation at the beginning. These plants will modify their bottom ash discharge to dry bottom ash discharge when it is up and running. This will guarantee that bottom ash discharge as a part of the overall thermo-recycling process will be much more efficient and the proceeds from the sale of metals will be used to reduce the financial effort in return.

The plant will be equipped with a triage for a bottom ash pre-separation. Iron will be separated; extraneous material removed and big dimensioned

recyclable material taken out manually. The coarse bottom ash will then be broken down, screened and fractioned and this way optimally prepared for the actual processing stage. The plant will both separate and refine the metals to create salable products. The process will make use of conventional equipment such as magnetic separators, Eddy Current separators, sensor sorters and crushers.

The process will be modular in design as only bottom ash from KEZO will be processed to begin with. This phase will provide an opportunity to further optimize the plant, adapt it to the latest conditions and conduct trials. Processing lines will then be extended in accordance with the amount of bottom ash provided by other waste-to-energy plants after their conversion. When it is fully complete the plant will be able to process 200‘000 metric ton per year on various processing lines. We are convinced that thermo-recycling will prevail in the future.



The Mineral Fraction in Bottom Ash

The progress achieved by ZAR in the field of metal recovery has a direct impact on the quality of the mineral content of dry bottom ash. Despite the high efficiency of modern metal recovery methods, the mineral content of bottom ash still contains residue metals that will result in an accumulation in the landfill in the short to mid-term. Last year, ZAR significantly increased its efforts in relation to the treatment of the mineral fraction. Various trials to characterize the mineral and chemical composition of bottom ash are currently ongoing. These investigations are being carried out in cooperation with Zurich University (ETH). One of ZAR's main objectives is the disposal of bottom ash without any need for post-closure care. Another objective is to recycle dry bottom ash, or least some of its components. To this end, ZAR is currently investigating the following:

Reclaiming specific elements or phases

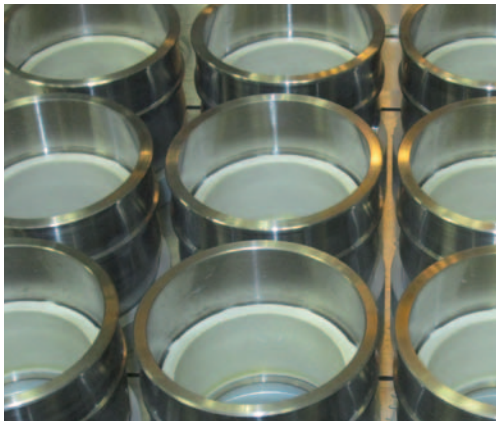
Processed dry bottom ash has a different composition to natural rock as it has a higher content of the elements chlorine, fluoride, phosphor and a greater proportion of various metals. A detailed examination of various samples should provide insights into the mineral phase and the possibilities of recovering these phases.

Recycling fractions of processed mineral dry bottom ash

Recovered phases will then be used as construction materials or as base materials for the same. Various investigations are necessary to determine the substance quality and to enable the recovered materials to be used without any problems. Recovering specific mineral phases and returning them to the cycle would reduce the amount of dumped waste and preserve natural resources.

Disposal of „residual material" with no need for post-closure care

The mineral residue remaining after metal separation would improve in comparison to the bottom ash produced today. However, the fraction still needs to be dumped. Various external tests were carried out to assess the installability of dry bottom ash. The results are not yet available in full. The emission behavior of dry bottom ash was also tested to quantify emissions. Processed dry bottom ash shall be filled separately in future to enable emission measurement and a comparison with the values of wet bottom ash.



Personnel

Dr. Paola Ardia joined the ZAR team in 2012.

Visits

The interest in the work of the ZAR Foundation remains high. More than 50 delegations were given a tour of the plant. The visitors came from Germany, Italy, France, England, Austria, Finland, Denmark, USA, Canada, China, South Africa and Japan.

Presentations

The ZAR team participated in various events at home and abroad to present its work to a broad audience.

Publications

Publication in Waste Management
"19th Oct. 2012: Morf et al., 2012, Precious metals and rare earth elements in municipal solid waste - Sources and fate in a Swiss incineration plant, waste management".

