Welcome To

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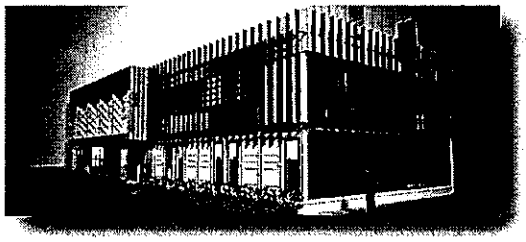
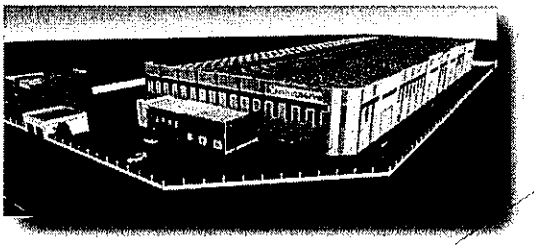
Saving the planet. Naturally.





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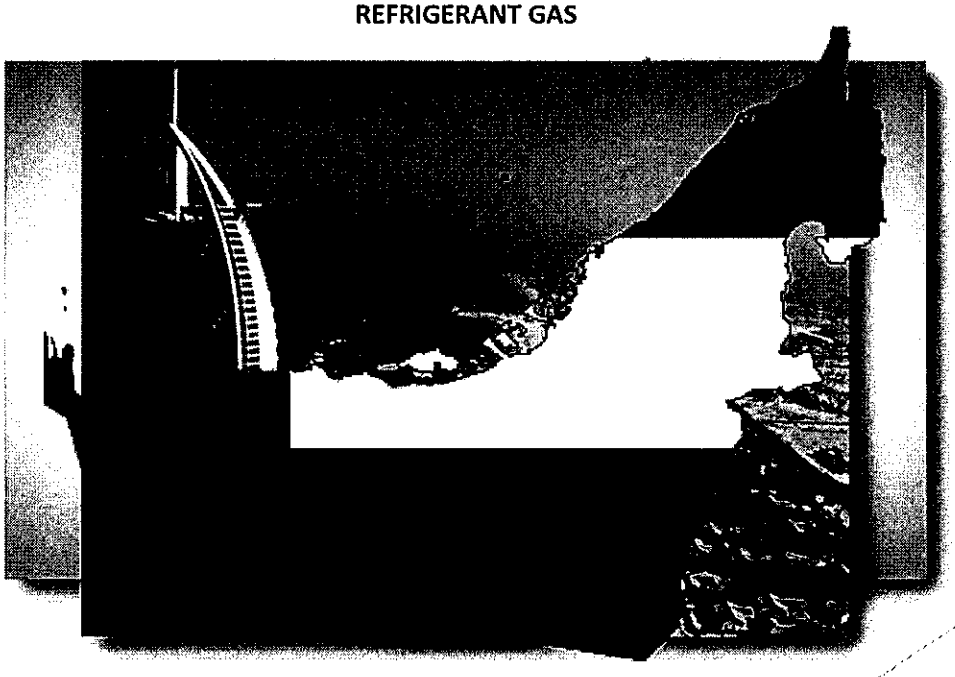
UAE
REFRIGERANT GAS



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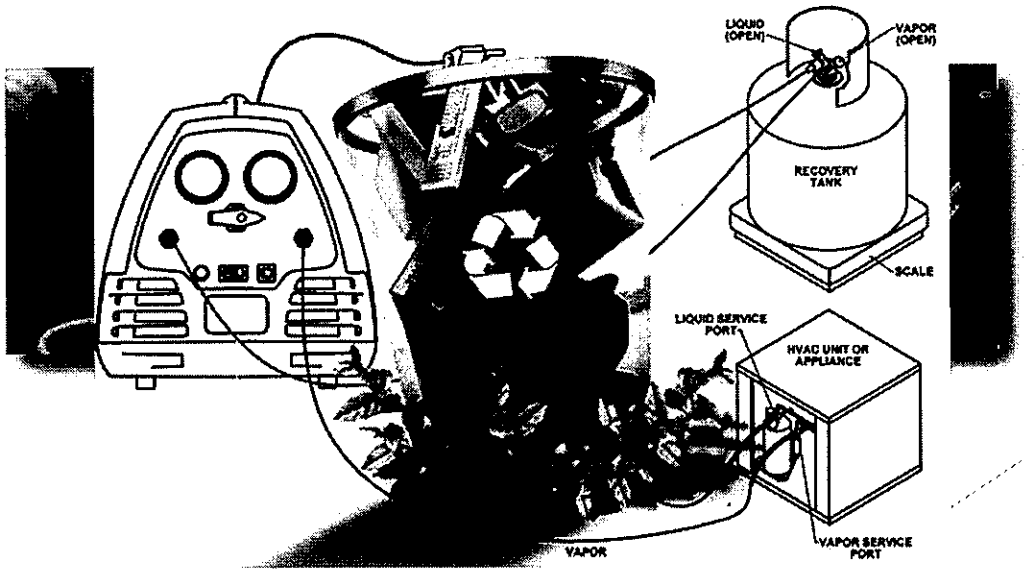
ELECTRONIC WASTE RECYCLING
REFRIGERANT GAS RECLAIMING



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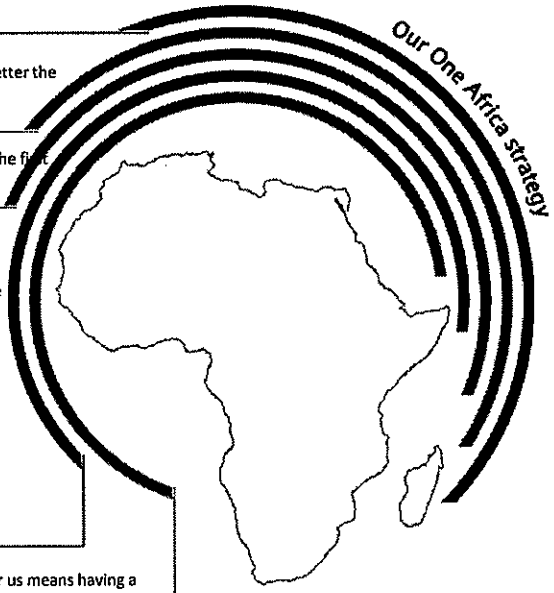

We are driven by our **Purpose** to better the environment in Africa

We are focused on our **Goal** to be the first choice for CSR services in Africa

Our Values define the way we think, work and act.

Respect	We respect and value those we work with and the contribution they make
Integrity	We act fairly, ethically and openly in all we do
Service	We put our customers and clients at the center of what we do
Excellence	We use our energy, skills, and resources to deliver the best sustainable result
Stewardship	We are passionate about leaving things better than we found them

We committed to **Change** which for us means having a positive impact on the environment and delivering a positive change to Africa

Our spread over 3 regions provides a holistic Balance which enables us to deliver a different kind of service to not only our customers but to all individuals

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AFRICA

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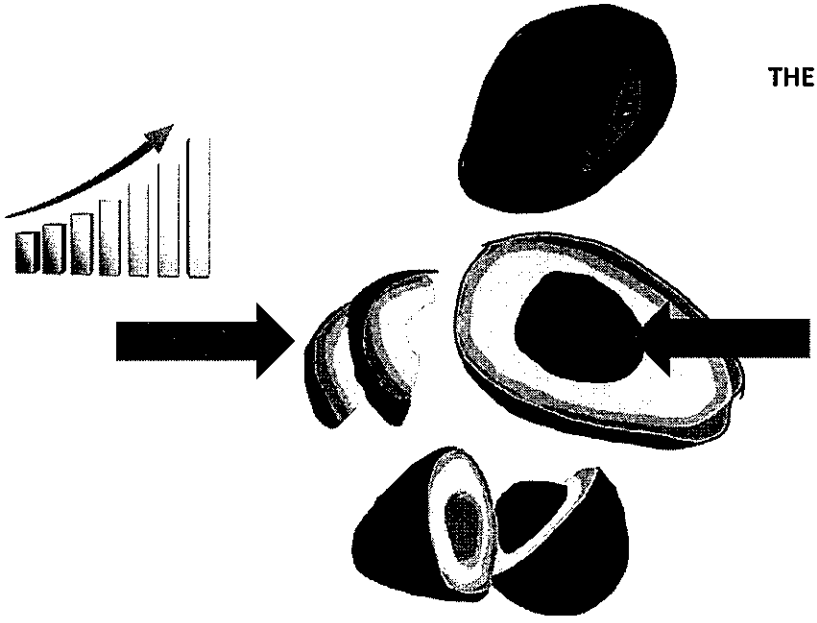
THE AVOCADO THEORY



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CSR & THE MIDDE EAST

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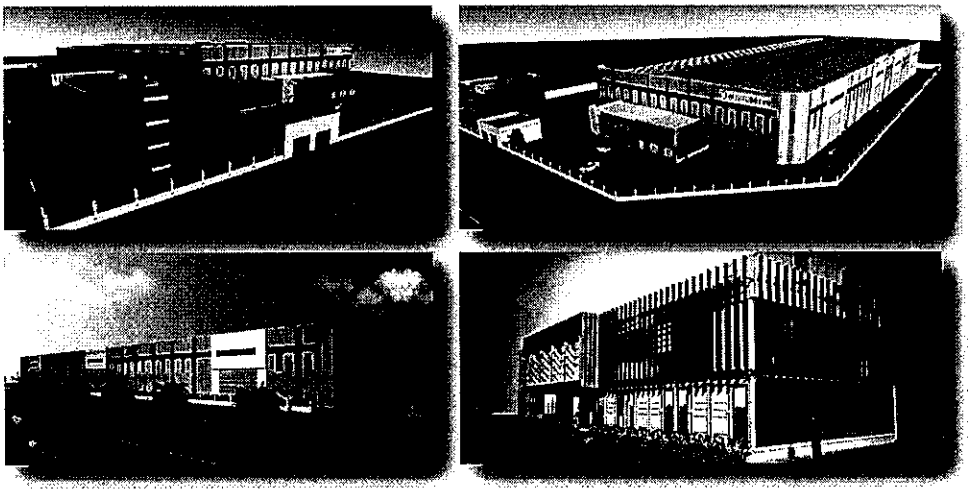
THE RECYCLING HUB



- FIRST OF ITS KIND IN MIDDLE EAST
- DUBAI INDUSTRIAL PARK
- COMPLETION APRIL 2018
- 39.000 TONS ANNUALLY
- ZERO LIQUID AND AIR EMISSION

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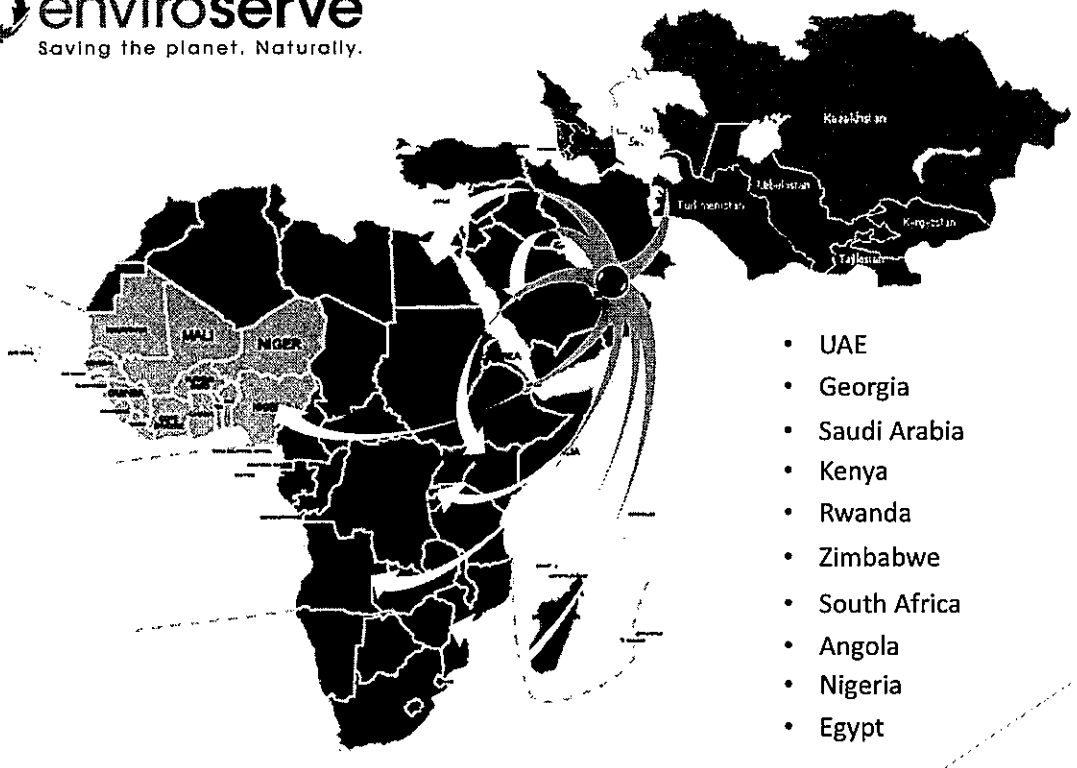

- UAE
- Georgia
- Saudi Arabia
- Kenya
- Rwanda
- Zimbabwe
- South Africa
- Angola
- Nigeria
- Egypt

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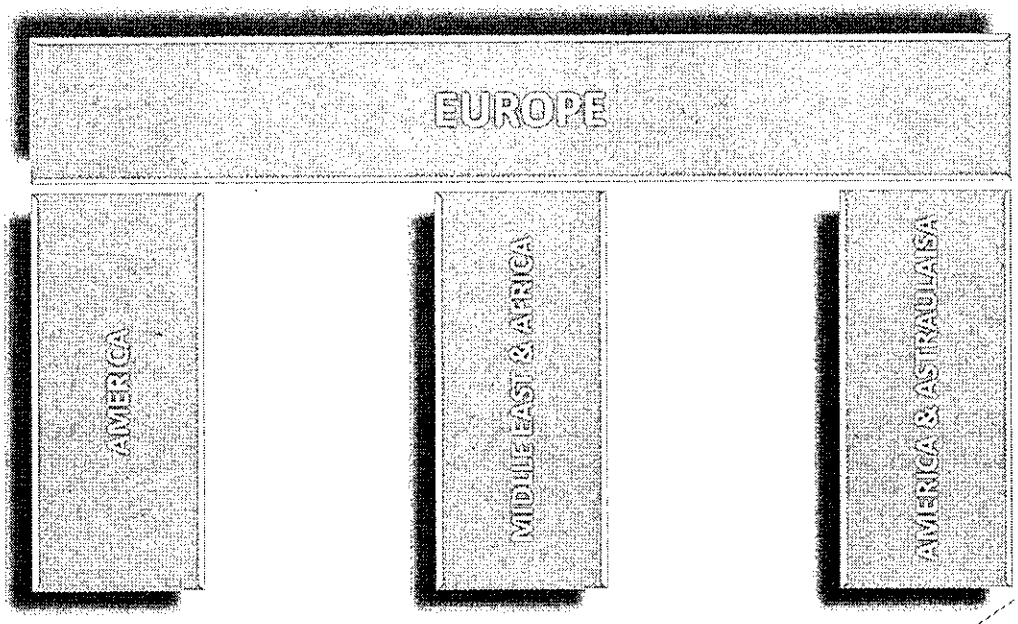
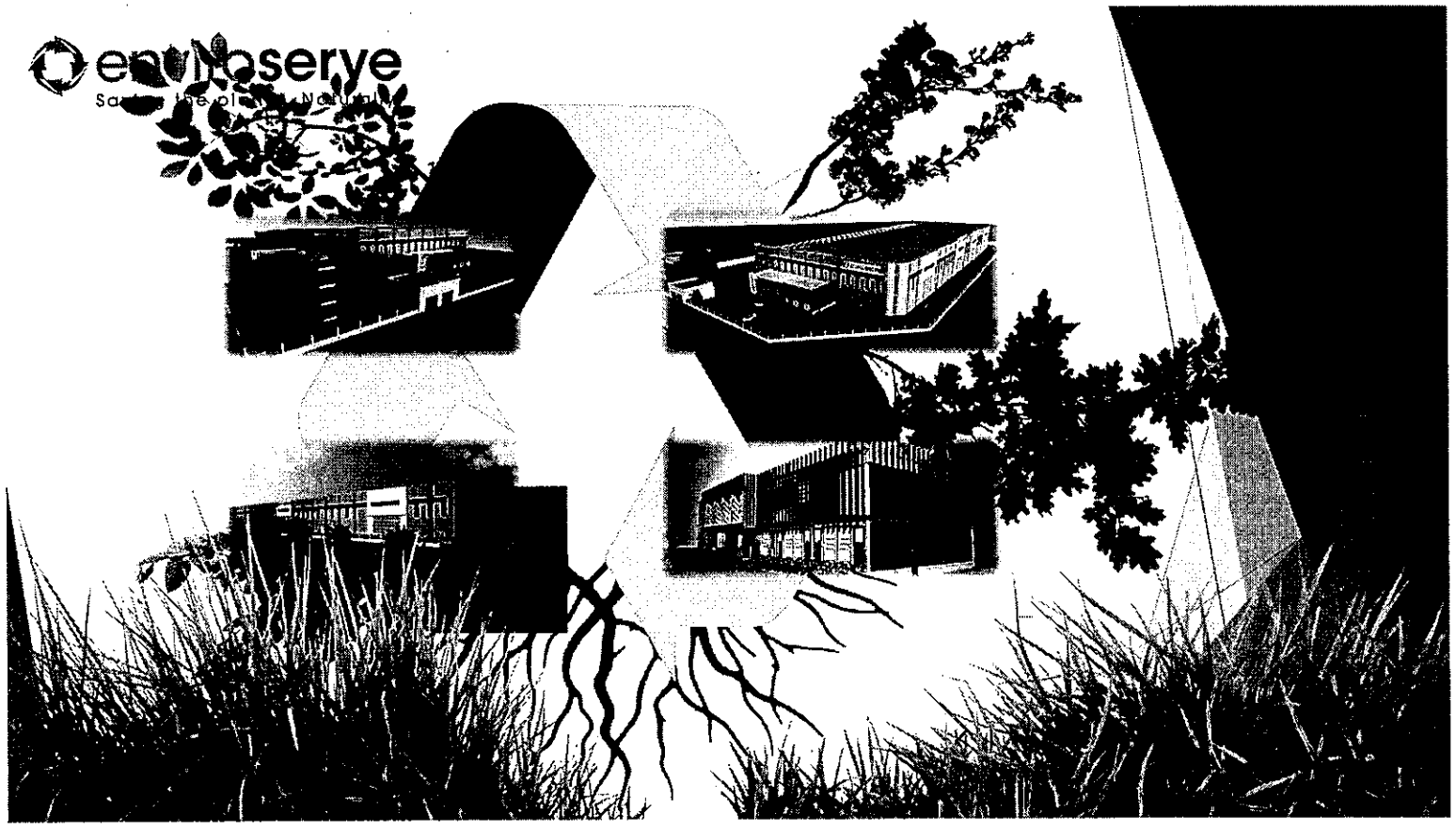




THANK YOU!

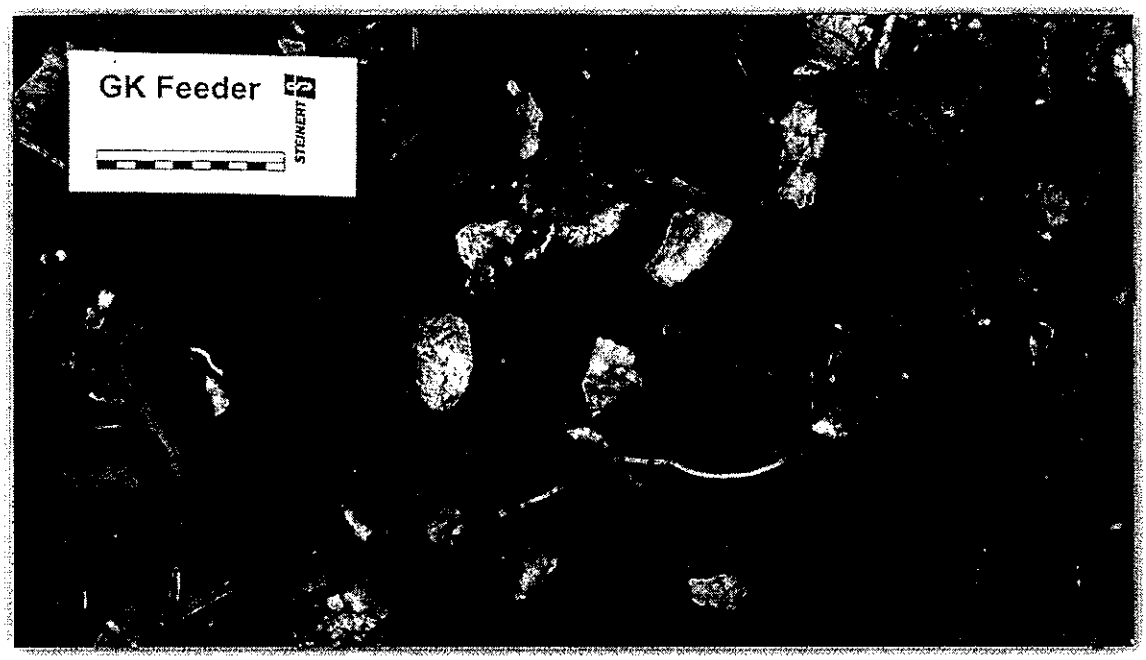
SAVE THE PLANET. NATURALLY.