Press (in German only)

Wie Abfall zum Rohstoff wird (From Waste to Resource)
Article in magazine „Saft&Kraft", Elektrizitätswerke Canton Zurich, Issue 3/12

Die Schlackenmanager (The Bottom Ash Managers)
Magazine „Umweltpraxis", Issue 01/2012

„Wir nennen es Thermorecycling" (We call it Thermorecycling)
Magazin „AT Recovery", Issue 01/2012

Gold aus dem Kehricht (Gold from Waste)
TV-documentary in „Schweiz Aktuell", SF DRS, 4th April 2012

Visions and Goals

Quality Assurance

The extensive optimization work carried out on our bottom ash processing plant has strengthened our conviction that dry bottom ash processing requires a tailor-made quality assurance system that will enable us to continuously monitor and improve the conditioning process and the quality of our products. The separation of fine copper and precious metal fractions is decisive for the economic and ecological success of bottom ash processing. In fact, success is due to the sum of a multitude of small yet important factors, as precious metals are only available in minute concentrations and are very difficult to separate.

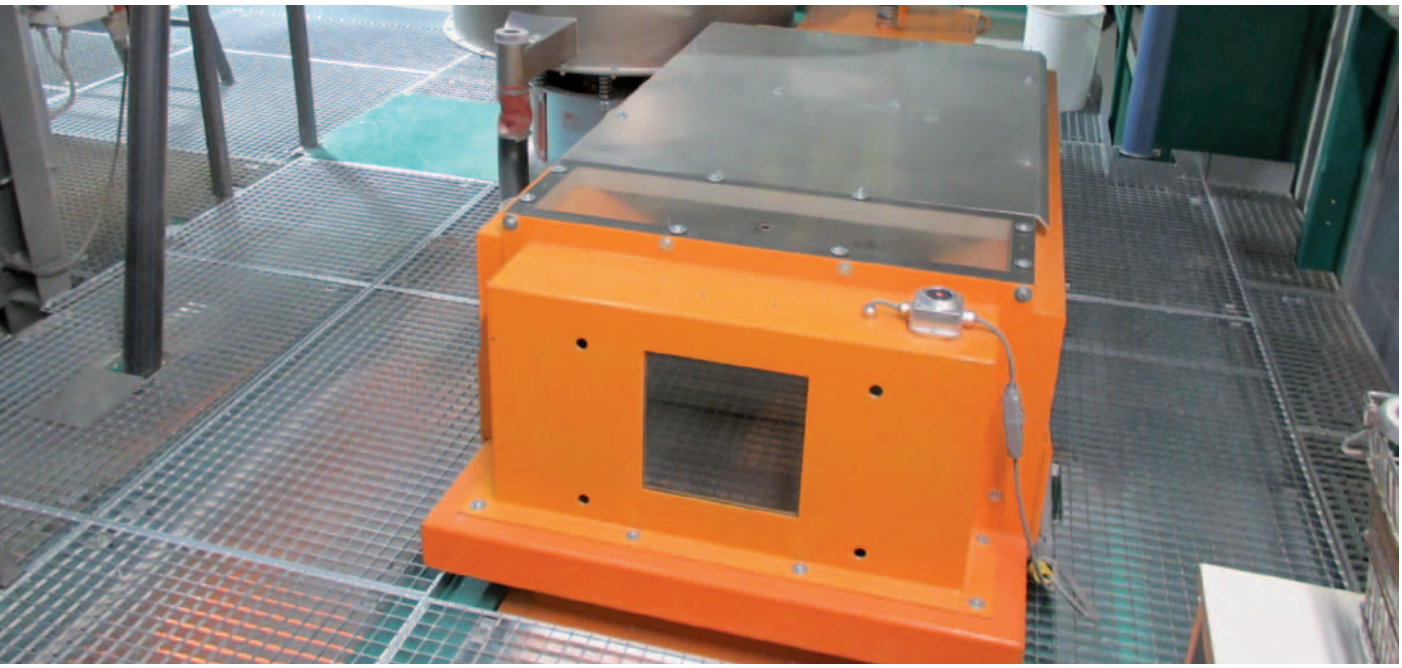
Whilst the effectiveness and efficiency of a processing plant depend on numerous small factors, it is the statistically proven sampling process, meticulous sample conditioning and exact analysis that are the key factors of process control. The Bachema analytical laboratory and the University of Duisburg-Essen have developed fundamental aspects of the future quality management of our processing plants on behalf of AWEL and the ZAR Foundation. A reliable analysis of NF metals is meanwhile possible.

Determining the gold content of base bottom ash or conditioned bottom ash after processing with an Eddy Current separator is, however, not yet completely reliable. This circumstance is the reason why we are to this day unable to make a clear statement on the effectiveness of precious metal separation in our plants. Estimating the potential of precious metals in bottom ash or even in waste remains a critical issue. The fact that we do not know the true efficiency of our precious metal separation processes means that we do not know how many precious metals lay buried in our landfills. This insight has inspired us to further improve minor aspects of our conditioning process to return even more precious metals to the recovery cycle.

We have, however, established with great satisfaction that the gold and silver separated by the end of the conditioning process is already sufficient enough to guarantee the commercially viable operation of our future large-scale plant.

Milestones

2005	Initial trials with dry bottom ash discharge on furnace line 2 at the KEZO incineration plant.
2006	Long-term trials with dry bottom ash discharge on furnace line 2 with ram bottom ash extractor and screening machine.
2007	Conversion of furnace line 2 to dry bottom ash discharge.
2008	Fine bottom ash treating plant taken into operation.
2009	Conversion of dry bottom ash discharge on furnace line 2.
2010	The foundation „Development centre for sustainable management of recyclable waste and resources ZAR“ is established. Dry bottom ash discharge taken into operation on furnace line 3. NF processing taken into operation. Creation of the thermo-re brand thermo re® .
2011	Optimization of Eddy Current Separator. Specification of the Ultra-Fine Bottom Ash treatment Optimization of screening in continuous operation mode. Conclusion of product development



2012

March

Start-Up of Ultra-Fine Bottom-Ash Treatment Plant

After an extensive start-up period the separation of ultra-fine metals from the bottom ash (0.2-1.0 mm) is started. Just on time with the annual ZAR Forum 2012 the plant can be presented to the public.

June

Non-Ferrous Processing Taken into Operation.

After sufficient NF metals have been separated also the separation tables are taken into operation. The NF metals are separated into an aluminum fraction and a NF rare metal fraction. It is therefore technically feasible to separate NF-metals with a grain size of 0.2–1.0 mm.

November

Purchase Order for Eddy Current Separator

Based on the experiences and results from the ultra-fine bottom ash treatment plant it is decided to replace the existing Eddy Current separator for the grain size 1.0–5.0 mm by products from the Italian company SGM Gantry S.p.A., which are constructed as defined by the ZAR.

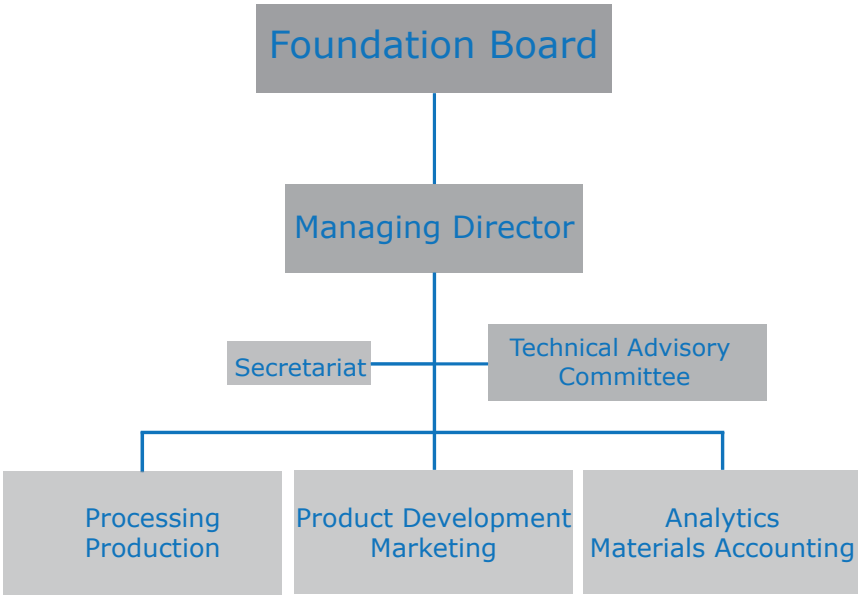
December

Completion Analyzing Method Non-Ferrous Fraction

After elaborate experiments two reliable methods are found to determine the composition of the non-ferrous fraction exactly.

Either a homogenous, melted sample is used to produce a suitable sample for the analysis with a spark spectrometer. Or the sample is milled < 0.2 mm dissolved in an acid and prepared for wet-chemical analysis.