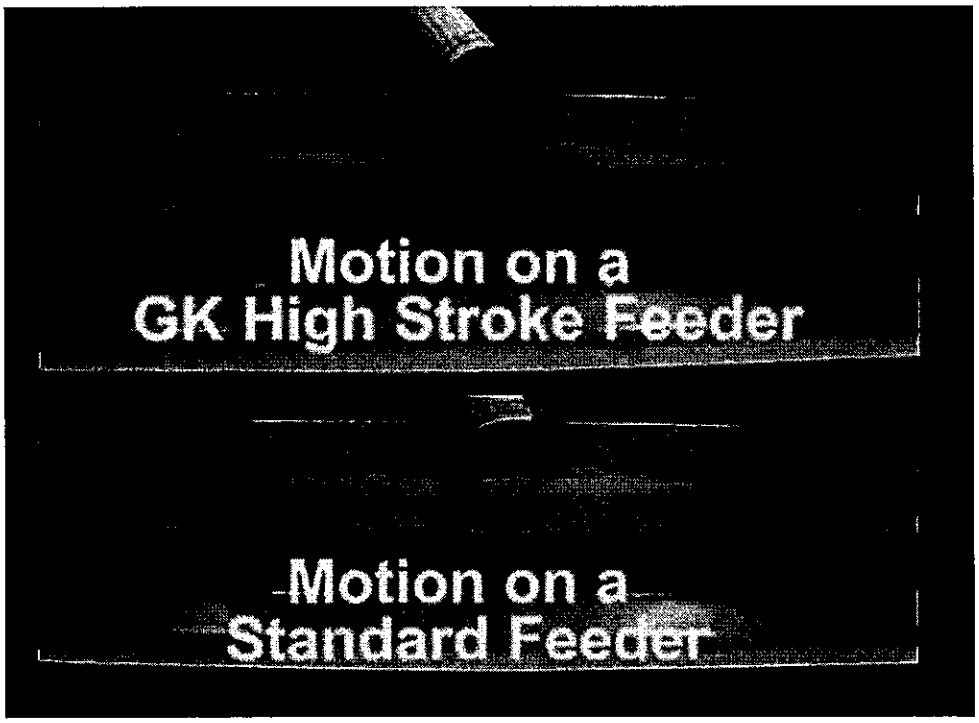
GENERAL KINEMATICS®

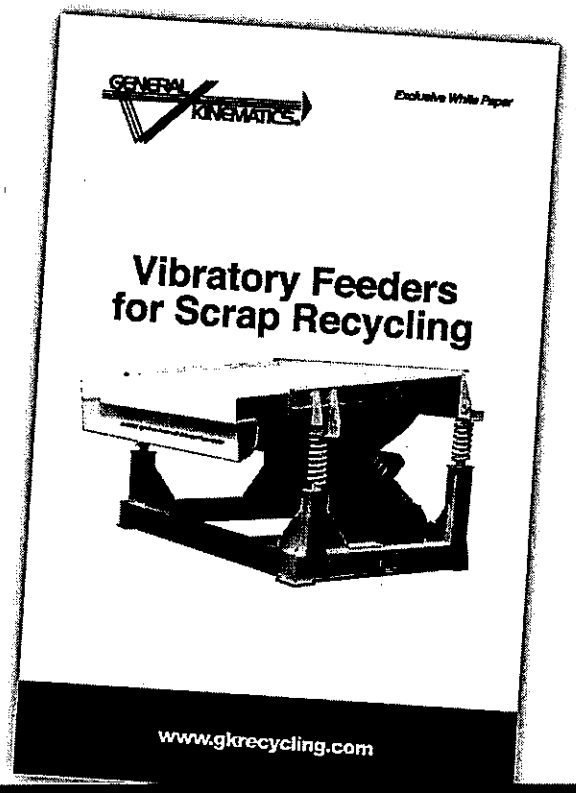
Increasing Purity of Non-Ferrous Scrap by using a Vibratory Feeder

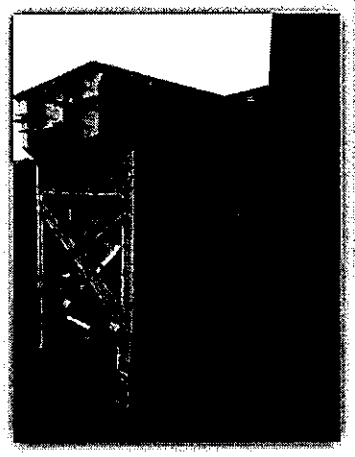
Dick Reeves
Director, Resource Recovery

GENERAL KINEMATICS®

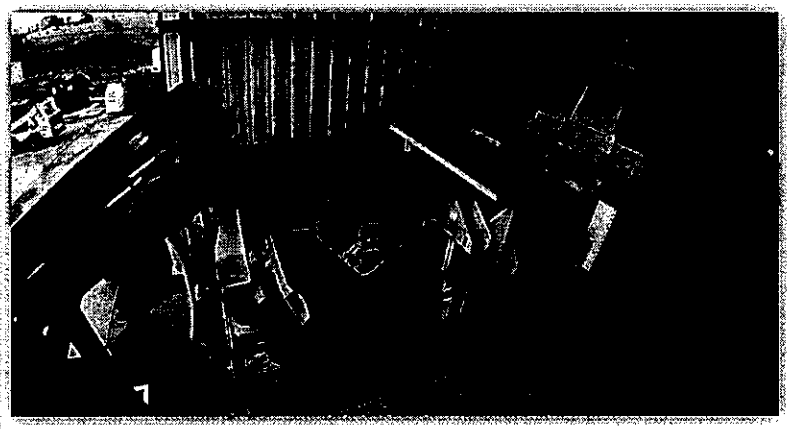



Motion on a
GK High Stroke Feeder
Motion on a
Standard Feeder


Exclusive White Paper
Vibratory Feeders
for Scrap Recycling
www.gkrecycling.com



Metering Feeder & Hopper



High Stroke Feeder & KSS Sorter

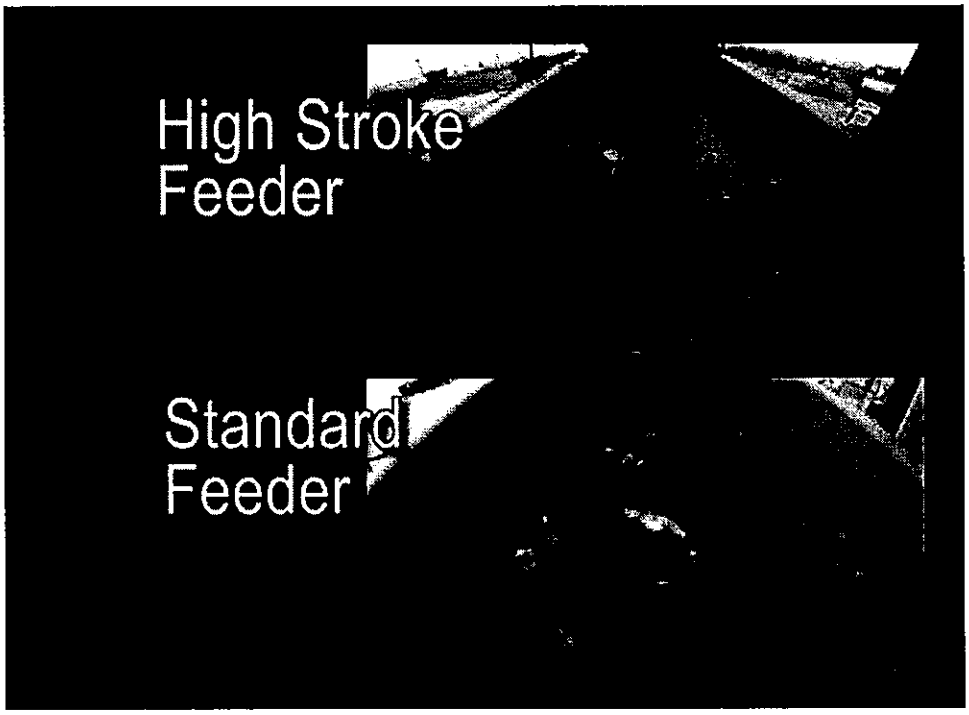
US R&D Lab

Old Feeder

Positive Weight	Positive % of total	Negative Weight	Negative % of total	PSI of Hopper	Purity of Positive
27 lbs.	17.6	126 lbs.	82.4	20	70%
27 lbs.	18.6	118 lbs.	81.4	40	40%
30 lbs	26.3	113 lbs.	73.7	60	48%

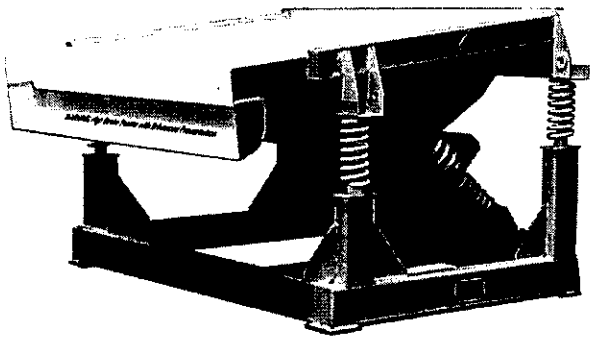
General Kinematics HSF

Positive Weight	Positive % of total	Negative Weight	Negative % of total	PSI of Hopper	Purity of Positive
21 lbs.	14.6	117 lbs.	85.4	20	74%
21 lbs.	16.5	106 lbs.	83.5	40	45%
19 lbs	15.7	102 lbs.	84.3	60	55%



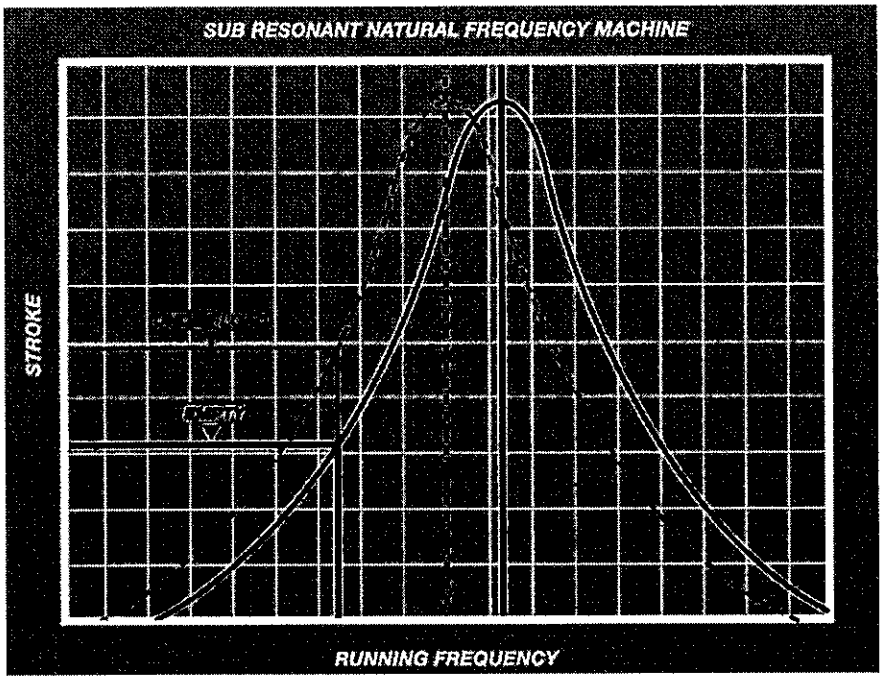
High Stroke + High G's =
Enhanced Metal Presentation

Two Mass, Natural Frequency
Small Exciter Force (HP)
Amplified with Springs
Uniform Stroke
Compensating Stroke with Load



$$Equation: NF = C \times \sqrt{(\frac{K_{eff}}{M_{eff}})}$$

NF	=	Natural Frequency
C	=	Constant
K_{eff}	=	Effective Spring Rate
M_{eff}	=	Effective Mass



TPH	% Metal	Lbs/hour	$/lbs	$/hour	Hours Week	Weeks Year	$/year
10	3%	600	$ 0.01	$ 6.00	40	52	$ 12,480.00

TPH	% Metal	Lbs/hour	$/lbs	$/hour	Hours Week	Weeks Year	$/year
10	3%	600	$ 0.05	$ 30.00	40	52	$ 62,400.00

Thank You

Recycling division ♻
Hellatron
Innovation driven

"Sorting of Exhausted Batteries & Alkaline and Zinc-Carbon Battery Recycling"

What we do

ENVIRONMENTAL OPERATOR – we run plants for key waste categories.

SOLUTION PROVIDER – we develop solutions, technology and processes, on our own or with business partners, to address key environmental issues.

COMMERCIAL COMPANY – we sell consulting services, technology and operational support for companies active in the environmental field.

The mind set

"PROBLEM" → **"OPPORTUNITY"**

- **FULLY UTILIZATION OF THE RESOURCES AVAILABLE**
- **CLOSED LOOP SOLUTIONS**
- **SUPERIOR ENVIRONMENTAL PERFORMANCE**
- **CONTINUOUS INNOVATION**

"AN INNOVATION DRIVEN COMPANY"

Related companies and partners

EVH S.r.l.

Recycling division Hellatron Innovation driven

RACYCLE

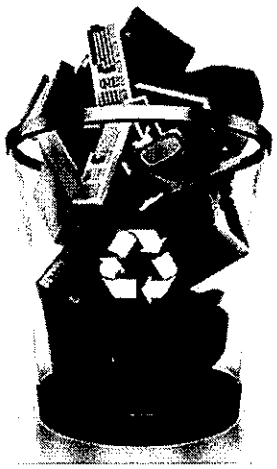
CHRYSOPOEIA

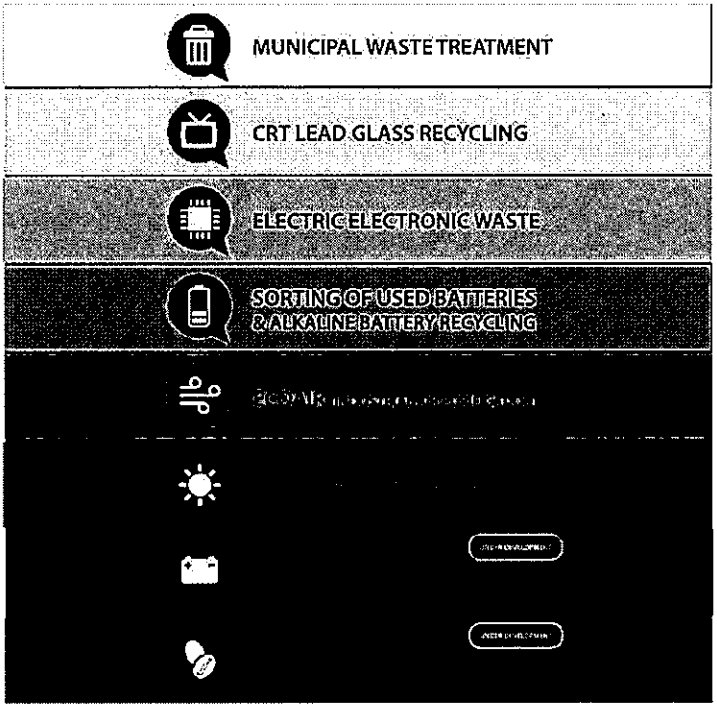
COMPTON S.R.L. TECNOLOGIE PER IL RICICLAGGIO DEI RIFIUTI

NC TECHNOLOGIES Committed to Sustainability

A TEC World Leader in Cement Pyroprocess Technology

Our solutions





Introduction

Sorting of exhausted batteries, Alkaline & Zinc-carbon batteries recycling

- ❑ Alkaline
- ❑ Zinc-carbon
- ❑ Lithium-Ion
- ❑ Ni/Mh
- ❑ Ni/Cd
- ❑ Button cells
- ❑ Dry lead batteries

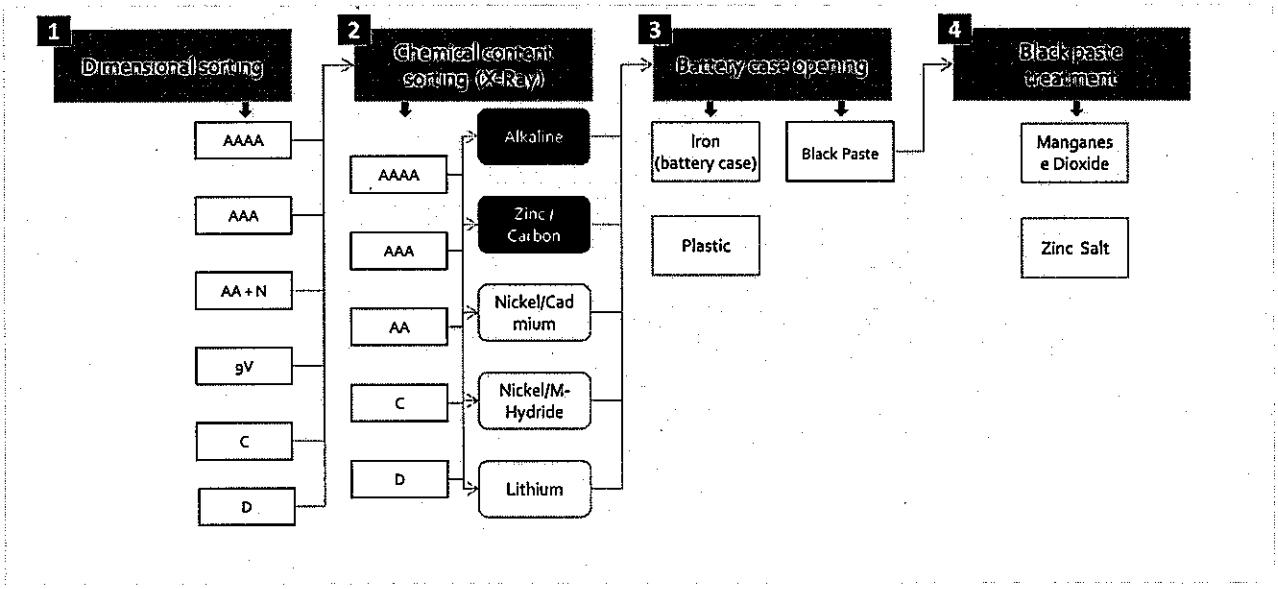
Introduction

From the basics to an Industrial process - some of the questions to be answered:

- What kind of batteries we collect today?
- How we should sort the batteries being collected?
- How to achieve accuracy on the sorting process?
- What types of batteries are we willing to recycle in house?
- How can we get a "pure" black paste?
- How can we treat the black paste in order to maximize the material recovery?

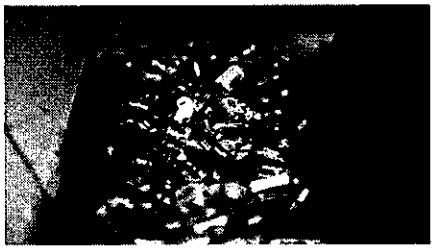
Process Flow

Overall Process Flow:



Sorting of used batteries – 1st treatment step

Dimensional Sorting - Sample images:



Sorting of used batteries – 1st treatment step

Dimensional Sorting - Sample images:

Sorting of exhausted batteries & Alkaline and Zinc-Carbon batteries recycling

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Sorting of used batteries – 2nd treatment step

Chemical type sorting - Sample images:

Sorting of exhausted batteries & Alkaline and Zinc-Carbon batteries recycling

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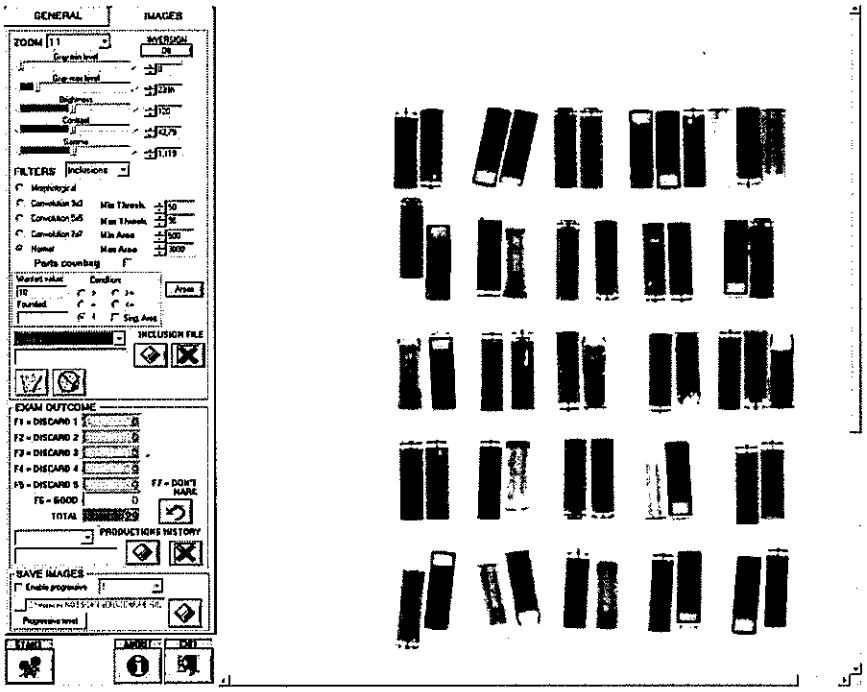
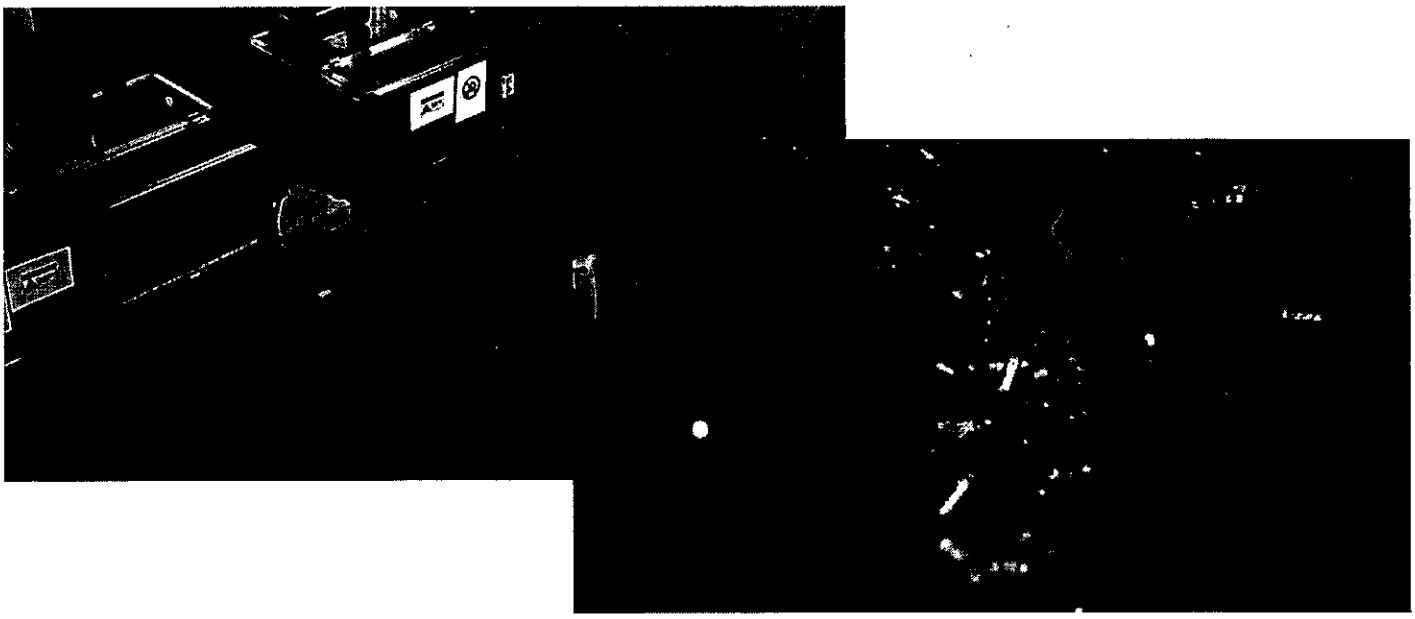
Sorting of used batteries – 2nd treatment step