Organization



Foundation Board (per 31.12.2012)

The foundation board is the supreme organ at ZAR. It currently consists of seven members comprising representatives from the waste management industry, the base materials industry, the recycling industry and environmental authorities. The foundation board represents ZAR in strategic, contextual and financial issues. The foundation board convenes at least twice a year and decides on the budget and the annual program.

Presidency

Dr. Büchi, Ueli	President of the KEZO supervisory board

Vice Presidency

Dr. Fahrni, Hans-Peter	Senior Consultant

Board Members

Adam, Franz	AWEL, waste management and operations, Department head
Vacant	VBSA
Vacant	Hitachi Zosen INOVA AG, Flue gas treatment systems
Christen, Daniel	SARS Swiss Automobile Recycling Foundation Managing Director
Dr. Hediger, Robert	SENS International, Managing Directorr
Kalunder, Werner	HOLINGER AG, Western Switzerland, Director
Martin, Johannes J. E.	MARTIN GmbH, Managing Director

Technical Advisory Committee

The Technical Advisory Committee supports the managing director in the pursuit of the foundation's objectives. It consists of members who have a high degree of expert competence and complement the competencies of the managing director.

Dr. Morf, Leo (Chairman)
Department for Waste Management and Operations,
Canton Zurich, WtE Plants and Sludge Processing

Prof. Dr. Brunner, Paul
TU Wien, Institute for Water Quality,
Resource Management and Waste Management, Vienna

Bühler, Anton
BSH Umweltservice AG, Sursee

Prof. Dr. Hellweg, Stefanie
ETH Zürich, Institute for Environmental Engineering, Zurich

Dr. Kündig, Rainer
Swiss Geotechnical Commission, Zurich

Dr. Liechti, Jürg
Neosys AG, Gerlafingen

Dr. Johnson, Annette
Eawag, Dübendorf, Water Resources and Potable Water

Sigg, Alfred
Hitachi Zosen INOVA AG, Zurich

Streuli, Adrian
Jura Cement, Wildegg

Dr. Zeltner, Christoph
Stahl Gerlafingen AG, Gerlafingen

Dr.-Ing. Koralewska, Rolf
Martin GmbH

Operation

Böni, Daniel	Managing Director
Di Lorenzo, Fabian	Project Manager metallic raw materials
Dr. Ardia, Paola	Project Manager mineral raw materials
Miràs Albino	Process development and production
Schellenberg, Peter	Process development and production
Bruno, Francesca	Secretariat

Founders

AWEL
Amt für Abfall, Wasser, Energie und Luft des Kantons Zürich
(The Cantonal Department of Waste, Water, Energy and Clean Air of Zurich)

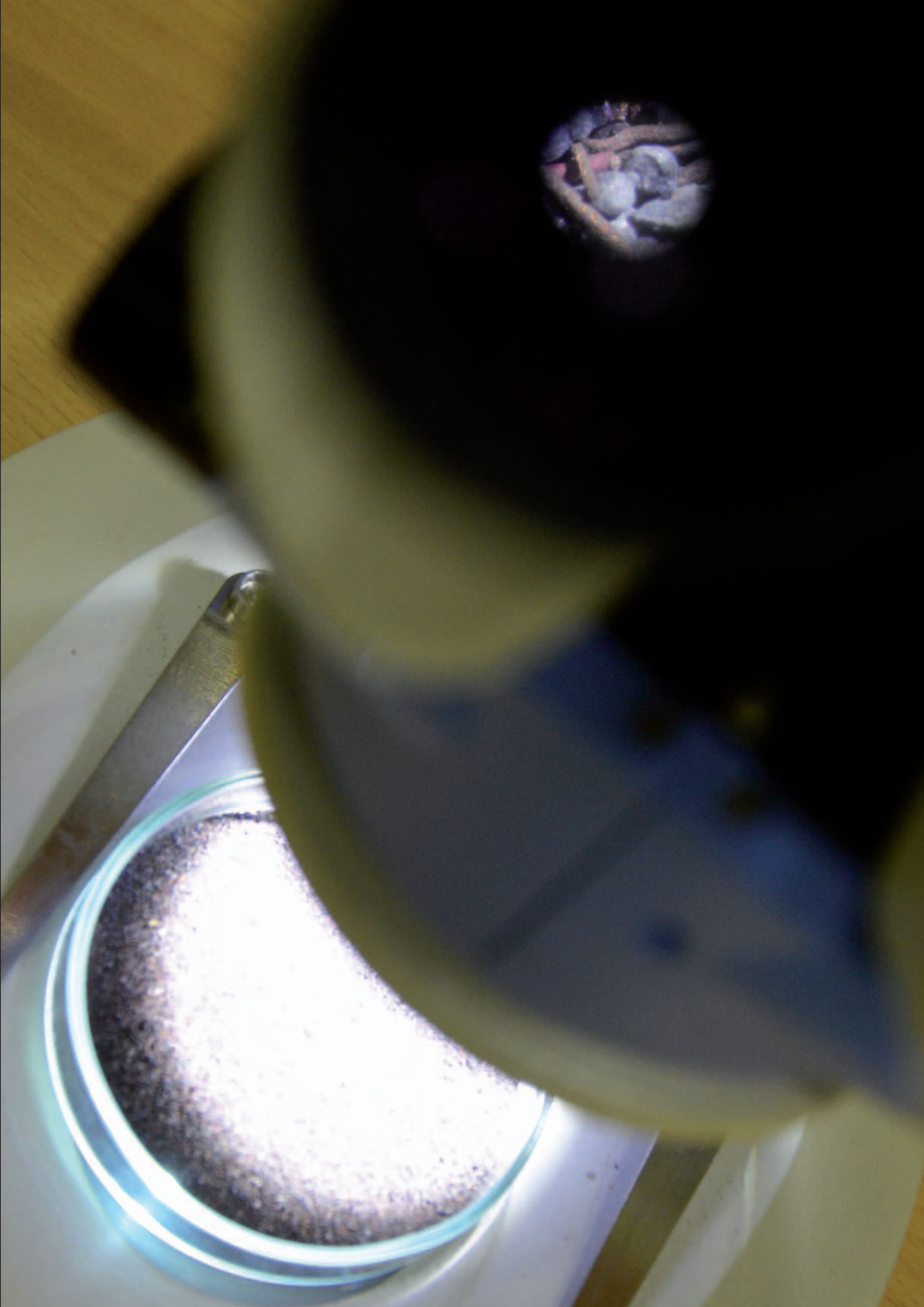
VBSA
Verband der Betreiber Schweizerischer Abfallverwertungsanlagen, Bern
(Association of operators of Swiss waste recovery plants, Berne)

KEZO
Zweckverband Kehrichtverwertung Zürcher Oberland, Hinwil
(Consortium waste recovery for region Zurcher Oberland, Hinwil)

Donors 2012

In alphabetical order

AFATEK A/S	Soborg (DK)
BACHEMA AG	Schlieren
Deponie Leigrueb AG	Lufingen
ERZ Entsorgung und Recycling Zürich	Zurich
Hitachi Zosen INOVA AG	Zurich
Kanton Zürich	Zurich
KEZO Kehrichtverwertung Zürcher Oberland	Hinwil
LIMECO	Dietikon
MARTIN AG für Umwelt- und Energietechnik	Wettingen
REAL Recycling, Entsorgung, Abwasser Luzern	Lucerne
SATOM AG	Monthey
STAG AG	Maienfeld
Stadtwerk Winterthur, Kehrichtverwertungsanlage	Winterthur
SARS Stiftung Autorecycling Schweiz	Berne
TBF + Partner AG	Zurich
Toggenburger Unternehmungen	Winterthur
VBSA	Bern
Verband KVA Thurgau	Weinfelden
VETROSWISS	Glattbrugg
WIEDAG AG	Oetwil a.S.
Zweckverband für Abfallverwertung im Bezirk Horgen	Horgen