Chemical type sorting - Sample image: X ray scanning sample



Alkaline and Zinc-Carbon batteries recycling – 3rd treatment step

Mechanical treatment - Sample image:



Alkaline and Zinc-Carbon batteries recycling – 3rd treatment step

Mechanical treatment - Sample image:

- Iron with less than 2% impurities
- Black Paste

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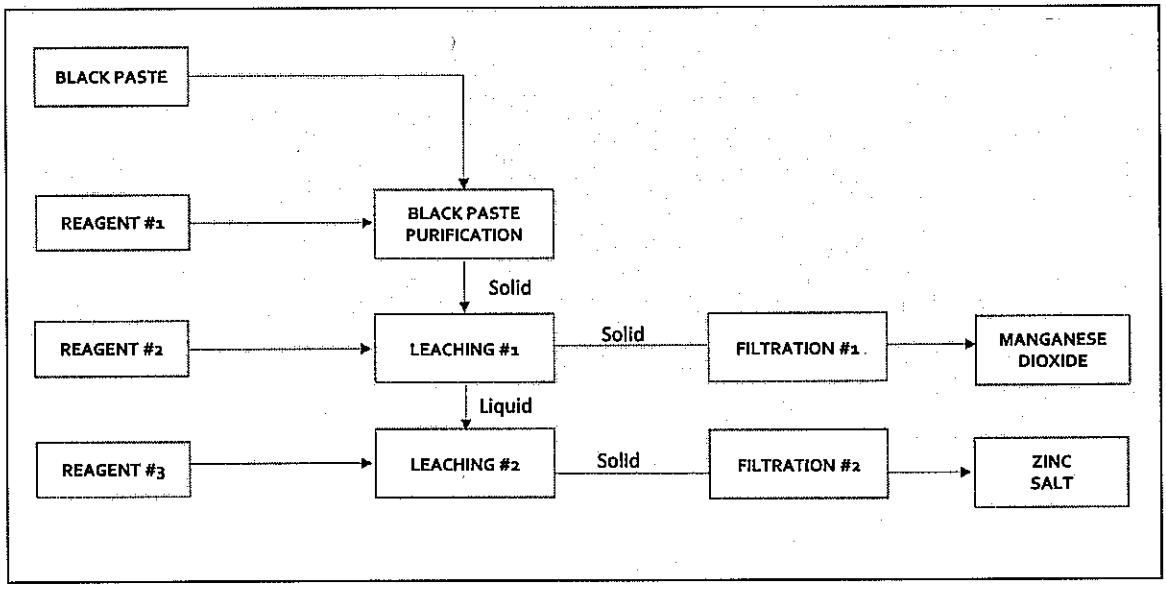
Alkaline and Zinc-Carbon batteries recycling – 4th treatment step

Chemical treatment - Flowchart:



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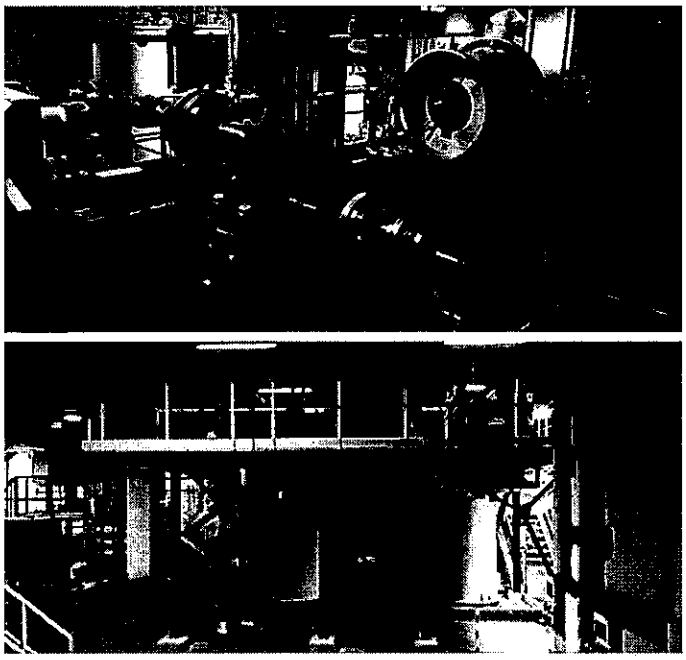
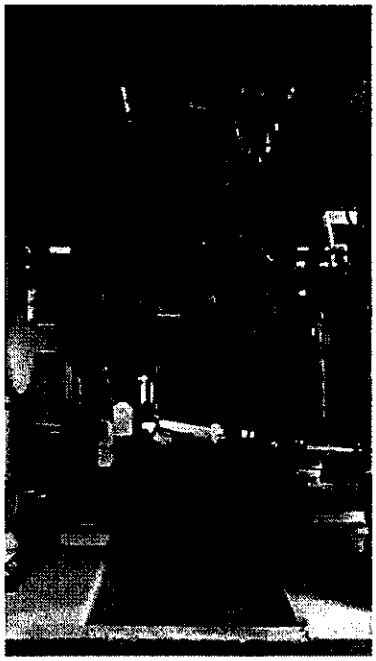
Alkaline and Zinc-Carbon batteries recycling – 4th treatment step

Chemical treatment - Sample images:





Sorting of exhausted batteries & Alkaline and Zinc-Carbon batteries recycling

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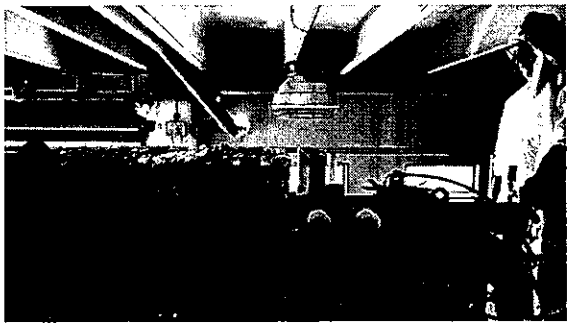
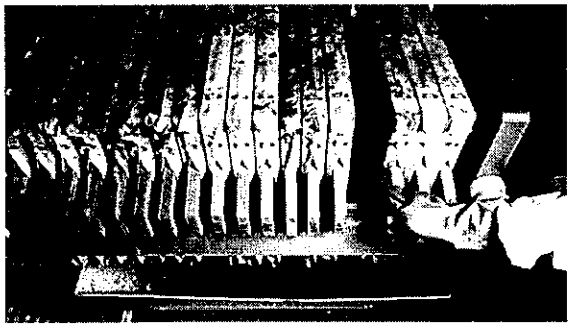
Alkaline and Zinc-Carbon batteries recycling – 4th treatment step

Chemical treatment - Sample images:





- Manganese Dioxide

Sorting of exhausted batteries & Alkaline and Zinc-Carbon batteries recycling

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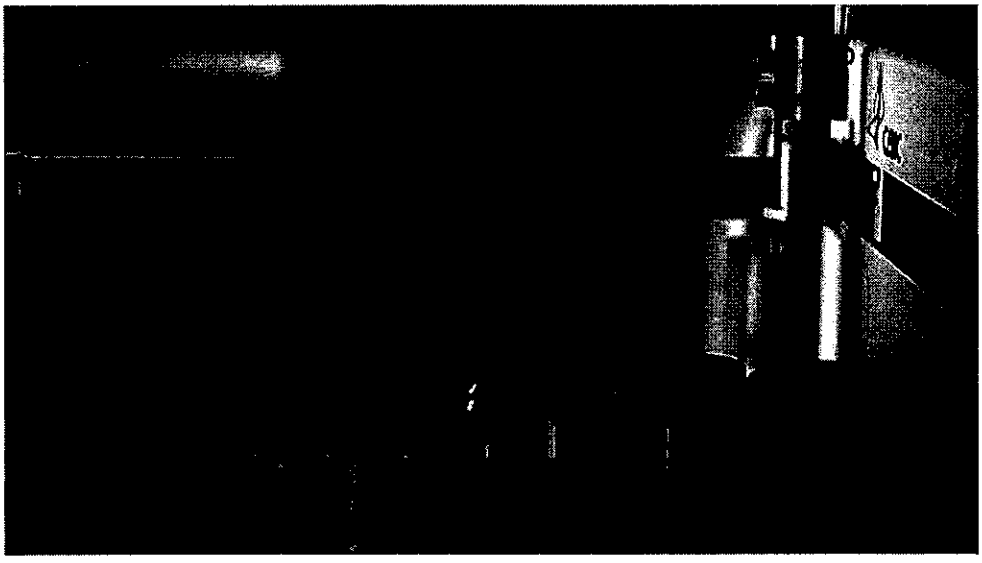
Alkaline and Zinc-Carbon batteries recycling – 4th treatment step

Chemical treatment - Sample images:

- Zinc Salt

Alkaline and Zinc-Carbon batteries recycling – 4th treatment step

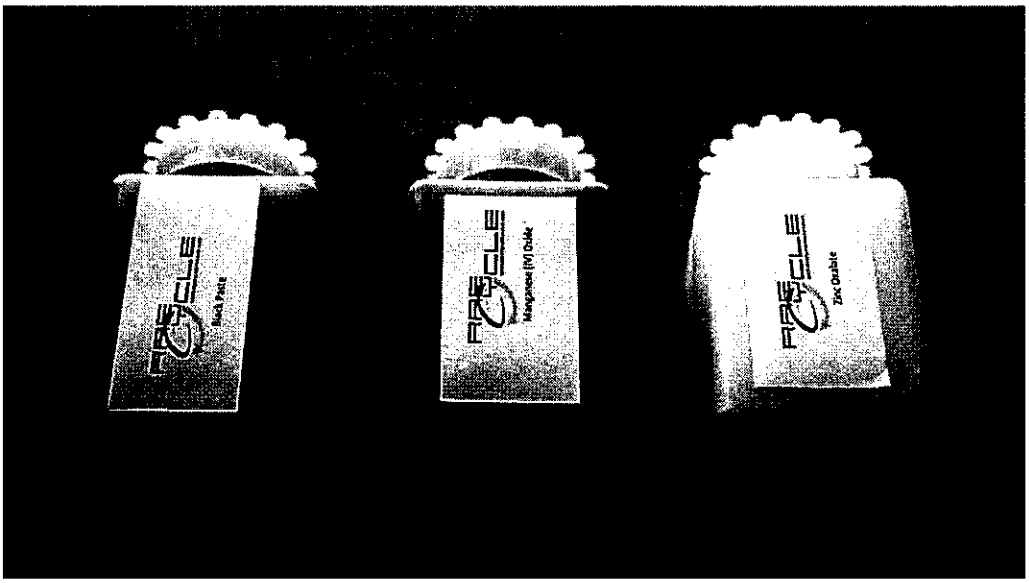
Chemical treatment - Sample images:



- Strong Quality control
- On line-real time analysis of the outgoing materials
- On site Hi-Tech Laboratory

Alkaline and Zinc-Carbon batteries recycling – 4th treatment step

Chemical treatment - Sample images:



Summary

- Automated sorting of chemical content of the batteries.
- Innovative "Smart cut" of the battery case.
- Cold-hydrometallurgical process for Alkaline and Zinc-Carbon batteries treatment.
- Flexible process, made by several phases and modules that are used or not depending on the material that needs to be produced.
- Recovery of important raw materials:
  - Zinc Salt;
  - Manganese Dioxide.

We have your SOLUTION

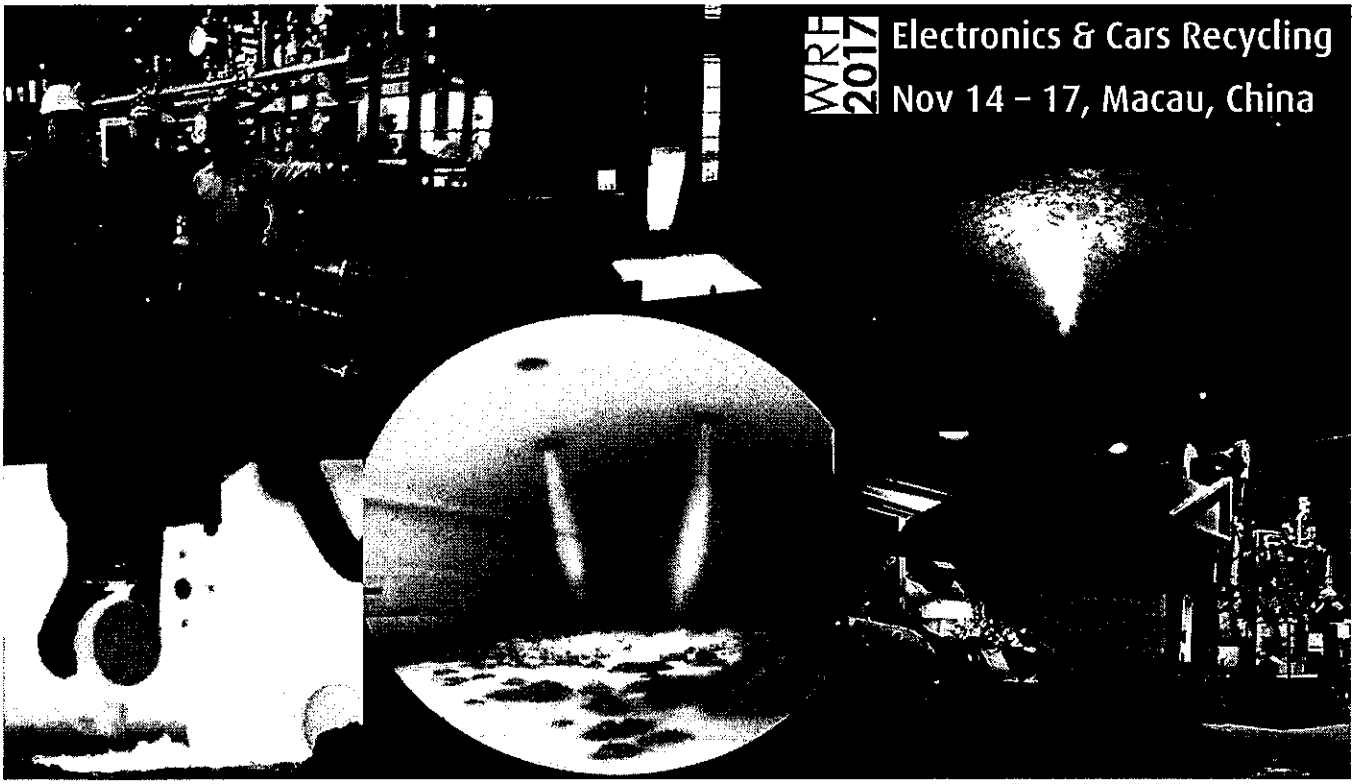
For any questions please contact

Recycling division ♻

Hellatron

Innovation driven

Mail: recycling.division@hellatron.it
Tel. +39-02-99.76.011



Technologies to Save Energy and Reduce Emissions in Metal Recycling Industries

Dr. Joachim von Schéele
Head of Steel, Metals & Glass – Asia Pacific

THE LINDE GROUP
Linde

Outline

asiaONE

THE LINDE GROUP
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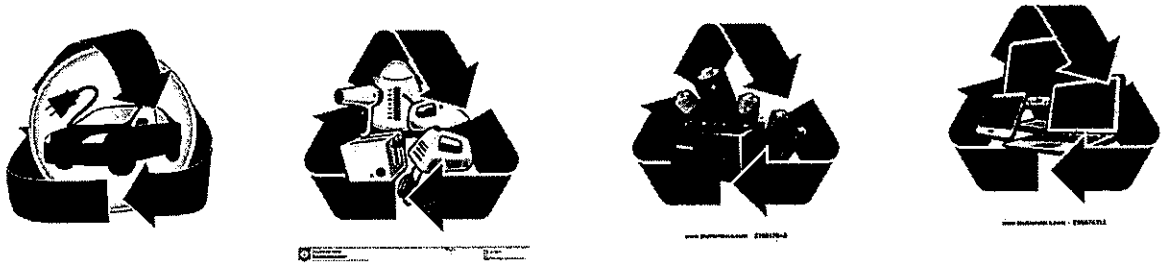
1. Background and Technologies
2. Examples at Steel and Iron Recycling
3. Examples at Non Ferrous (Cu/Al/Pb) Recycling
4. Examples at Glass Recycling
5. Summary

Background: Circular Economy

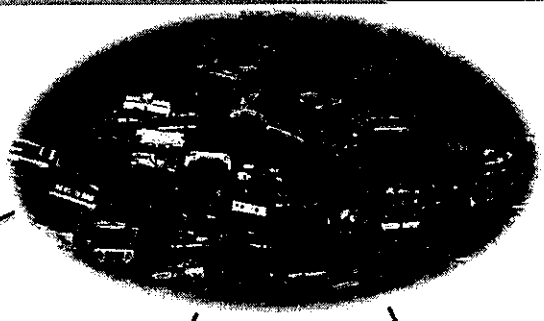
- Raw materials will likely become more challenging in the future.
- End-of-life vehicles and electric waste have received a widespread attention.
- More than 10 million cars need to be recycled in 2020 in China only.
- More than 70 million tonnes waste electrics are generated, growing 20% annually.
- Most of the world waste electrics will be recycled in APAC.
- **These trend offers a largely increase supply for the recycling industry.**



Background: Sustainable Resources for Metals production

"Urban Mining"
"Circular Economy"

Linde Oxyfuel
Melting Technologies

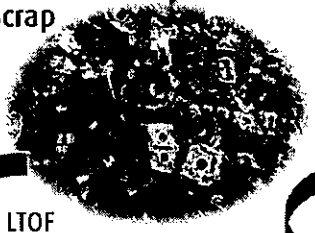


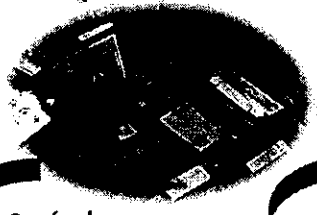
Steel Scrap

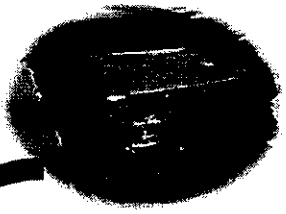
Aluminum Scrap

Waste Batteries

Glass Scrap





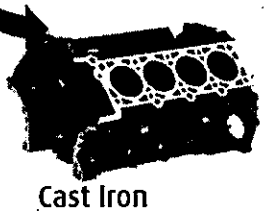


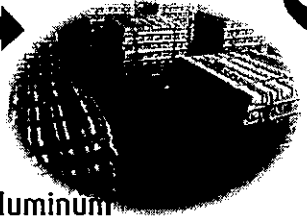
HIGHJET TDI

LTOF

Oxyfuel

CGM





Cast Iron

Aluminum

Lead

Glass Fiber

1. Background and Technologies

- The combustion processes in the heavy industries area are a large user of energy and source of emissions. Those are mainly applied for heating, melting smelting, and reheating of the materials being produced.
- There was more than 120,000 industrial furnaces in operation in China.
- The energy use in industrial furnaces accounts for more than 25% of the total energy use in China, and more than 60% of energy use in industry.
- Steel, Non Ferrous Metals, Foundry, Cement, and Glass industries are the main energy users.

<u>There are two main ways to Save Energy and Reduce Emissions</u>

- The Direct way: The most efficient short-term ways to save energy and decrease emissions are to minimize the need and generation, respectively.
- The Indirect Way: energy recycling and post treatment to remove CO_2, NO_X, SO_X, etc., e.g., using SCR/SNCR/LowTOx

1. Background and Technologies

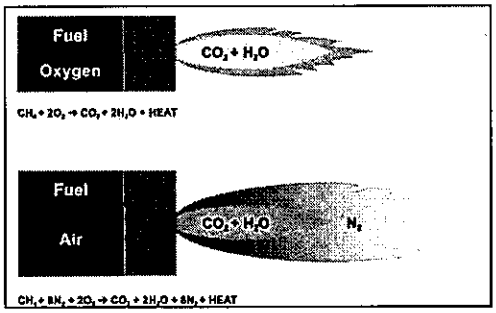
- It has been proven that the need for energy in many of these processes can be reduced by 20-50% by applying different types of oxyfuel combustion.
- Reduction of CO_2 emissions will follow the reduced energy need.

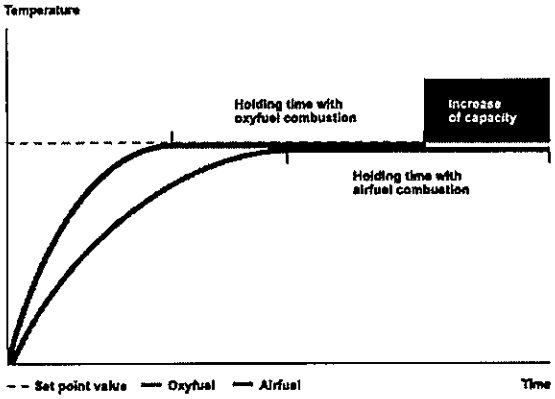
- Also other emissions can be reduced, like NO_X and SO_X.
- A special combustion technology called flameless oxyfuel is very efficient to reduce NO_X emissions.
- Linde has pioneered the development and implementation of flameless oxyfuel technology in the steel and aluminum industries.

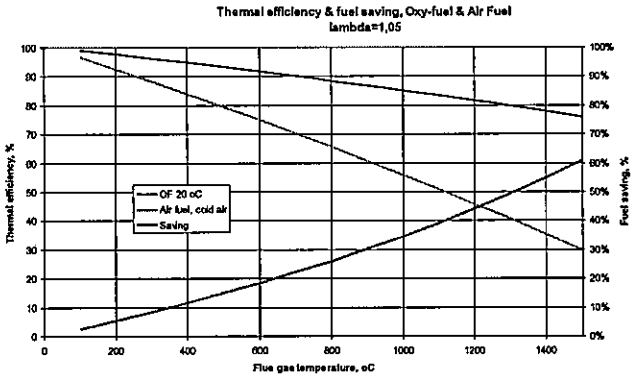
- The presentation will give an overview of efficient use of oxyfuel and results obtained in numerous installations throughout the steel, non ferrous, and iron foundry industries.