Financial Reports

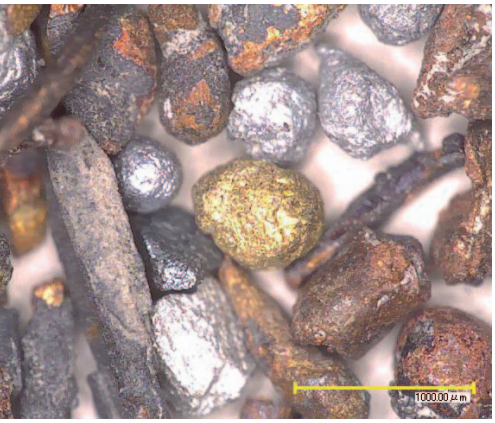
INCOME STATEMENT

	Statement 2012 in CHF	Budget 2012 in CHF	Statement 2011 in CHF
INCOME			
Donors	785‘340	810‘000	825‘000
Interest	2‘800		3‘155
TOTAL INCOME	**788‘140**		**828‘155**
EXPENDITURE			
Material	50‘480	50‘000	63‘085
Analyses	98‘615	80‘000	40‘333
Third party services	90‘335	60‘000	79‘943
Salary	423‘861	420‘000	365‘725
Social Insurance	98‘797	110‘000	80‘954
Training	949	5‘000	0
Rents	0	5‘000	252
Maintenance / Optimization	20‘115	0	754
Administration costs	337	5‘000	498
Advertising costs	7‘612	0	4‘291
Cost of representation	6‘993	15‘000	3‘017
Foundation board expenses	5‘861	10‘000	120
Technical advisory board expenses	300	0	
ZAR operation expenses	3‘403	0	4‘352
Bank expenses	13	0	472
Technical equipment	0	100‘000	0
Miscellaneous	0	20‘000	0
Transport	0	5‘000	0
TOTAL EXPENSES	**807‘671**	**885‘000**	**643‘796**
RESULT	**-19‘531**	**-75‘000**	**184‘359**

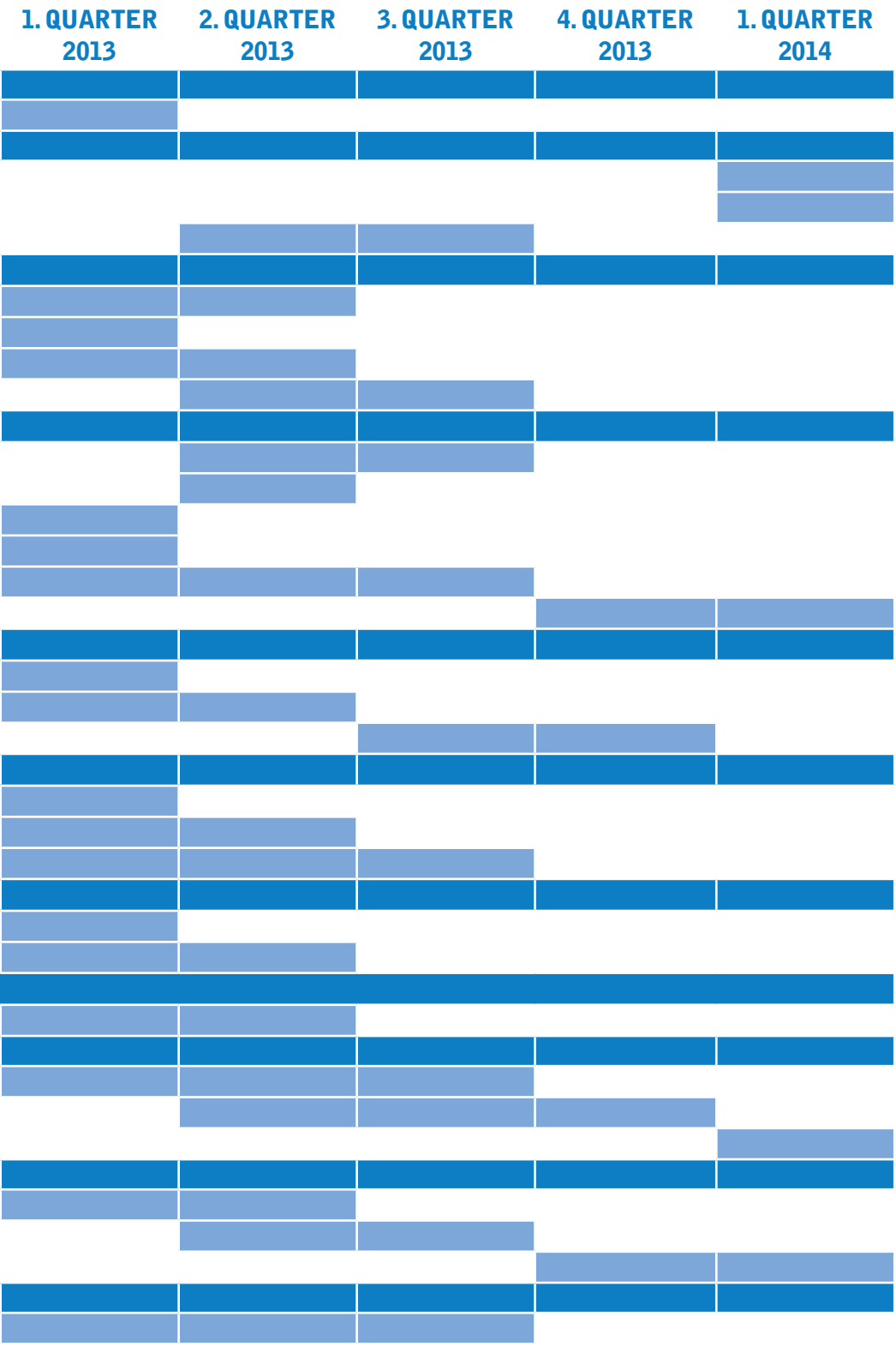
BALANCE SHEET

	31.12.2012 in CHF	31.12.2011 in CHF
ASSETS		
Raiffeisen Uster CH22 8147 1000 0047 5263 5	424‘161	650‘762
Raiffeisen Uster CH59 8147 1000 0047 5264 8	601‘499	351‘639
Debtors	60‘340	451
Input taxes on debtors	44‘836	0
Withholding tax on debtors	2‘084	1‘104
TOTAL ASSETS	**1‘132‘920**	**1‘003‘956**
LIABILITY		
Creditors	84‘748	15‘005
Input taxes on creditors	6‘650	0
KEZO	456‘196	435‘716
Sales tax	0	-29‘595
Transitory liabilities	85‘235	63‘208
Foundation capital	100‘000	100‘000
Project reserves	419‘621	235‘262
ANNUAL RESULT (PROJECT RESERVE)	**-19‘531**	**184‘359**
TOTAL LIABILITY	**1‘132‘920**	**1‘003‘956**

Activities 2013



ZAR Project	
2	**ULTRA-FINE BOTTOM ASH PROCESSING (0.1–0.7 MM)**
	Optimization
4	**THERMORECYCLING**
	Resh
	Mixed Plastic – electronic waste
	Contaminated substrate
5	**PRODUCT DEVELOPMENT / MARKETING**
	NF-heavy (1.0–5.0 mm)
	NF-metals (0.2–1.0 mm)
	Aluminium (0.2–1.0 mm)
	NF-metals / rare metals (0.2–1.0 mm)
8	**COARSE BOTTOM ASH**
	Trials on mineral triage
	Comminution trials on the landfill
	Basic engineering processing plant
	Iron processing
	Detail engineering processing plant
	Construction and commissioning
9	**CENTRAL BOTTOM ASH PROCESSING**
	Concept
	Logistics
	Unloading at the processing plant
10	**ANALYTICS**
	Sampling and processing
	State of the art
	Evaluation analytics (differences between metals and oxides)
11	**STATE OF THE ART**
	Evaluation state of the art
	Specification state of the art
12	**SEWAGE SLUDGE ASH**
	Further use of sewage sludge ash concentrated with phosphor
M1	**THE MINERAL PORTION IN THE BOTTOM ASH**
	Characterization and potential in mineralic bottom ash
	Product specification
	Product development
M2	**LANDFILL**
	Depositing behavior (laboratory tests)
	Forming potential of gas
	Eluate behavior
M3	**BUILDING MATERIALS**
	Cement trials (JuraCem)


1. QUARTER 2013
2. QUARTER 2013
3. QUARTER 2013
4. QUARTER 2013
1. QUARTER 2014

Caption

Title	ZAR Treatment Plant for Dry Bottom Ash Photo: Roger Strässle ©
4	NF precious metal fraction (1.0 – 5.0 mm)
5	Sieve Eddy Current Separator Feeding to separation tables
6	Metal Density Separator (MDS), Firma Liquisort, NL Wet, heavy fraction of NF precious fraction after separation with MDS
7	Rotating dividers Funnel for NF precious fraction 1.0–3.0 mm
8	3D-CAD-drawing of planned coarse bottom ash treatment plant
9	Washing of bottom ash in a cement mixer for sample production Sample container for XRF-analysis Cement samples (expansion behavior)
11	Mill for the grinding of the NF precious fraction < 0.1 mm (Analytical laboratories BACHEMA AG)
12	Eddy Current separator for very fine bottom ash
17	NF metals (0.2–1.0 mm) under a microscope
20	NF precious fraction 0.2–1.0 mm under the microscope
Rear side	Process diagram - Bottom ash treatment at KEZO (as at March 12)