1. Background and Technologies
Oxyfuel Solutions, Energy Efficiency

1. No nitrogen in
2. No nitrogen out
3. Radiation
4. Lower flue-gas velocity







1. Background and Technologies
Conventional Oxyfuel vs. Flameless Oxyfuel

Conventional oxyfuel

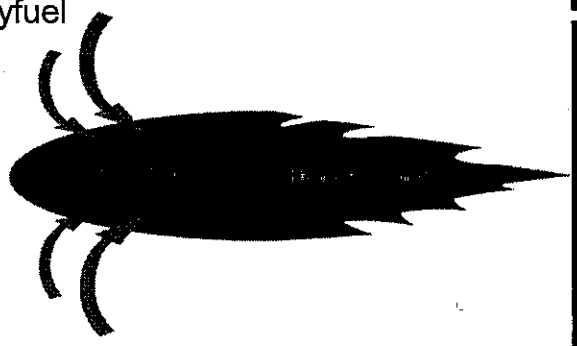
Fuel
Oxygen

CO_2 H_2O

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + HEAT$

Flameless oxyfuel

Fuel
Oxygen

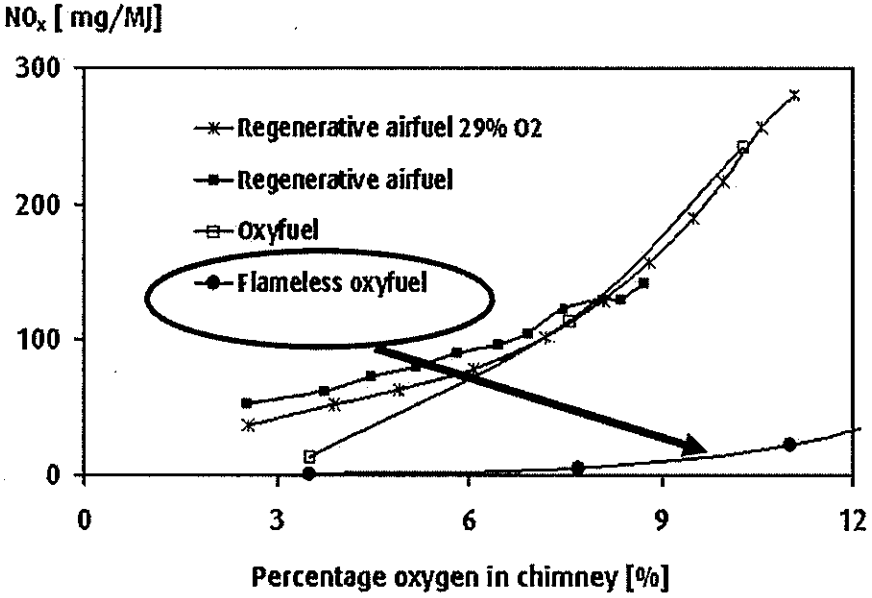


$CH_4 + 2O_2$ + Hot furnace gases $\rightarrow CO_2 + 2H_2O + HEAT$

Flameless Oxyfuel
90% Lower NOx Emissions

Measured NO_x, data from evaluation by KTH（瑞典皇家理工学院）

NOx levels not sensitive to in-leakage of air



2. Examples from the Steel industry
REBOX® Flameless Oxyfuel

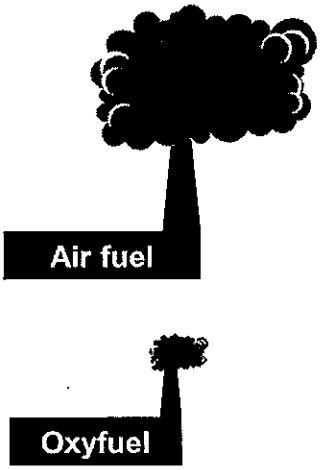
Installations of REBOX Oxyfuel Solutions in Steel Reheating Have Resulted in:

- Fuel Savings of up to 50% (some cases 65%)
- Reduction of CO_2 Emission by up to 50%
- Substantial reduction of NO_x Emission
- Capacity Increase by up to 50%
- Improved temperature uniformity, max. +/-10°C
- Decrease of Scaling Losses by up to 50%

Total Energy Requirement Comparison

		Air-fuel	Air-fuel with recuperator	REBOX® oxyfuel
Enthalpy in steel	kWh/t	200	200	200
Transmission losses	kWh/t	10	10	10
Flue-gas enthalpy	kWh/t	290	155*	50
Flue-gas temperature	°C	1,200	850	1,200
Air preheating	°C	20	450	20
Thermal efficiency	%	42	60	80
Energy need	kWh/t	500	365	260
Energy need	GJ/t	1.8	1.33	0.94
Oxygen production	kWh/t			25

*after recuperation

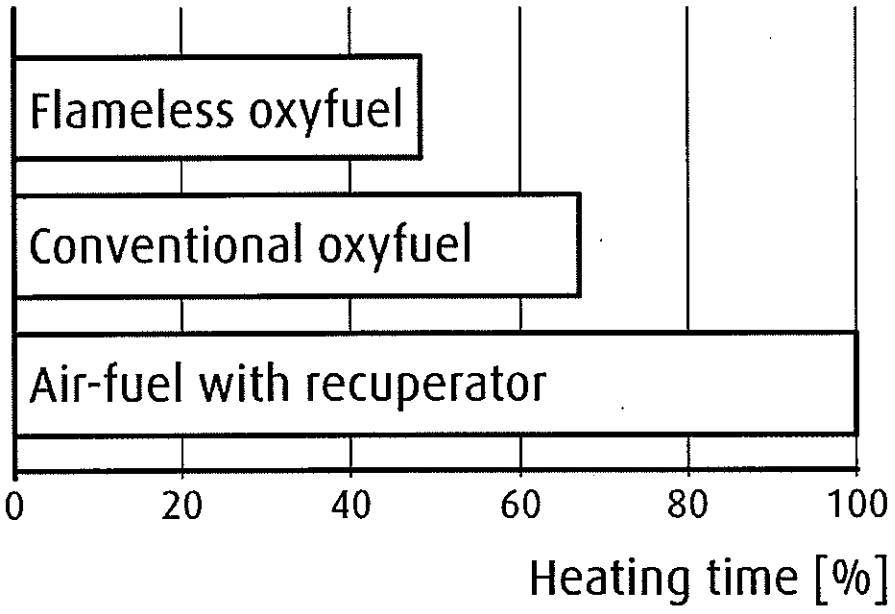


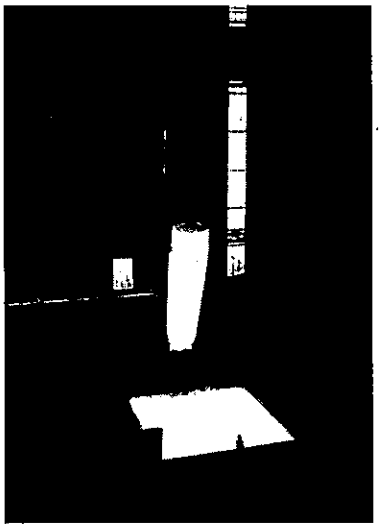
70-80% Less Flue Gas

Low flue-gas velocity, gives high effeciency

Reduced Emmissions

2. Examples from the Steel industry





Comparison of total heating time at Ovako's Hofors Works, Sweden, using different combustion technologies in Soaking Pit and Rotary Hearth Furnaces.

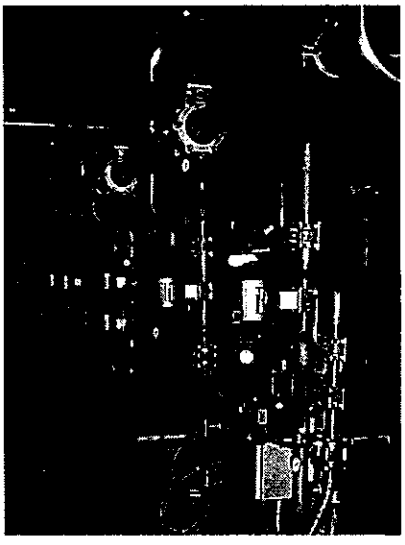
2. Examples from the Steel Industry
150+ REBOX® Oxyfuel Installations at 30+ Steel Mills Across the World

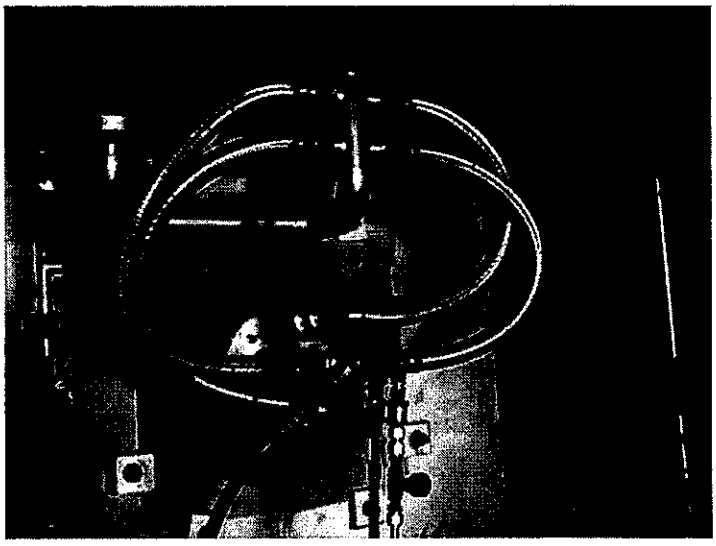
ArcelorMittal, Galati (RO)
ArcelorMittal, Shelby (US)
Ascométal, Les Dunes (FR)
Ascométal, Fos-sur-Mer (FR)
Brach, Bremen (DE)
Buderus, Wetzlar (DE)
Dongbei Special Steel, Dalian (CN)
Ellwood City Forge, Ellwood City (US)
Evraz Steel, Claymont (US)
Jindal SAW, Nashik (IN)
Kalyani Carpenter Special Steels, Pune (IN)
Mahindra Sanyo Special Steel, Khopoli (IN)
Michigan Seamless Tube, South Lyon (US)
North American Forgemasters, New Castle (US)
Outokumpu, Avesta (SE)
Outokumpu, Degerfors (SE)
Outokumpu, Nyby (SE)
Outokumpu, Tornio (FI)
Ovako, Hofors (SE)
Ovako, Smedjebacken (SE)
POSCO, Pohang (KR)
Salzgitter Flachstahl, Salzgitter (DE)
Sandvik Materials Technology, Sandviken (SE)
Scana Steel, Björneborg (SE)
Siam Yamato Steel, Rayong (TH)
SSAB, Borlänge (SE)
Tayo Rolls (Tata Group), Jamshedpur (IN)
ThyssenKrupp Steel, Bruckhausen (DE)
ThyssenKrupp Steel, Finnentrop (DE)
Yongxin Stainless Steel, Huzhou, China (CN)

2. Examples from the Steel industry
REBOX® installations at Outokumpu, Sweden

Catenary furnace at Outokumpu, Avesta (Sweden).
Conversion into all flameless oxyfuel operation.

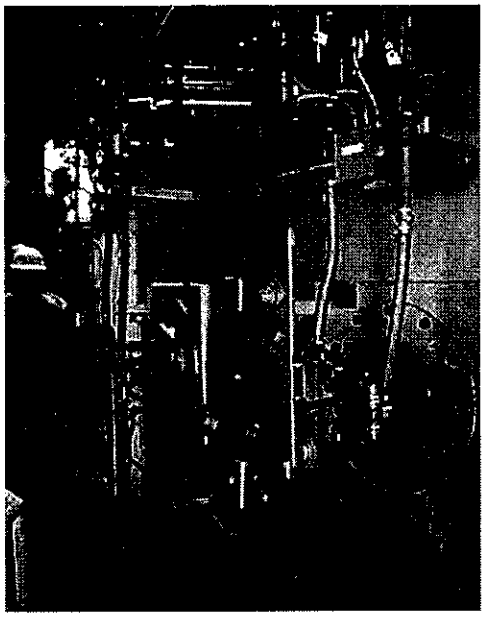
40 MW Flameless Oxyfuel; Capacity 150 tph



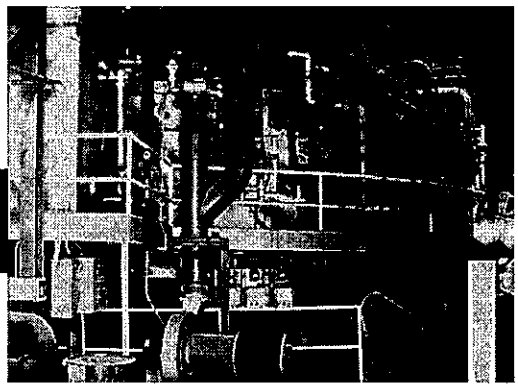


2. Examples from the Steel industry
ArcelorMittal Shelby, Ohio, USA

>50% Fuel Savings
>50% Less CO2 Emission!
AIST Energy Award



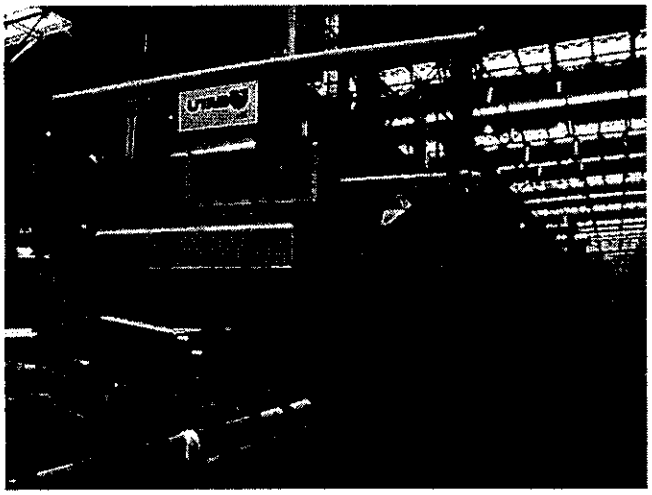
Before;
Air-fuel



After;
REBOX

2. Examples from the Steel industry
Dongbei Special Steel, Dalian

In-line Direct Solution Treatment for 300 series stainless steel wire rods



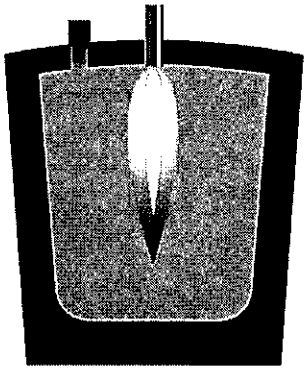
Flameless Oxyfuel Heating
Fuel gas: Generator Gas (also BF Gas used)
Working temperature: around 1200°C
Installation: 2009
Wire Rod diameter: 4.5–20 mm

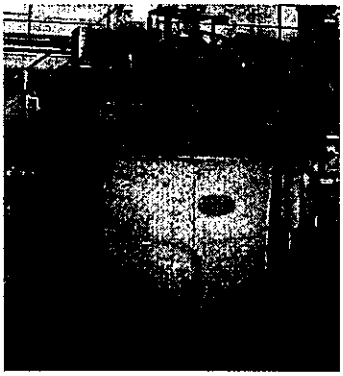
Continuous operation, capacity: 70 t/h
Reducing the Treatment Time by >90%!

2. Examples from the Steel industry Oxyfuel in Vessel Preheating

Benefits from higher heating temperature of a steel-making vessel:

- No need to have too high temperature of the steel in the EAF/BOF/AOD
- Shorter heating cycles for less number of vessels needed
- Only 75-80% flue gases due to less fuel and no nitrogen in combustion – smaller flue-gas system
- 50-55% lower CO2 emission compared to air-fuel system
- Possibility to reach very high pre-heating temperatures when wanted (Example 1500°C for atomizing customer)





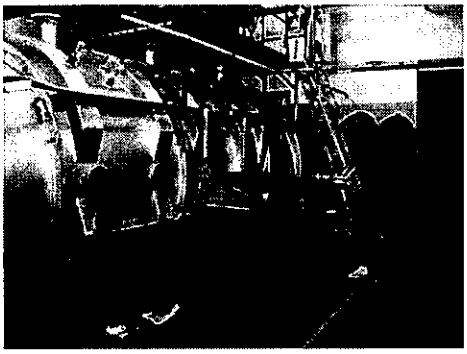
Simple, compact and low weight installation as compared to air-fuel system with recuperator or regenerative solution

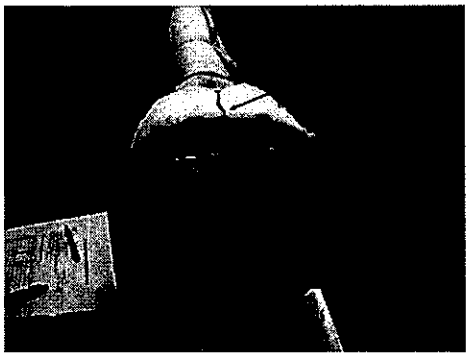
<u>Added features in Flameless oxyfuel:</u>

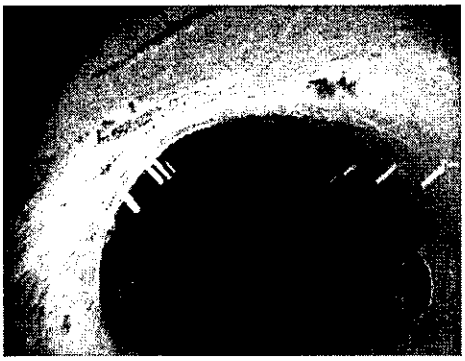
- **Further improved heat distribution in vessel**
- Ultra low NO_x emissions
- **Extended refractory lifetime due to higher and more even temperature distribution in vessel**

3. Examples from the Non Ferrous industry Aluminium – Heat Transfer Evaluation

PhD work Jörgen Furu of Norwegian University of Science and Technology,挪威科技大学



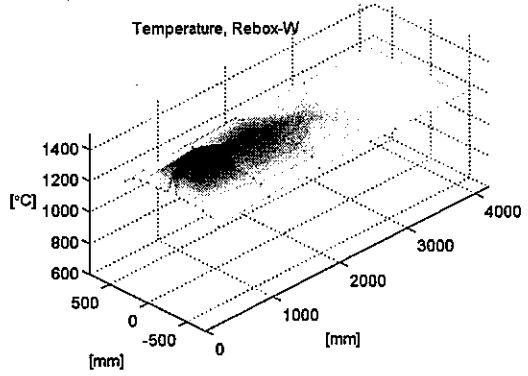




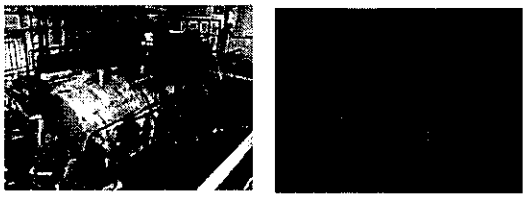
	Burner Power (kW)	Water cooling (kW)	Average temperature at Al sample (° C)	Heat flux (kW/m²)
Air-fuel	311	23	1151	79
Low-temperature Oxyfuel	257	66	1152	109 (+39%)

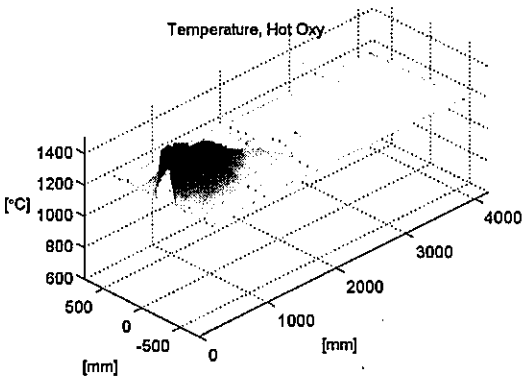
3. Examples from the Non Ferrous industry
Flame temperature profiles

Data from evaluation by KTH (Royal Institute of Technology, Sweden瑞典皇家理工学院研究报告), furnace at 1200°C



LTOF无焰燃烧 Low Temperature Oxyfuel





普通纯氧燃烧 Conventional oxyfuel

burner	Peak flame temp
LTOF burner	1434°C
Regenerative burner	1398°C
air-fuel burner	1404°C

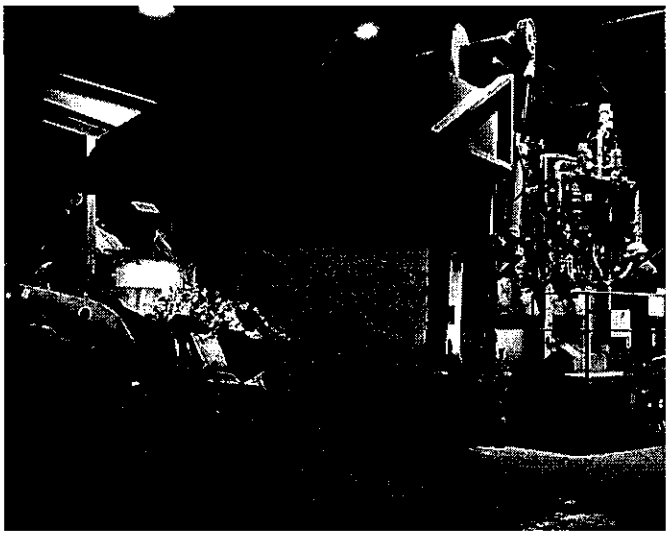
3. Examples from the Non Ferrous industry
LTOF, Granges, Sweden

28-tonne Aluminium re-melting furnace
Rolling mill scrap, primary ingots

Oxyfuel since 1995, 2.6 MW

Low-temperature Oxyfuel, 2005, 3 MW

- 90% reduction in NOx
- Up to 9% less dross formation
- 23% increase in melt rate
- 550 kWh/t
- 495 kWh/t
- 66% increased process efficiency
-



3. Examples from the Non Ferrous industry
Results at installations in Aluminum industry

Stena Aluminum，Sweden, 23 t URTF (Universal Rotary Tillable Furnace可倾动旋转炉)

solution改造方案：

Two oxygen lances：600 Nm^3/h

LTOF burner：4 MW

Flue-gas monitoring by laser sensor

Temperature monitoring

Remote control

results obtained运行结果：

Metal recovery	+2% to 3%
Fuel consumption	-40%
CO2 emission	-40%
Salt reduction	-70%

Video of URTF in Stena

3. Examples from the Non Ferrous industry
New 40 ton melting furnace at Granges, Sweden

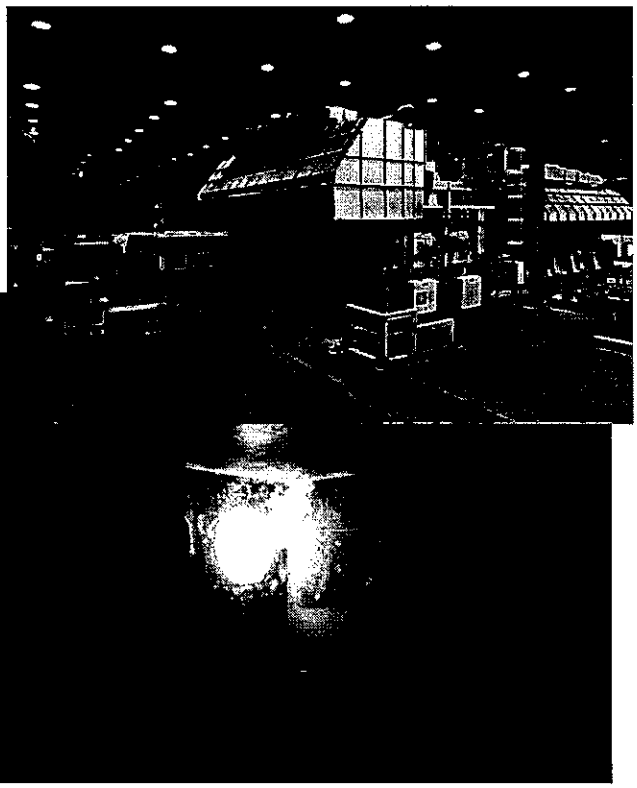
4 x 2 MW Low-Temperature Oxyfuel burners