FOUNDATION DEVELOPMENT CENTRE FOR SUSTAINABLE MANAGEMENT
OF RECYCLABLE WASTE AND RESOURCES

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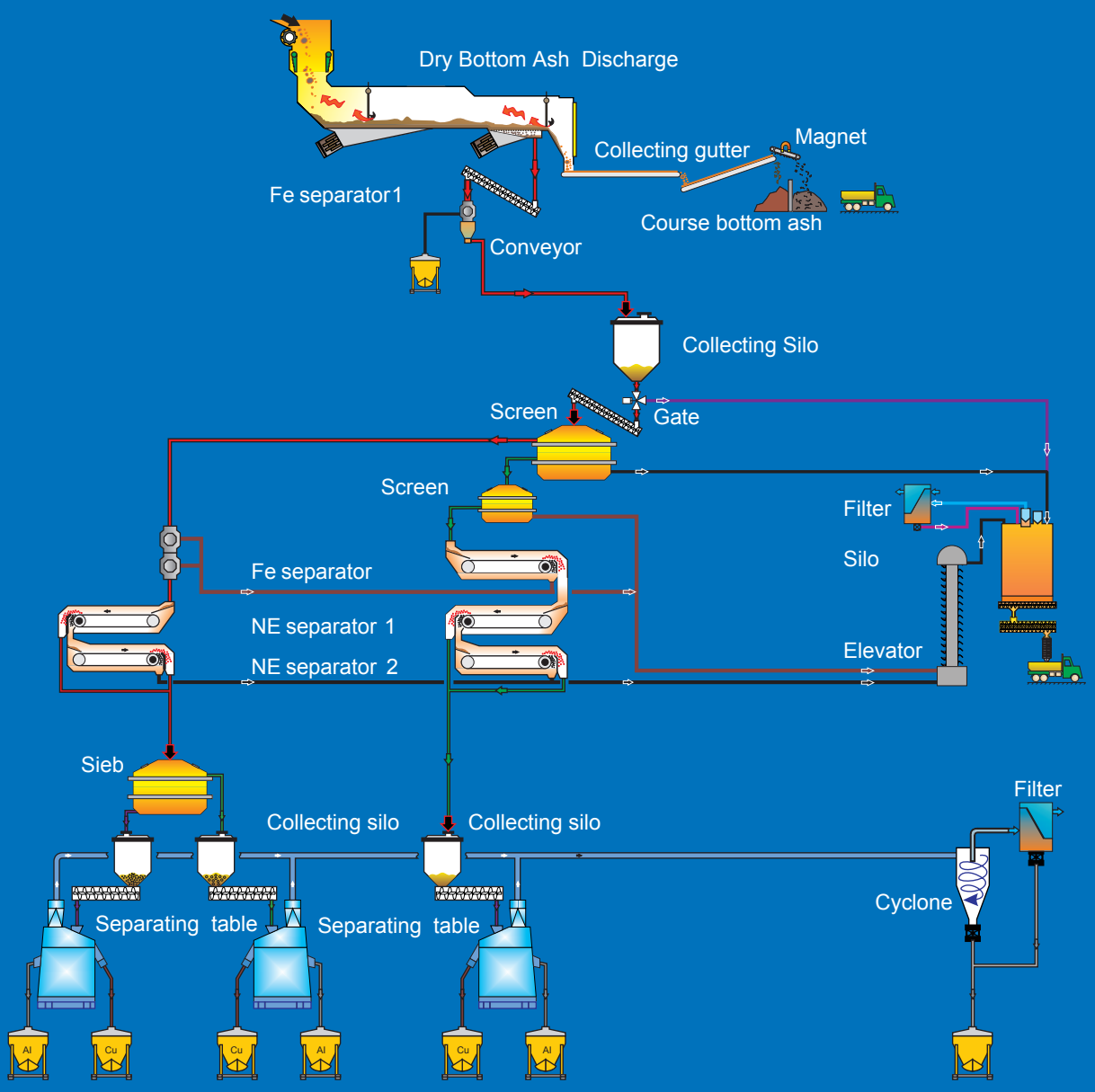
Dry Bottom Ash Discharge
Collecting gutter
Magnet
Fe separator1
Course bottom ash
Conveyor
Collecting Silo
Screen
Gate
Screen
Filter
Silo
Fe separator
NE separator 1
NE separator 2
Elevator
Sieb
Filter
Collecting silo
Collecting silo
Cyclone
Separating table
Separating table
Al
Cu
Cu
Al
Cu
Al