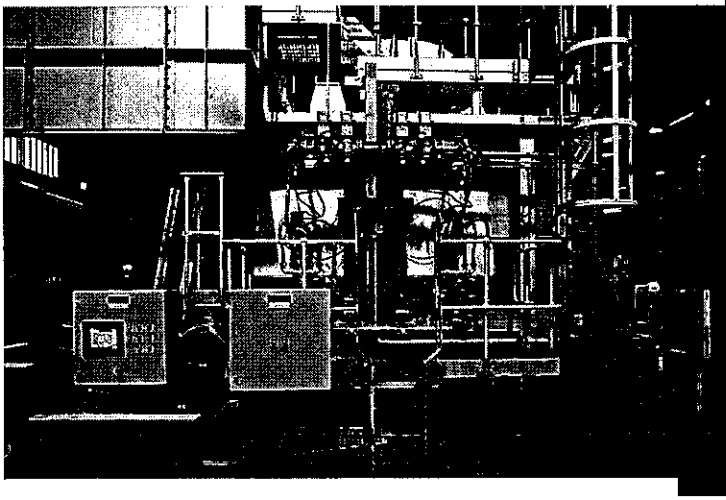
Direct charge furnace

Specified specific melt rate 7.5 ton/h

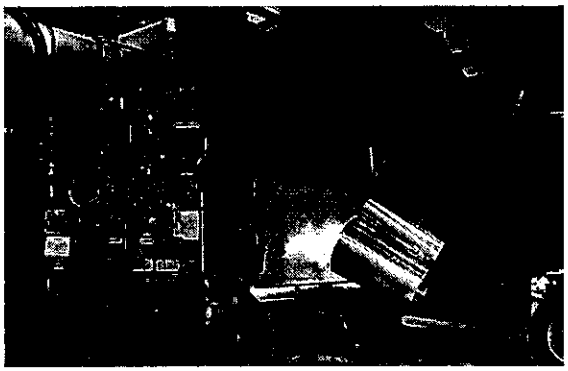
New cast house plant

In operation 2012

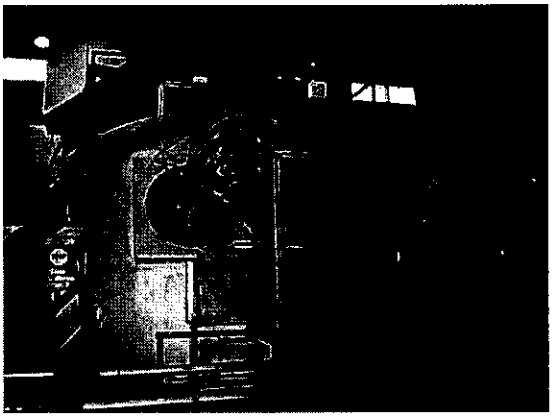




3. Examples from the Non Ferrous industry
NOx Emission Decrease



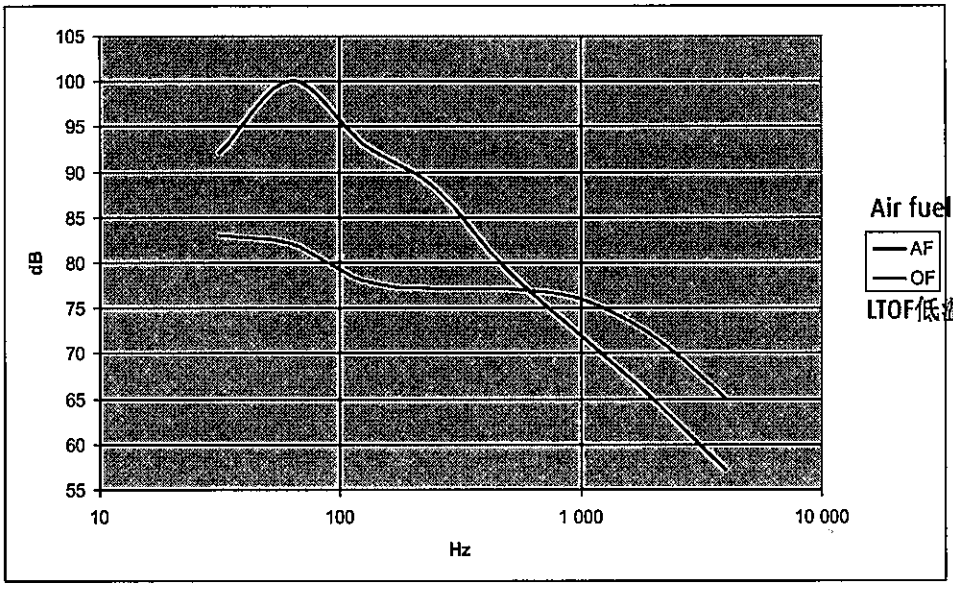
Granges, Sweden
NOx<100 mg/MJ
90% reduction



Hydro, Norway
NOx<100 mg/MJ
64% reduction

3. Examples from the Non Ferrous industry
Reduced noise emissions, Hydro, Norway

	Airfuel dB(A)	Low-temperature Oxyfuel dB(A)
At furnace	88	81
Inside control room	58	49

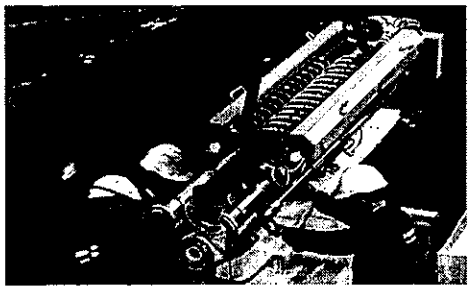


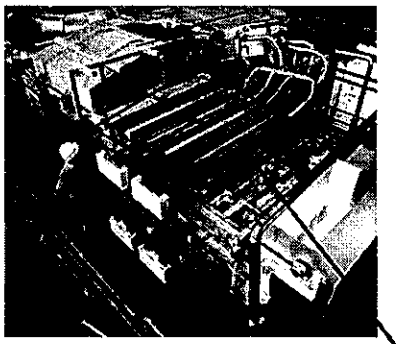
3. Examples from the Non Ferrous industry LTOF installations at Aluminium producers

Linde has installed oxyfuel in more than 130 furnaces for Aluminum melting 80 companies in 20 countries

Customer	Furnace type	No burners	installation
Granges, Sweden	28t, Reverb furnace	4	2005
RUSAL ,Sweden	50t, Reverb furnace	4	2007
Hydro, Årdal, Norway	2x30t alloying/Reverb	1 per furnace	2007
Hydro, Årdal, Norway	2x38t alloying/Reverb	2 per furnace	2008
Stena Aluminium, Sweden	25t, URTF, Rotary furnace	1	2009
Stena Aluminium, Sweden	30t alloying/reverb	1	2009
Constellium, France	7t, URTF, Rotary furnace	1	2011
RUSAL, Sweden	50t, casting/Reverb	2	2011
SAG, Austria	30t , Reverb furnace	1	2012
Granges, Sweden	40t, Reverb furnace	4	2012

3. Examples from the Non Ferrous industry Direct Flame Impingement Technology



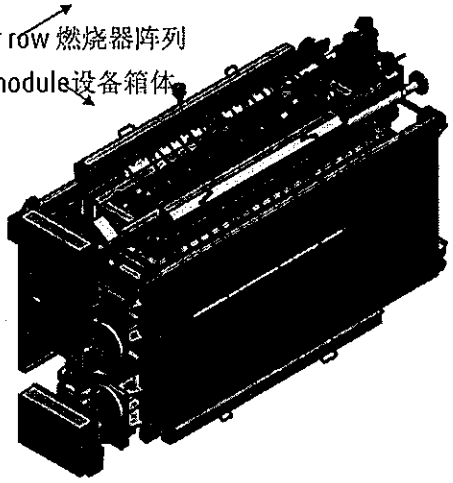


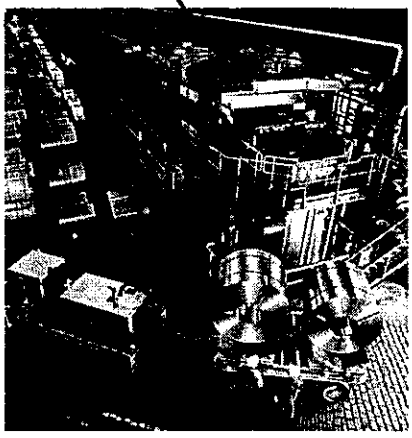
DFI preheating unit at a annealing line

直接火焰加热设备安装在退火和热镀锌生产线

burner row 燃烧器阵列

and module设备箱体



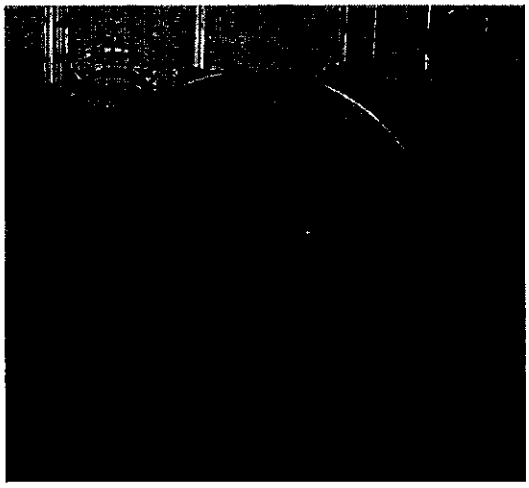


3. Examples from the Non Ferrous industry
DFI Annealing of Aluminium Sheets

- Flames heating directly onto a moving metal strip 火焰喷射加热运动的铝卷材
- Quickly raise material temperature within a compact furnace 在炉膛内通过时快速完成加热
- High localized energy input, local heat flux could be up to 1000kW/m^{2}数倍于常规空气加热的局部能量输入

DFI for Aluminum industry
Linde's DFI lab in Sweden

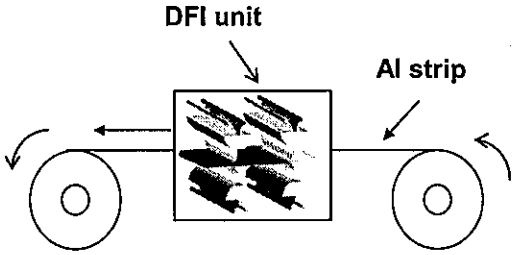
Max DFI burner power 200 kW
Max speed of strip ca 200m/min
Coiled strip width: 200mm
Max coil weight: 500 kg
Plate sampels: 200 x 200mm



coil machine for DFI pilot line

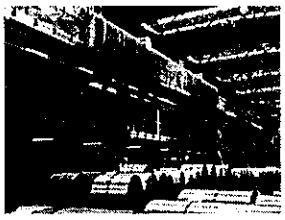
3. Examples from the Non Ferrous industry DFI for Aluminium Production

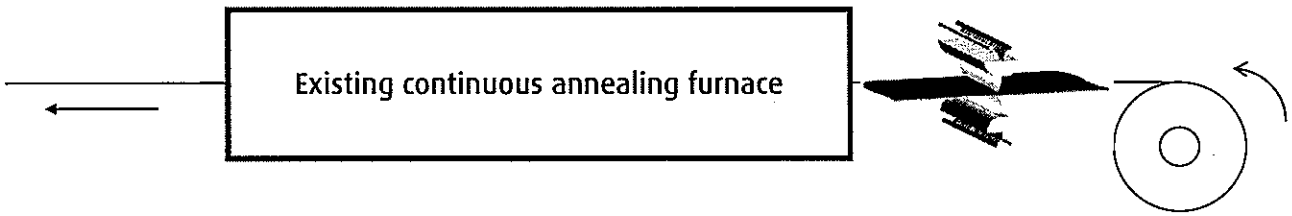
- More uniform quality
  - Every segment of the strip gets the same energy dose
- Potential for improved metal properties
  - Strength and ductility
- A faster annealing process (30-60 minutes) compared to 8-13 hours
  - Improved logistics
  - Less working capital in production line
- No staining on the metal surface
  - Lubricants are burnt by the DFI flames
  - No need for nitrogen atmosphere



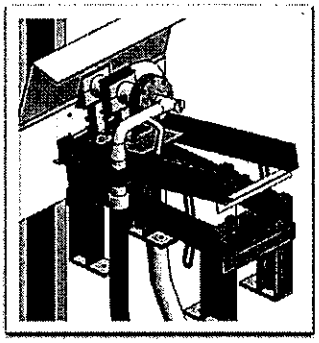
3. Examples from the Non Ferrous industry DFI for Aluminium Production

- Pre-heating of Aluminium strips at a continuous furnace, example Auto Body Sheet annealing
- Integrate DFI in continuous processes for Aluminium strip and plate
- Replace batch coil annealing processes for a continuous DFI process





3. Examples from the Non Ferrous industry Installations in Copper Recycling



References:

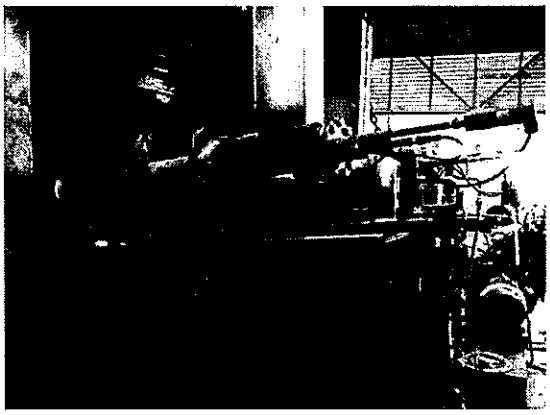
80t reverb furnace, Anhui, 2016

80t reverb furnace, Anhui, 2016

100t reverb furnace, Jiangxi, 2015

100t reverb furnace, Sichuan, 2014

200t reverb furnace, Austria, 2002



3. Examples from the Non Ferrous industry Copper Recycling

Results obtained:

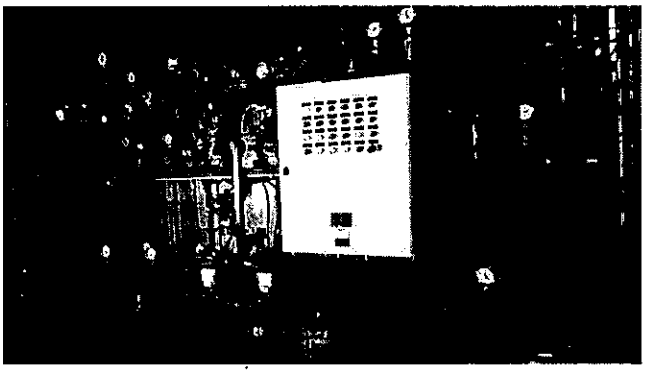
100t reverb furnace, Sichuan, China, 2014

compared items	Air-fuel	Oxyfuel
Productivity (ton Cu/day)	100	108 (+8%)
Fuel consumption (Nm^3/ton Cu)	110	50 (-55%)
Oxygen consumption(Nm^3/ton Cu)	--	100 (+100%)

3. Examples from the Non Ferrous industry
Lead Recycling

Equipment, control and gas supply

Oxyfuel burner



Flowtrain

LOX station

3. Examples from the Non Ferrous industry
Results at installations in Lead Recycling

References:

- Rotary, Bangkok, 2013
- Rotary, Chongqing, 2014
- Rotary, Jiangxi, 2015
- Rotary, Sichuan, 2015
- Reverb, Hebei, 2015
- Rotary, Hubei, 2016

about 90 references world-wide for rotary furnaces

3. Examples from the Non Ferrous industry
Results at Installations in Lead Recycling

Results obtained:

rotary: energy saving 30-50%; productivity 15 -30%;

reverb: energy saving 40-60%;

Specific fuel consumption/ton bullion lead produced:

rotary: heavy oil 45-65 liters/ton; NG 60-70 Nm^3/ton;

the larger the furnace, the better the fuel consumption;

oxygen 100 -160 Nm^3/t;

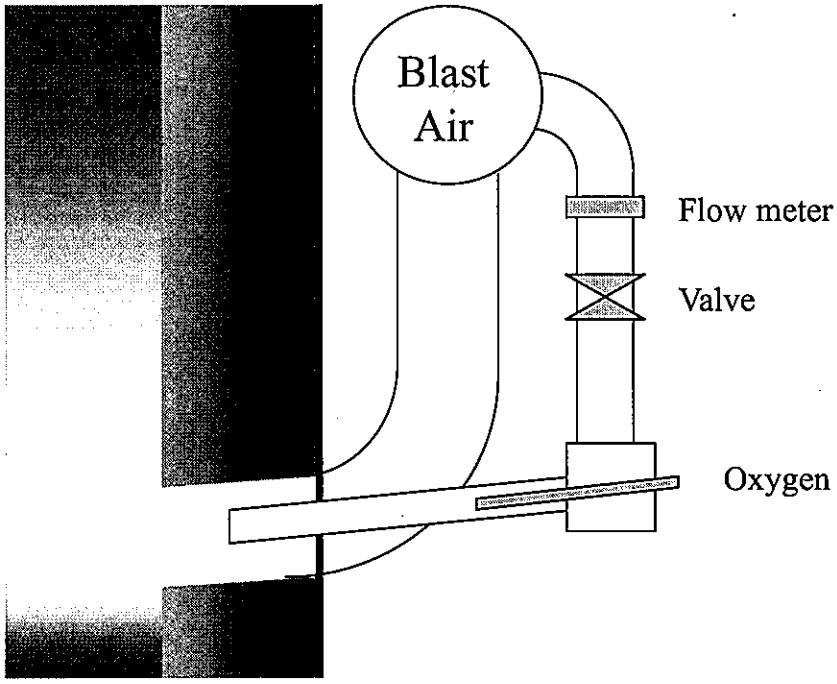
reverb: NG 40-65 Nm^3/t; oxygen 85-145 Nm^3/t;

4. Examples from the Iron Foundry Industry
HIGHJET® TDI Oxygen Technology

HIGHJET® TDI Oxygen Technology is a well-proven technology with many successfully running installations.

HIGHJET® TDI provides for the best possible oxygen utilisation in the furnace.

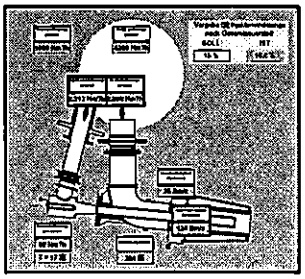
4. Examples from the Iron Foundry Industry
HIGHJET® TDI Oxygen Technology



4. Examples from the Iron Foundry Industry
HIGHJET® TDI Oxygen Technology

Typical Results:

- Dust reduction in the off-gas 70%
- CO/CO2 emissions are reduced by 30 %
- SO2 emission is reduced by 20 %
- Melt rate increase of 30%
- Blast volume reduction of 30%
- Coke reduction of 20%
- Off-gas volume reduced by 30%
- Reduction of bad smell around the cupola furnace

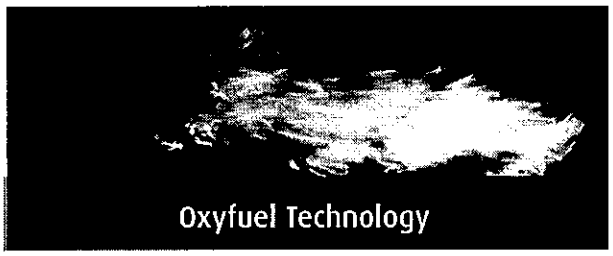


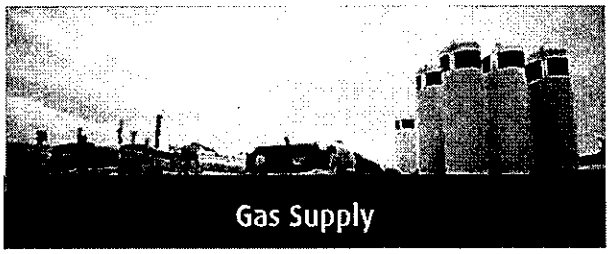
6. Summary
Benefits of Linde's Oxyfuel Technologies

THE LINDE GROUP

Linde

Solution Provider





Benefits

- Low carbon, energy savings
- CO2, NOx emission reduction
- efficiency increase
- quality improvement
- flexibility increase

Linde Combustion Technologies
林德低排放节能高效燃烧技术

THE LINDE GROUP

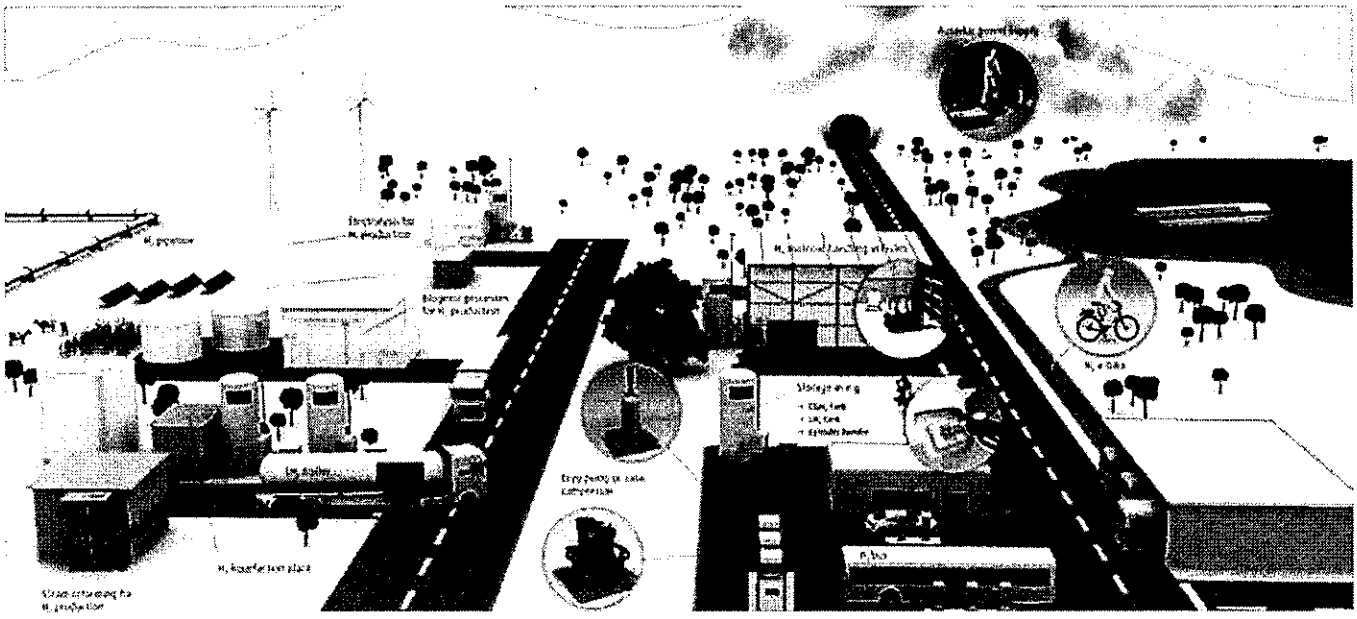
Linde

Supporting energy savings & emission reductions, to help achieve the blue sky China dream!
助力节能减排，助力蓝天碧水中国梦!

感谢您的关注!

Thank you for your attention!

Linde Hydrogen Energy



Contingent Valuation for Urban Solid Waste Recycle in Macau

Zhishi Wang Professor and Director
Macau Environmental Research Institute
Macau University of Science and Technology

Quantifying environmental benefit assessment

- Rapid economic development and tourism development exert stresses on the environment of Macau
- To sustain the city development with friendly environmental conservation, the government has to carry out the policy with high input of capital and labor for urban solid waste treatment
- However, if circulation economy concept to be introduced into the urban solid waste treatment, the benefits of the innovative policy should be valuated properly,
- which is of an application of contingent valuation method for non-traditional market service environmental valuation

CVM for environmental benefit Assessment

- Contingent Valuation Method CVM is a sample survey technique that attempts to elicit the maximum WTP or WTA for the environmental resources by asking people hypothetical questions.
- CVM has become the most popular non-market valuation method
- In USA, CVM has been acknowledged by the court as a legitimate procedure for environmental resource valuations

Current Status of Urban Solid Wastes in Macau

- Macau urban solid wastes annually increased by 25% since 1998, in which
- 75% of the total is for municipal solid wastes including kitchen residue containing mainly biomass wastes with high water content
- The major reason for rapid increase of solid wastes of Macau is due to rapid growth of Macau tourist economy and sustaining urbanization

Current Practice of Macau Urban Waste Treatment and Disposal

- Solid waste incineration is the major way to treat and dispose with a heavy cost mainly for keeping high temperature within the incinerator by adding fuel oil to prevent from dioxins generation
- Macau is of a city with extremely shortage of natural resource supply, most of which rely on import from the outside (food, fuel, electricity)
- Strategic innovation is needed for resolving the problem of urban waste management and resource shortage with emphasize on circular economy concept

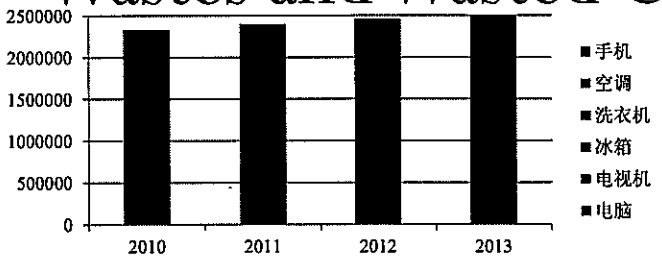
Global E-Waste: Environmental Dilemma or Economic Windfall (Maria Burke 2010)

- Roughly generate 40 m t/year of e-wastes globally
- Currently a quarter of Europe's e-wastes unaccounted for
- Informal recycling poses a great threat for developing countries due to generation of hazardous emissions
- Worldwide market for e-waste recovery grows from $5.7 bn in 2009 to $12.7 bn in 2014

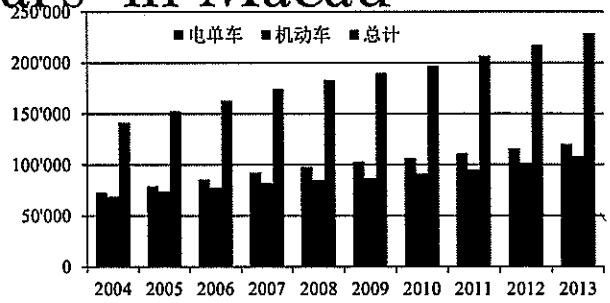
Change Environmental Dilemma into Economic Windfall

- The key is to try to get economic benefit from urban waste treatment and disposal, instead of simply capital input and expenditure for the treatment
- Recycling scenario of urban e-waste can be initiated, which involves both application of recycling technologies and exploring the way of marketization of relevant recycling industries and projects with incentive policy and green financial support
- Then urban biomass wastes can be converted to biofuel (biogas) or bioenergy (electricity) supply for benefit, too

Potential Mineral Resources from E-Wastes and Wasted Cars in Macau

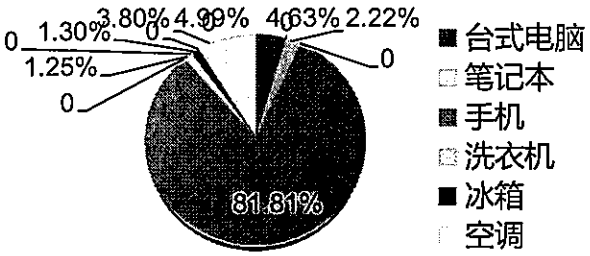


E-waste total quantity in Macau (set)

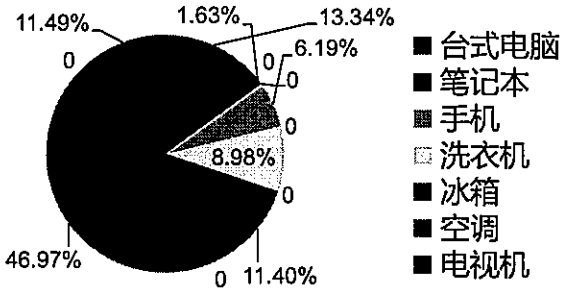


Total vehicle in Macau (number)

Categories of E-Wastes in Macau 2010



(by number , set)



(by mass , t)

Future Annual Increases of E-Wastes

年份	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
number（万台）	102.54	158.44	153.31	176.30	178.51	183.37	186.52	187.73	191.04	194.42	197.87
mass（万吨）	4467.4	4907.2	4986.1	6573.3	7012.4	7843.5	6768.9	5462.0	5480.2	5499.7	5519.3

Composition of Macau Municipal Solid Wastes （%）

Compositions	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	.....
Food	32.93	22.70	14.08	14.50	11.11	6.28	4.33	20.9	54.2	45.65	22.67
Paper and cardboard	15.01	10.56	12.86	16.90	12.16	13.15	3.63	15.8	19.9	16.30	13.63
Plastics	15.20	16.67	16.53	22.20	20.00	11.51	24.38	40.9	9.4	14.13	19.09
Glass and stones	10.51	5.03	4.18	5.10	5.60	5.83	3.81	5.4	6.3	5.43	5.72
Metals	2.72	2.80	0.51	7.80	2.70	4.04	1.21	2.3	2.4	3.26	2.97
Textiles	3.20	6.11	5.10	5.30	6.15	7.78	13.67	5.6	0.3	2.17	5.54
Wood	2.25	2.01	6.53	2.40	7.30	3.44	2.77	5.9	1.2	8.70	4.25
Other	18.20	34.20	40.20	25.70	34.98	47.98	46.20	3.2	6.3	4.35	26.13

'Other' represents mainly the kitchen residue and so urban biomass wastes account for 53.05% of the total, which can be converted to biofuel for power generation or running vehicles.

Preferable Development of Biofuel Industry in Macau

- A pilot study can be firstly made with a biomass waste conversion facility with daily production of 600 t/d of biofuel, equivalent to methane gas of 30000 cubic meters per day
- Through purification, 18000 cubic meters of biofuel gas can be produced, which can substitute annual fossil fuel consumption for public buses with running 30million kilometers, leading carbon emission reduction of 17000 t of CO2 emission
- If 30% kitchen residue is withdrawn from municipal solid waste, the calorific value can be increased by 27%, leading to electric generation increase by 20%

Green Finance and Incentive Policy

- Development of circulation economy (e.g., urban e-waste recycling) and of low carbon economy (e.g., clean energy resources from urban bio-wastes) both need financial support, i.e., green financial investment and incentive policy of government
- However, the bank investment decision to the low carbon and waste-recycling industries depends upon cost-benefit analysis and risk assessment for these non-traditional marketing industries
- Contingent valuation method CVM may be one of the new assessment tools for investment of the green economy, i.e., circulation economy and low carbon economy
- CVM approach has been already applied for environmental service (e.g. urban solid waste reuse and recycle project) and eco-product or resources (e.g., black-faced spoonbill)

A Case Study – Willing to Pay (WTP) for A New Urban Solid Waste Management With A Recycling Scenario

- 80.56% of the total correspondents (Macau citizen) prefer to willing to pay (WTP) for the new proposed program
- WTP is 16.82 MOP per capita each month with annual economic value of 9.05×10^7MOP
- With the same procedure, we can make a CVM assessment for valuation of projects of urban biofuel or e-waste recycle
- CVM is a useful tool for valuation of non-market eco-products and waste recycle industry

Thanks

Policy Framework and Cases of Circular Economy in China

中国循环经济的政策框架与实践案例

Dr., Prof. Huanzheng DU

UNEP-Tongji Institute of Environment for Sustainable Development

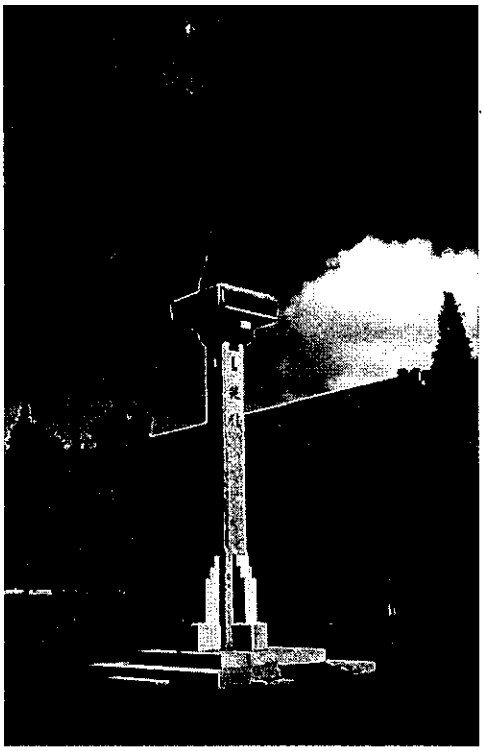
Dr., Prof. Huangzheng DU

- Circular economy expert of the World Bank and Chinese ministries including NDRC, MIIT, and MOC.
- Professor, UNEP-Tongji Institute of Environment for Sustainable Development
- Director, Tongji Circular Economy Research Institute
- Chief scientist, Tongji Sustainable Development and New Type Urbanization Think Tank
- President, The Yangtze River Delta Research Academy of Circular Economy and Technology (Zhejiang)
- Vice director, Environmental Management Committee, China Management Science Society
- Vice director, Circular Economy Committee, Chinese Society for Environmental Sciences

Interview by People's Daily Online in 2007

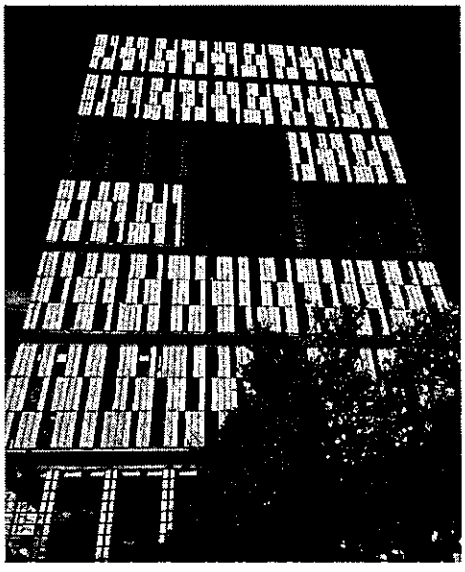
Tongji University
同济大学

- Established in Shanghai, 1907, by a German doctor
- 17500 undergraduate students, 13800 master students, 4500 doctoral students, 3800 international students; 2770 faculty members
- Subjects leading in China include architecture, arts, civil engineering, environmental science and engineering, European studies, mechanical engineering, and transportation engineering
- Toward a **sustainability-oriented** university in the 21st century

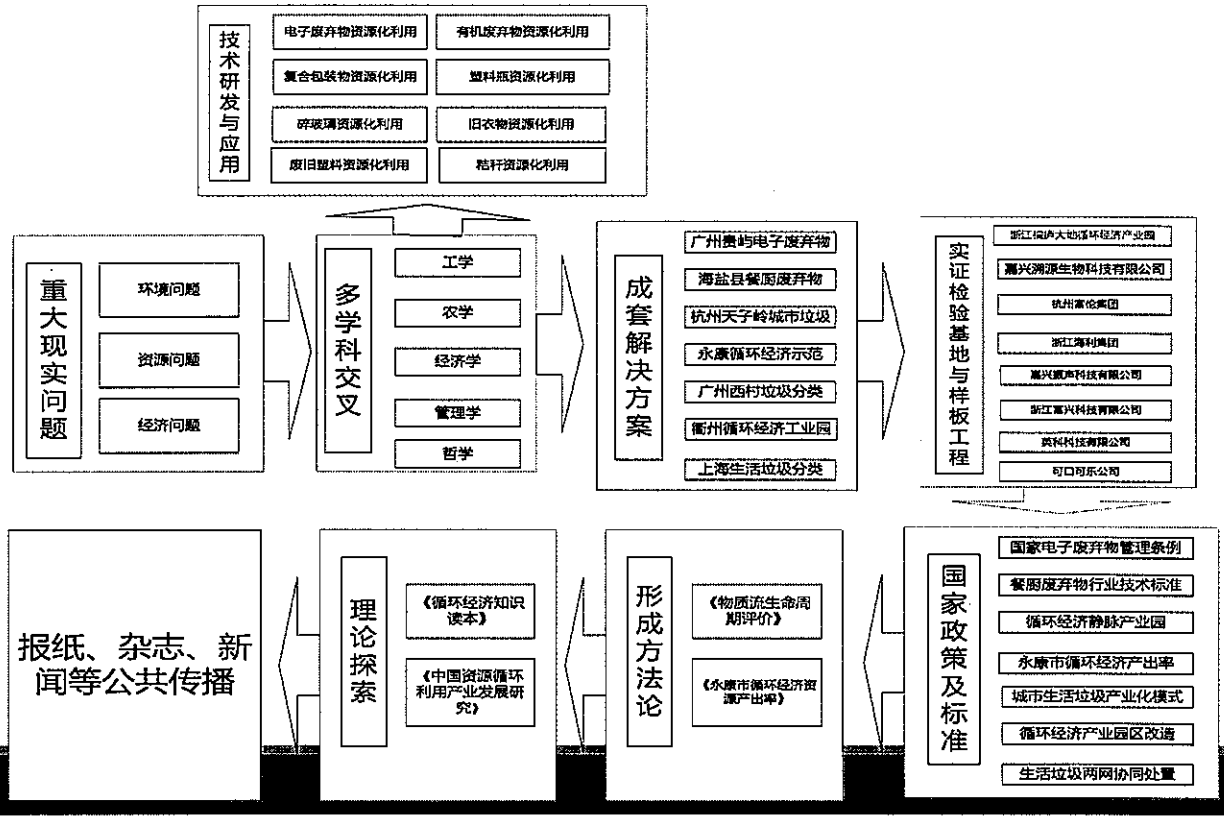


Tongji Circular Economy Research Institute (Tongji CE)
同济大学循环经济研究所

- 10 researchers and about 20 students
- Focusing on policies and technologies of circular economy, as well as multi-disciplinary studies of regional economics, ecological civilization, and sustainable development
- Providing system solutions to governments and businesses
- Leading circular economy think-tank in China
- Open platform integrating research, education, industries, and public services



Research mode and areas 研究模式



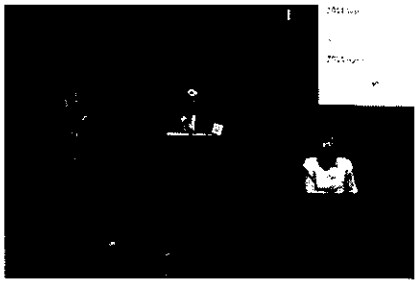
International cooperations
国际合作研究

- Sino-Japan intergovernmental cooperative research: Urban waste management and recycling

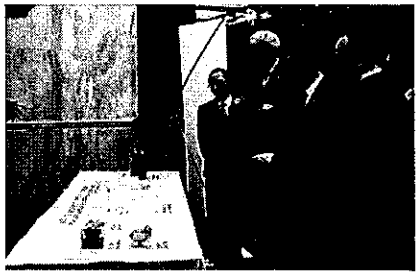
  中日政府间合作项目“中日城市典型废弃物循环利用体系建设及示范试点项目

- U.S.-China eco-partnership program: CocaCola sustainable bio-plastics (replacing PET bottles)

  中美绿色合作伙伴计划，与美国可口可乐公司合作“农业废弃物秸秆取代石油制备可循环生物质聚酯（植物环保瓶）”



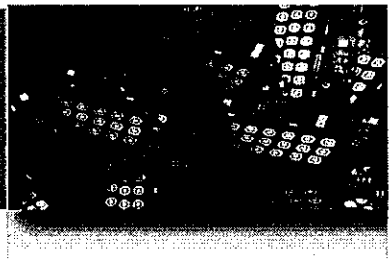
U.S.-China eco-partnership meeting at Washington DC, 2015



U.S.-China eco-partnership exhibition at Beijing, 2016

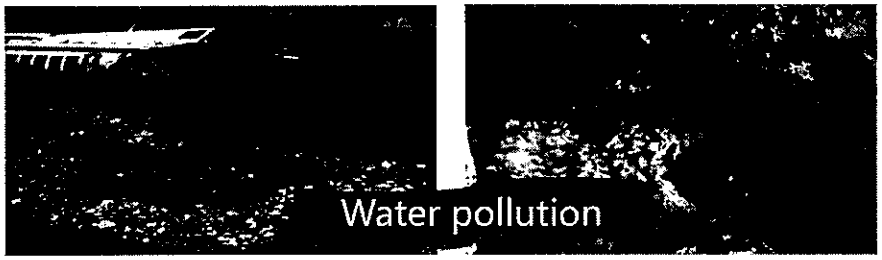
Part 1

中国的环境问题与生态文明转型



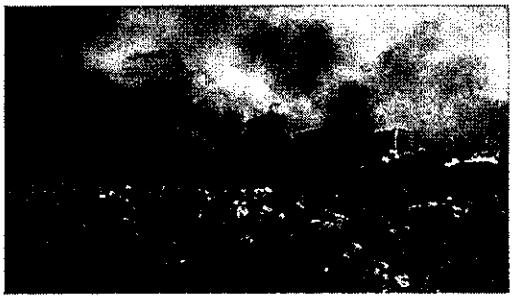
Environmental crisis in China and transition toward eco-civilization

Hefty environmental prices paid
高速发展的环境代价



- China becoming the world 2nd largest economy after 30-yr rapid growth
- Prices of environmental and ecological degradation:
  - Lake Tai (1hr driving from Shanhai), eutrophication threatening domestic water supply to many millions in summer 2007
  - Hundreds of cities in North China lost in winter haze in the 2010s
  - Guiyu, No.1 e-waste town in China, one of the most toxic places on Earth

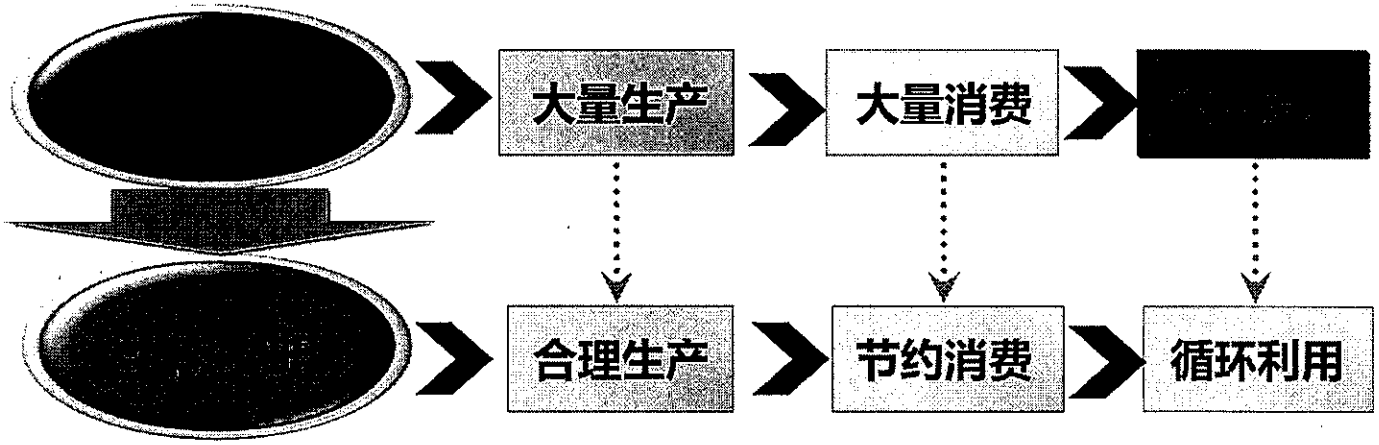
Cities besieged by waste
垃圾围城




- Big city = Big waste producer;
- 180 mega-tonnes of municipal solid waste generated by 244 cities in China in 2014

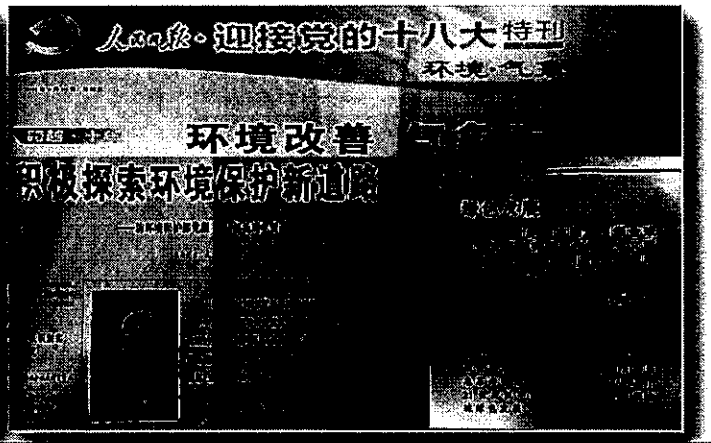
Transition from industrial to eco-civilization
工业文明向生态文明转型

- Conventional development is **unsustainable**
- Transition from industrial to eco-civilization (from "massive production, consumption, and waste disposal" to "reasonable production, conserving consumption, and optimized recycling"



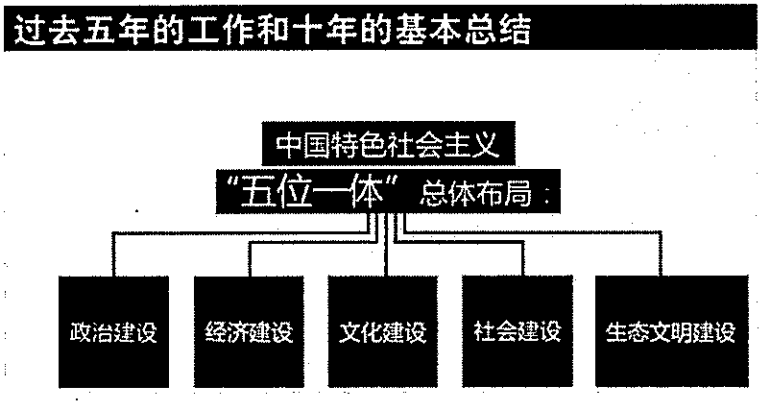
Dr. Du interviewed by CCTV and writing for People's Daily on eco-civilization

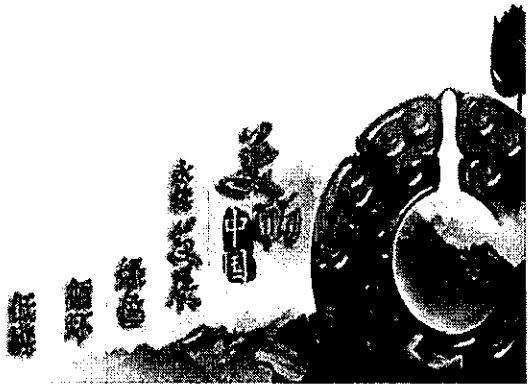
同济大学杜欢政教授在2012年9月19日的人民日报十八大特刊上发表**“21世纪的中国将引领全球绿色发展，实现由传统工业文明向合理生产、节约消费、循环利用的生态文明的大转型。”**观点高度概括了我国产业转型升级的“绿色发展”方向，**倡导大力发展循环经济，振兴资源循环利用产业**



Three approaches to achieve eco-civilization

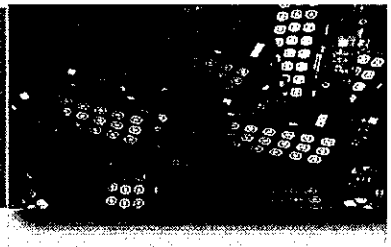
- 十八大作出中国特色社会主义经**“五位一体”**的总体布局，提出**把生态文明建设放在突出地位，融入经济建设、政治建设、文化建设、社会建设各方面和全过程**，努力建设美丽中国，实现中华民族永续发展
- 着力推进绿色发展、循环发展、低碳发展，是生态文明建设的主要内容
- Three approaches: Green, **Circular**, Low-carbon development





Part 2

中国的循环经济政策



Framework and evolution of circular economy policies in China

Early political statements of circular economy in China
循环经济的早期政策表述

- President JIANG Zeming' speech at GEF Conference, 2002

  江泽民主席全球环境基金成员国会议的讲话，"走以最有效利用资源和保护环境为基础的循环经济之路"

- President HU Jintao's speech at the Conference of Population, Resources, and Environment, 2003

  胡锦涛主席中央人口资源环境工作座谈会的讲话，"将循环经济的发展理念贯穿到区域经济发展、城乡建设和产品生产中"

- 4th Plenary Session of the 16th CPC Conference, 2004; Governmental work report, 2005

  十六届四中全会（2004年）及2005年政府工作报告提出要"大力发展循环经济"

Institutions of circular economy development
中国循环经济的机制与制度发展

- Establishment of CE Division in National Development and Reform Commission, 2005

  国家发改委环资司成立循环经济处

- Circular Economy Promotion Law, 2009

  中华人民共和国循环经济促进法

中华人民共和国
循环经济促进法

Circular economy becoming a national strategy in 18th CPC Conference in 2012

- 十八大报告指出：着力推进绿色发展、循环发展、低碳发展， 形成节约资源和保护环境的空间格局、产业结构、生产方式、生活方式，从源头上扭转生态环境恶化趋势，为人民创造良好生产生活环境，为全球生态安全作出贡献
- 2012年12月12日国务院常务会议讨论通过了《“十二五”循环经济发展规划》：发展循环经济是建设生态文明，实现可持续发展的途径和基本方式

Evolution of circular economy policies in China's FYP
中国的循环经济政策演变

- 11th Five Year Plan (2006-2010), on priority areas, sectors, cities, and enterprises

  围绕环境污染严重的节点，在重点领域、重点行业、重点企业、试点城市等点上推进

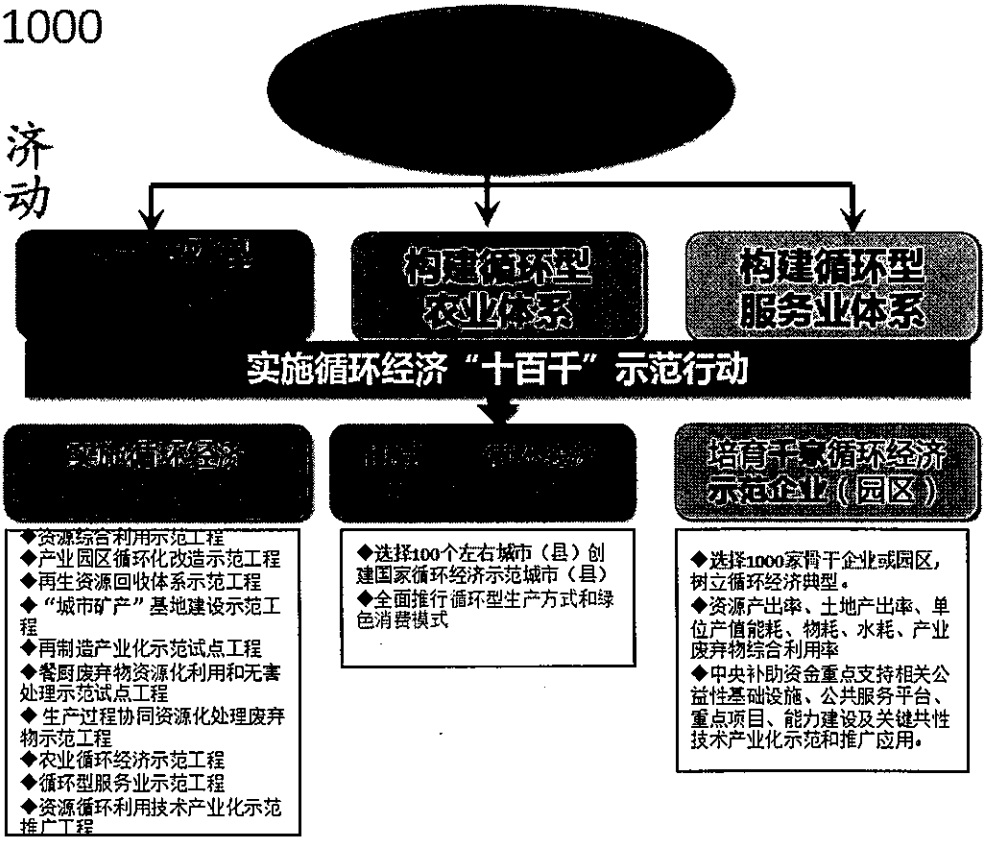
- 12th Five Year Plan (2011-2015), 10-100-1000 model programs

  循环经济“十百千”示范行动

- 13th Five Year Plan (2016-2020), Guidance of circular development

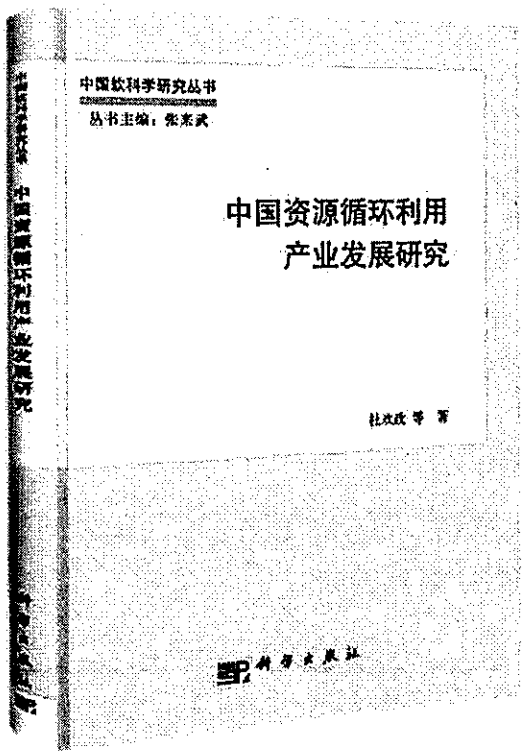
  循环发展引领计划：绿色循环低碳产业体系、城镇循环发展体系、新的资源战略保障体系、绿色生活方式

12th FYP: CE 10-100-1000 model programs
十二五期间循环经济“十百千”示范行动



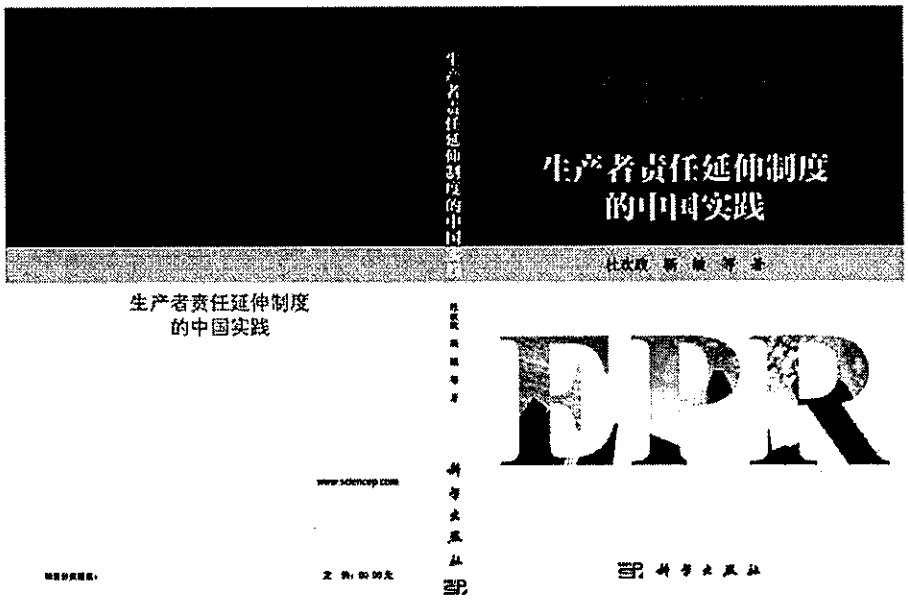
Recycling industry becoming one of the national strategic and promising new industries

- 杜欢政教授首先提出**资源循环利用产业**的概念，协助推动资源循环利用产业被列为国家七大**战略性新兴产业**中节能环保产业的子产业
- 撰写的《中国资源循环利用产业发展研究》一书是中国关于该产业的首本专著，作为国家“十一五”重点图书出版
- Du was the author of China's first book on recycling industry



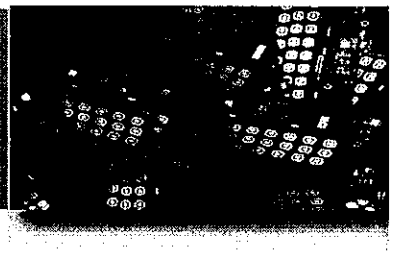
EPR as a policy instrument to promote circular economy development in China

- Extended producer responsibility (EPR) adopted by governments and industries in China
- In his book, Prof. Du reviewed EPR's practices as a policy tool



Part 3.1

实证案例：电子废弃物（广东贵屿）

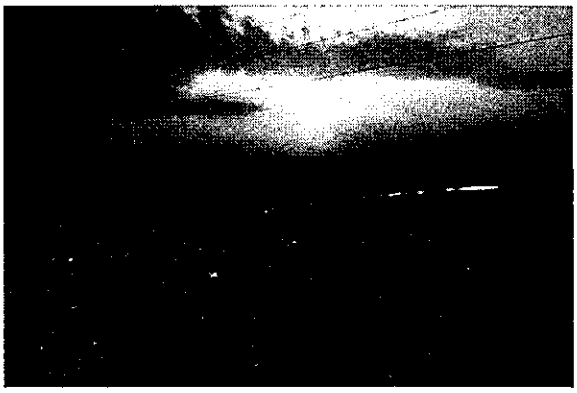


Case study 1, E-waste (Guiyu)

Guiyu, No.1 e-waste town

广州汕头贵屿镇，电子垃圾拆解第一镇

- Guiyu, a town in Shantou City, Guangdong Province
- Perceived as the largest electronic waste (e-waste) site in the world
- Soil, water, air and people paying a high price
- One of the **most toxic** place on Earth (*CBS 60 Minutes*)



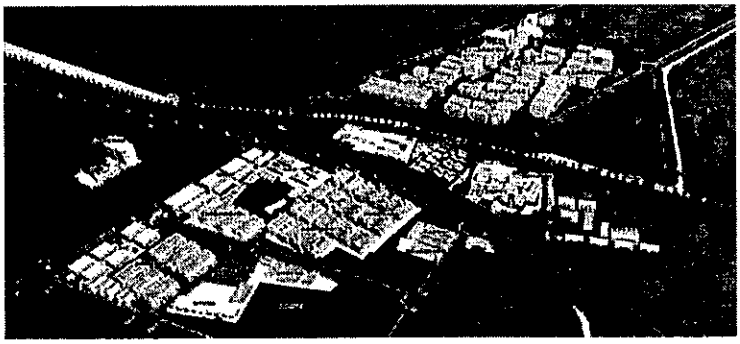
Comprehensive approaches to solve the Guiyu dilemma

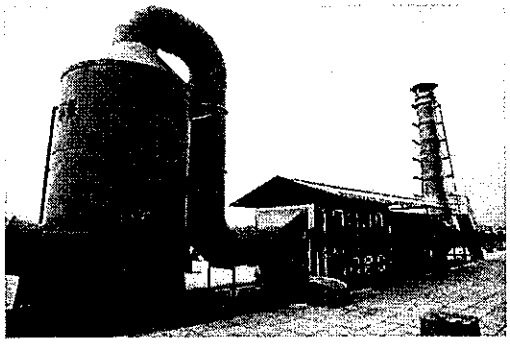
贵屿综合治理

- Upgrading the recycling industry
- Restoring the environment
- Ensuring labor safety and hygiene
- Curing the victims

➢ State-of-the-art 3R
  - Used products reuse
  - Components remanufacturing
  - Material recycling

➢ Pollution prevention
  - PCB
  - Lead
  - Other toxics

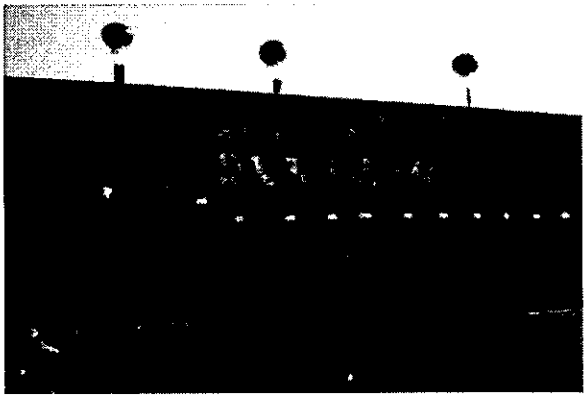




Tongji CE's commitment to environmental restoration and industrial development of Guiyu

贵屿的环境治理与产业升级研究

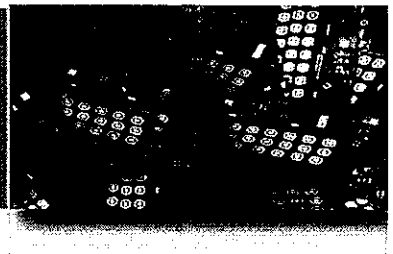
- 受国家发改委委托，开展贵屿电子废弃物研究
- 承担**国家软科学计划**课题"我国再生资源回收体系建设研究"
- 围绕**环境治理**和**再生资源回收利用**问题，形成涵盖**产业升级、环境治理、职业卫生、受害人群康复**的系统解决方案
- Dr. Du undertook a number national and regional research programs for Guiyu's environmental improvement and industrial development



Du addressing at the groundbreaking ceremony of WEEE centralized treatment plant of Guiyu

Part 3.2

实证案例：餐厨垃圾（浙江海盐）

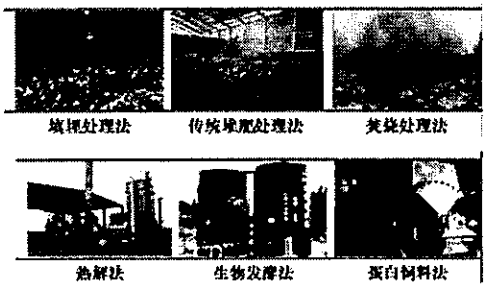


Case study 2, food waste (Haiyan)

Tongji CE's innovation of food waste utilization

餐厨废弃物昆虫蛋白转化的技术与商业模式创新

- 围绕**餐厨废弃物处理**和**食品安全**问题，针对堆肥、热解等传统工艺的不足
- 同济大学循环经济研究所与嘉兴溯源生物科技公司合作，打造**全新的餐厨废弃物资源化利用和环保盈利模式**，带动产业技术革命
- Food waste is a great challenge to China's environment and food security. Tongji CE offers an environmental-friendly and profitable solution

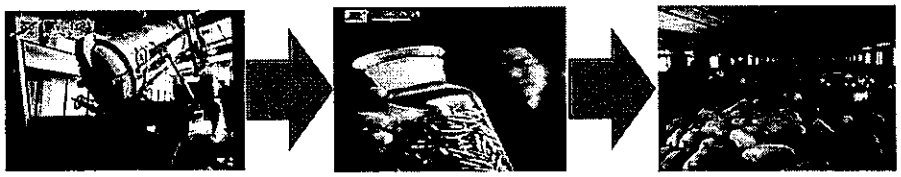


Conventional treatment technologies not

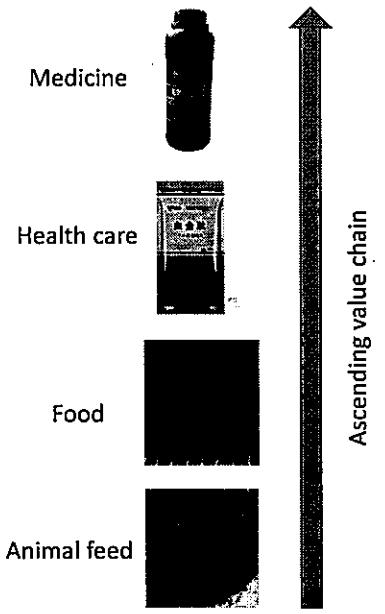
Test food waste treatment plant in Haiyan,

Food waste to insect protein innovation
餐厨废弃物昆虫蛋白转化的技术与商业模式创新

- Food waste industrial chain transforming food waste to insect protein (magmeal) to high value-added products (e.g., medicine and health care)
- Targeting on a market of 50 billion CNY, climbing up the value chain



Food waste collection | Magmeal transformation | Husbandry feed

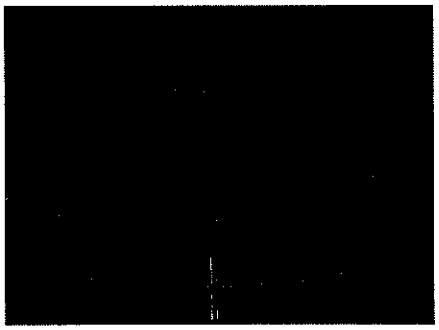


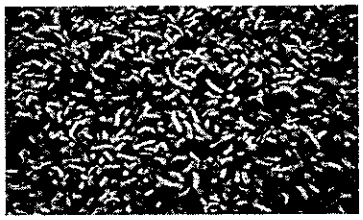
Advantages of Tongji CE's food waste technology
餐厨废弃物昆虫蛋白转化的技术优势

餐厨废弃物资源化利用生产昆虫蛋白，昆虫蛋白深加工为高价值的保健品及化妆品

- 资源“全”循环
- 过程“全”无污染
- 产品“全”高附加值
- 解决饲料化“蛋白质同源性” 难题

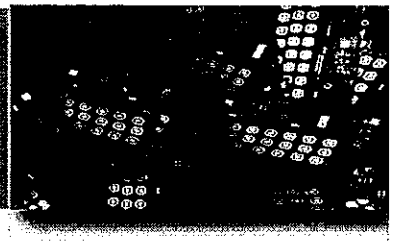
Comprehensive utilization of food waste, minimizing pollution, high value-added





Part 3.3

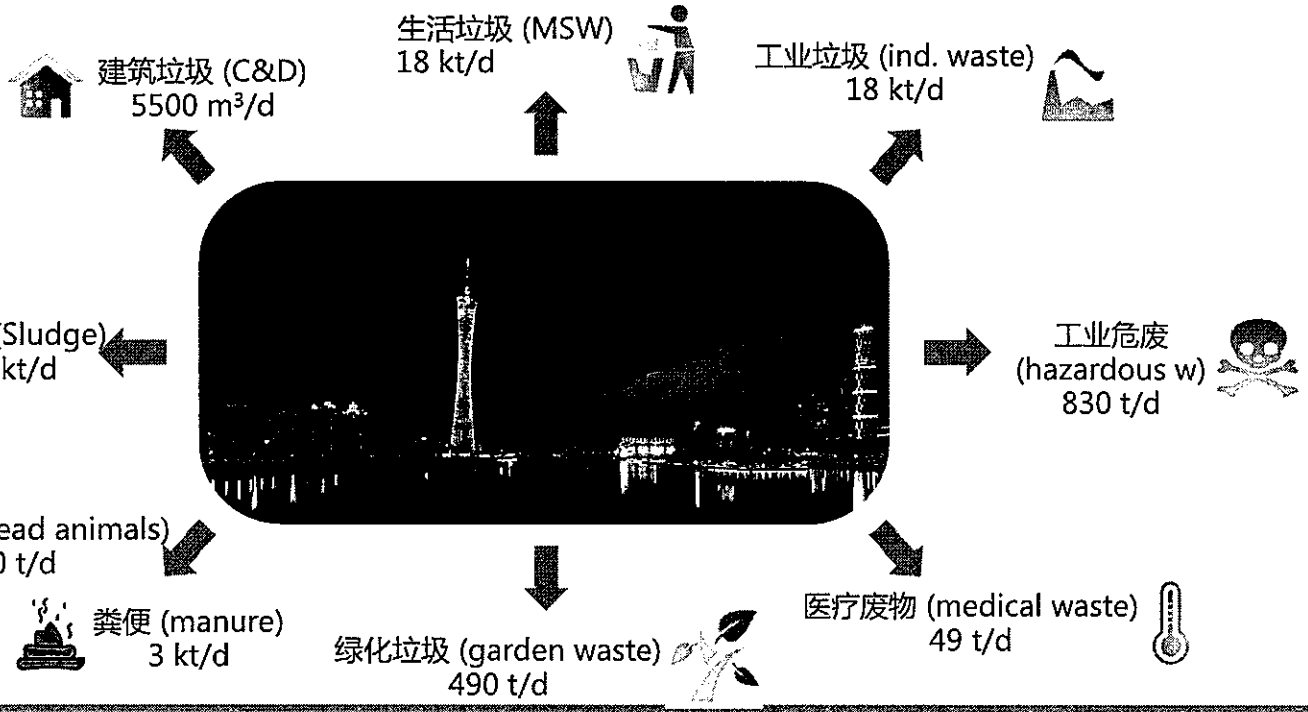
实证案例：城市垃圾一体化解决方案（广州）



Case study 3, MSW (Guangzhou)

Guangzhou (Canton) City: A mega waste producer

大城市就是大型废物工厂，以广州为例



Mobilization of government, enterprises, and academia to save Guangzhou from solid waste seige

政产学研协力，破解垃圾围城

Professor of Waste (Du)

Mayor of Waste (Chen, center), and

CEO of Waste (Guan, right)

Photographed in March, 2013

Integrated MSW solution: Thoughts and objectives

广州城市垃圾分类减量一条化解决方案：思路及目标

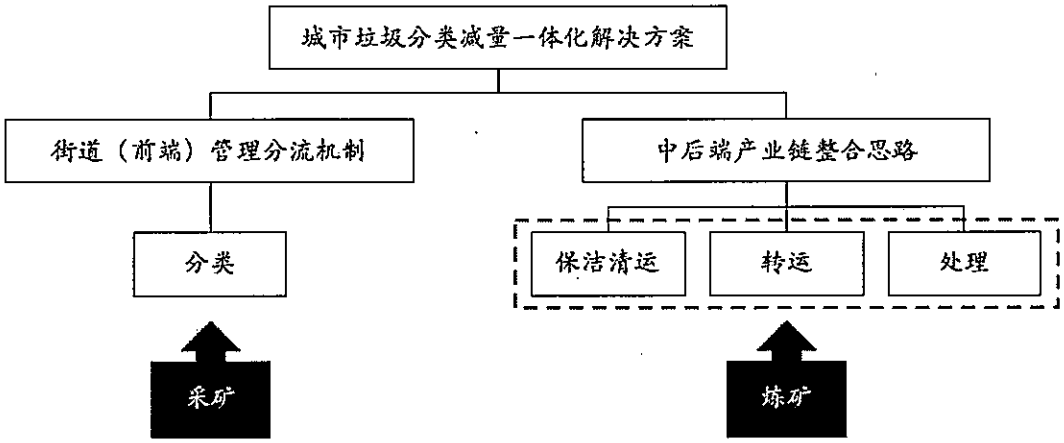
Long-effective waste sorting and management system that

- Guided by the government
- Participated by the public
- Operated by enterprises, and
- Facilitated by NGOs

以“**政府主导、全民参与、企业运作、社会组织推动**”为原则，通过顶层设计，引入企业创新社区垃圾分类前端作业机制，明确区分街道办与企业的责权利，让企业具体运作街道垃圾分类促进中心，把垃圾分类推动工作中非政府部门力所能及的垃圾分类服务剥离出来，交给有能力、有意愿的企业操作。

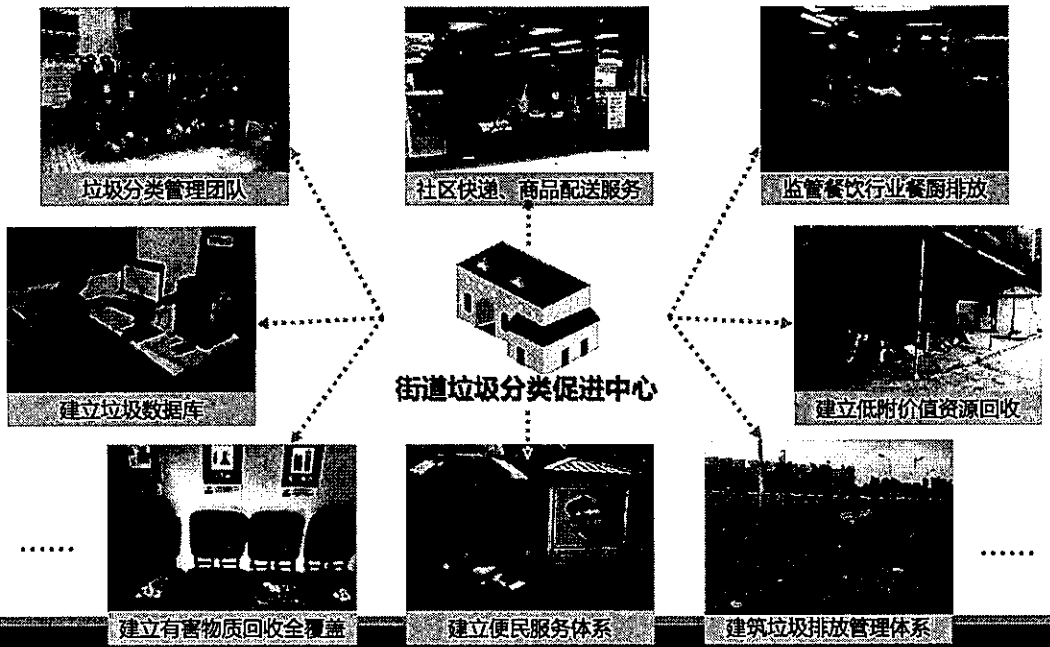
形成可持续的盈利模式
建立垃圾分类长效机制

Integrated MSW solution: Planning
方案设计



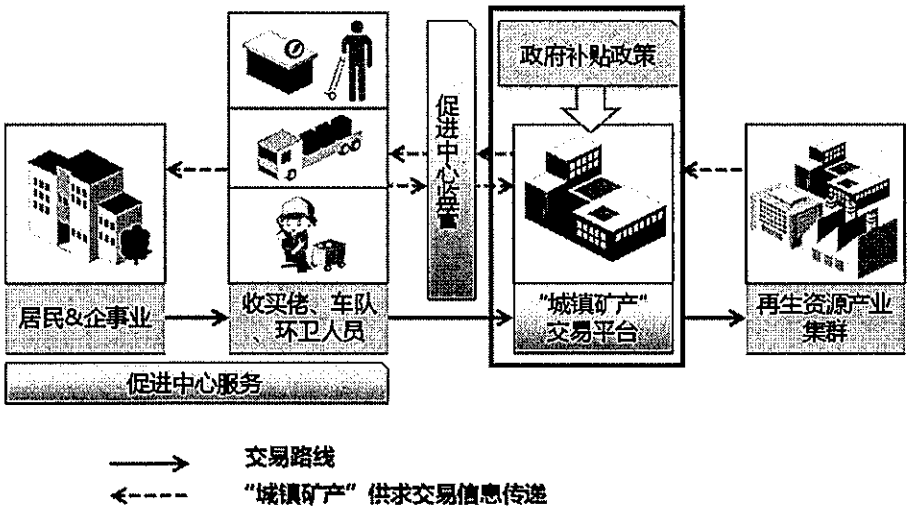
通过促进居民和机团单位参与垃圾分类的街道（前端）管理分流机制，以物流平台的力量，整合分布于分类、保洁、运输、处理等四大业务环节的、涉及城市垃圾分类处理的各种企事业资源，构建挖掘城市矿产的产业链，最终通过产业链分流处理的方式，辅助传统生活垃圾处置体系（保洁-运输-烧埋）减轻作业负担（末端处置减量），从而不断缩减政府财政在垃圾处置上的庞大财政支出

Key element 1 of Guangzhou solution: Market-oriented, community-based waste sorting promotion center
方案关键1：街道垃圾分类促进中心



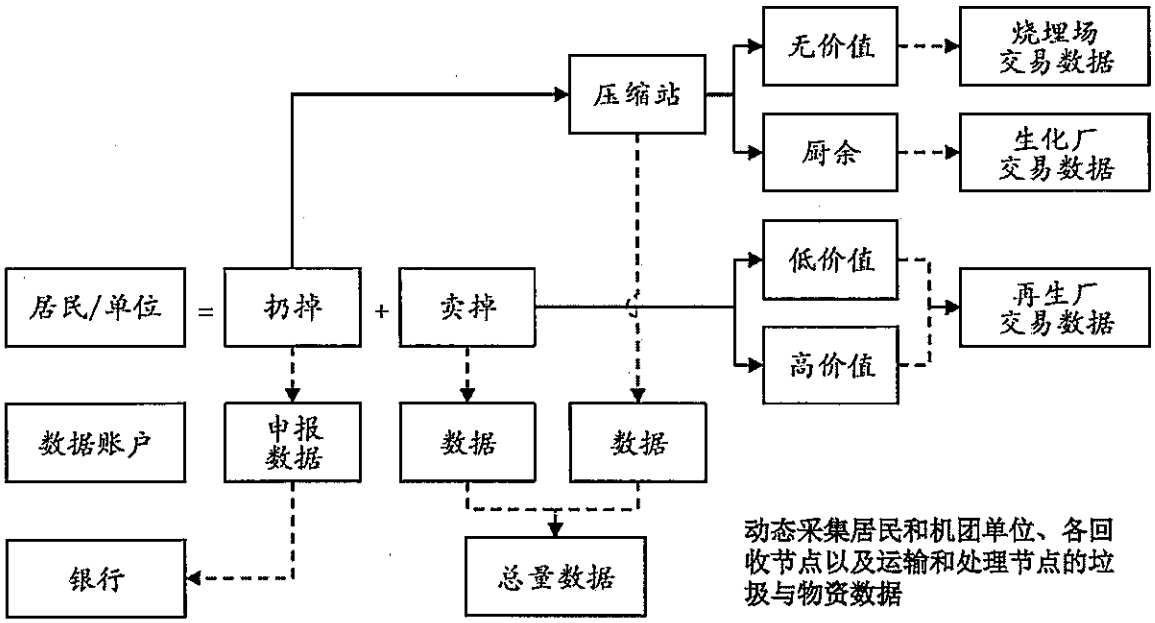
Key element 2: Urban minerals trading platform and governmental subsidies and supervision

关键2：城市矿产交易中心及政府补贴与监督机制

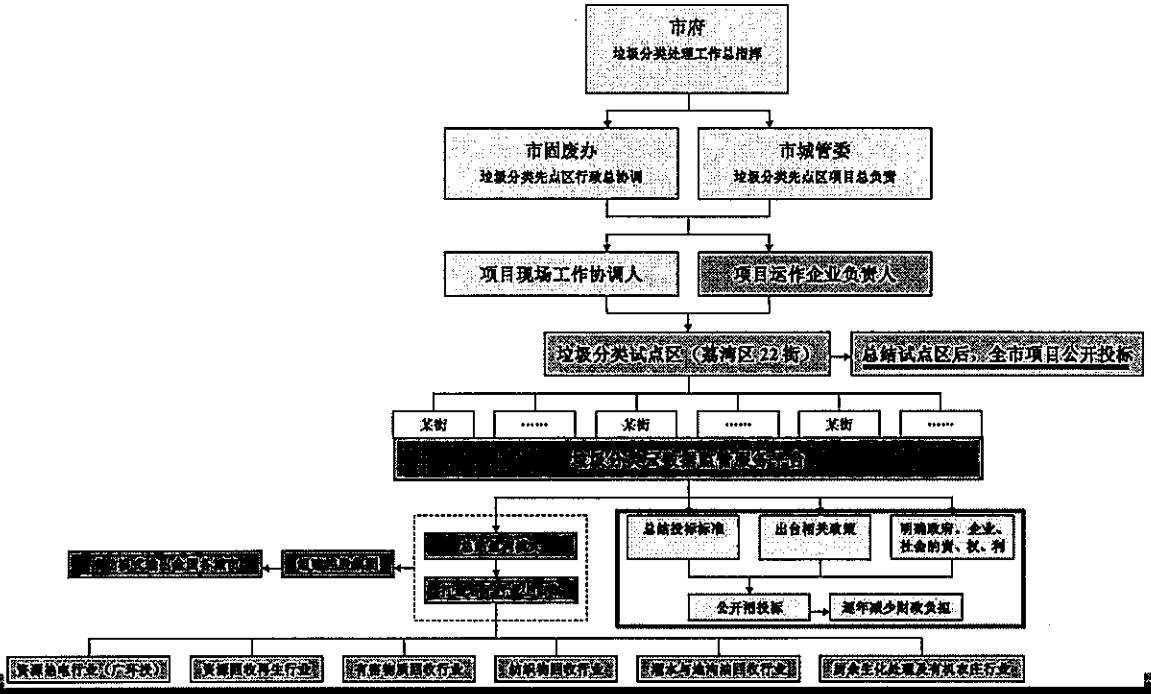


Key element 3: MSW information management system

关键3：城市生活垃圾分类减量化数据管理系统



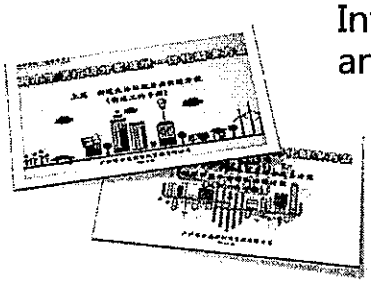
Key element 4: Waste management sites, infrastructure, and policies
关键4：场地保障与政策保障



Major innovations
研究创新点

① 构建城市生活垃圾分类减量一体化系统解决方案

Integrated solution for waste sorting and reduction

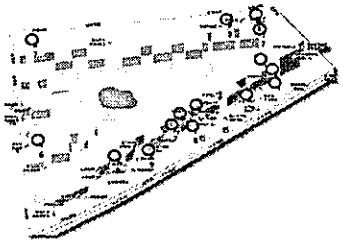


② 市场机制下企业运作的街道垃圾分类促进中心，明确其权责

Market-oriented, community-based waste sorting center

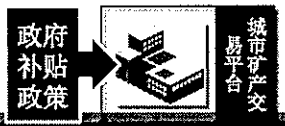
③ 基于大数据的城市垃圾分类与资源化数据管理系统设计方案，建立城市垃圾产出点分布数字地图

Advanced IT system and waste e-map



④ 建立利于政府补贴机制实施的全覆盖型的城市矿产交易平台

Urban minerals trading system



Summary
小结

- 方案是对我国现行城市生活垃圾管理体制机制的创新基本形成了符合我国国情、行之有效的城市生活垃圾分类减量一体化方案
- 在城市垃圾管理体系中创新式的建立了街道垃圾分类促进中心，让专业的企业全面统筹街道垃圾分类回收工作
- 构建了城市垃圾分类与资源化数据管理系统设计方案，建立城市垃圾产出点分布数字地图
- 建立了引导社会参与垃圾分类的机制，尤其是城市居民主动参加自产生活垃圾源头分类投放的驱动机制
- Long-effective waste sorting and management system developed in Liwan District of Guangzhou City, being transplanted to other districts and cities

谢谢
Thanks!

资源有限 循环无限
Limited Resources
Long-lasting Recycling

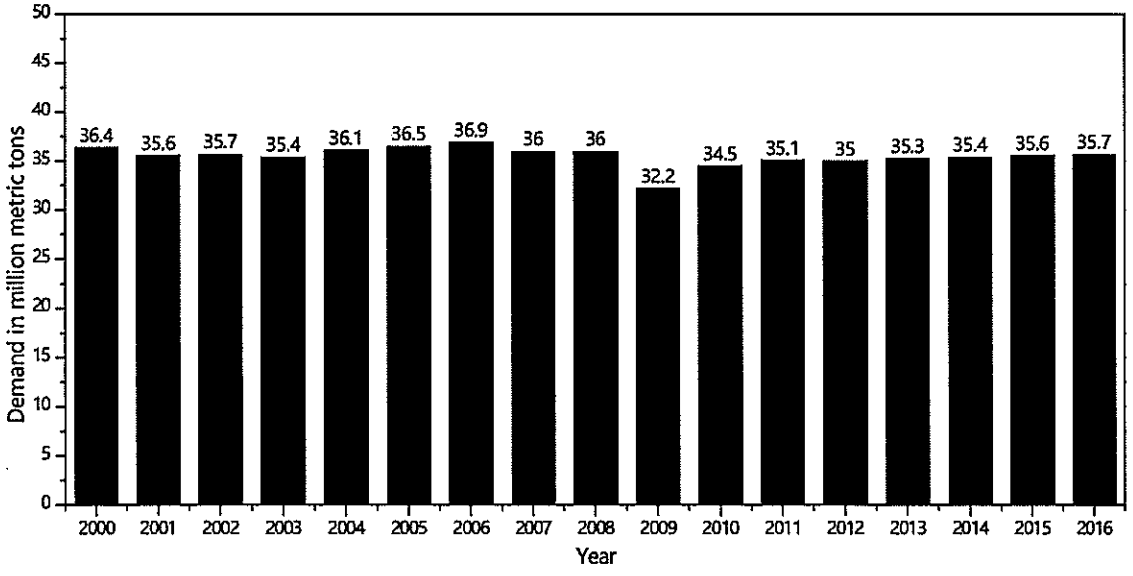
Waste Oil Recycling and Challenges in China

Duan Weng*, Qi Song
School of Materials Science & Engineering, Tsinghua University
Email: duanweng@tsinghua.edu.cn
(2017-11-15)

⇒ Lubricants Demanding and Production

⇒ Waste Oil Recycling Technology

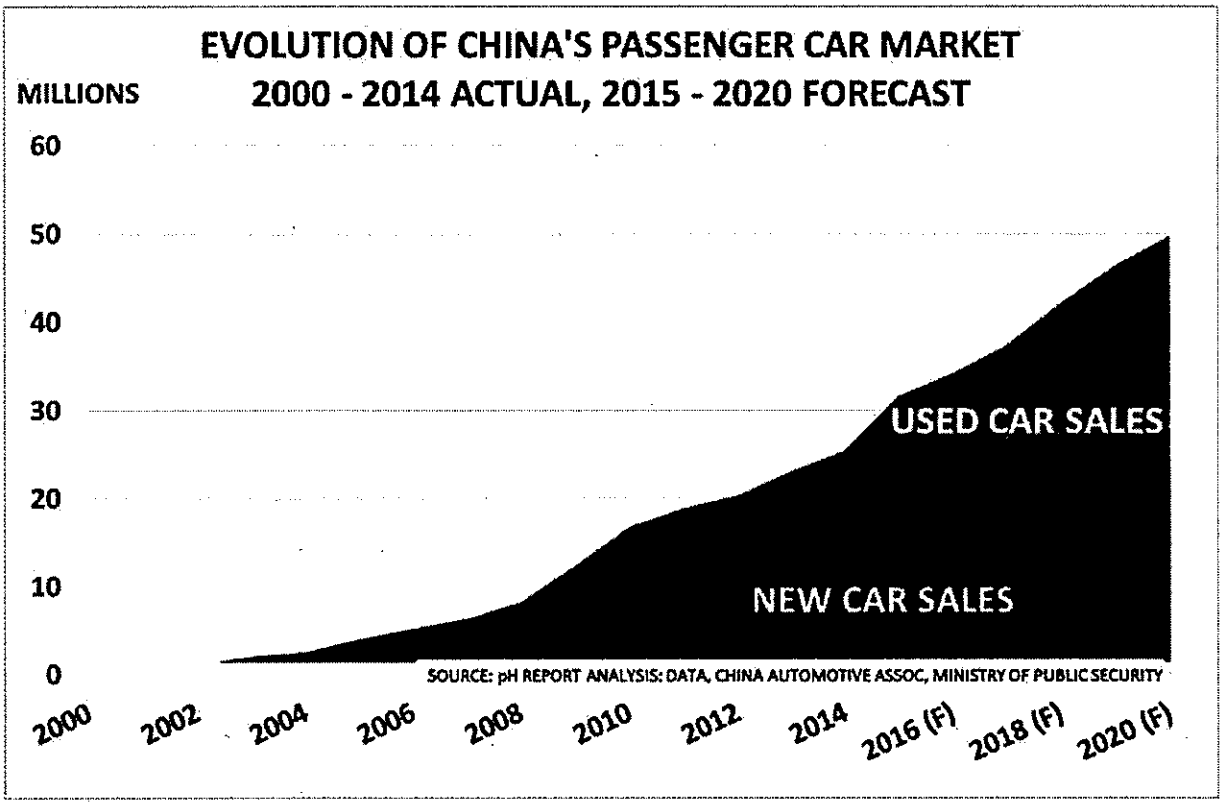
⇒ Global Demand for Lubricants



➢ Global demand for lubricants from 2000 to 2016 maintains stable.

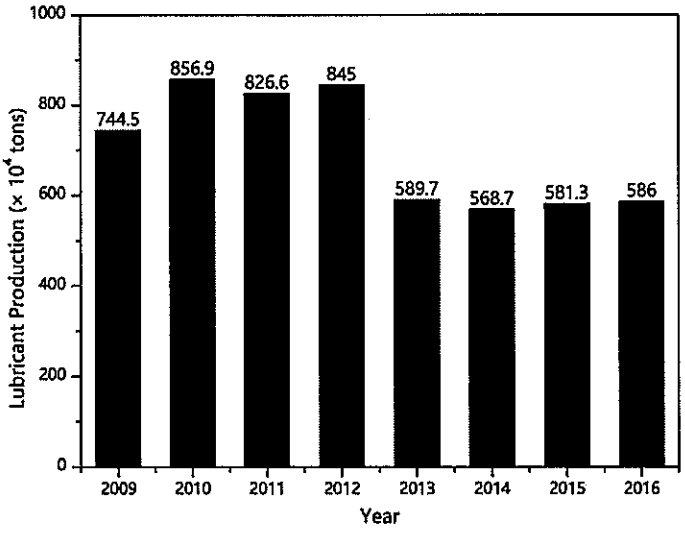
[1] https://www.statista.com/statistics/411616/lubricants-demand-worldwide/

⇒ Forecast of China's Passenger Car



By Victor Li in WRF 2016

⇒ Lubricants Production in China



- These four years, lubricants production in China has beome stable.
- After 5000 kilometers' running, lubricant need to be changed.
- Recycled lubricant is less than 20% of the waste oil.

[1] http://www.chyxx.com/industry/201706/528177.html.

⇒ Waste Oil Recycling Technology

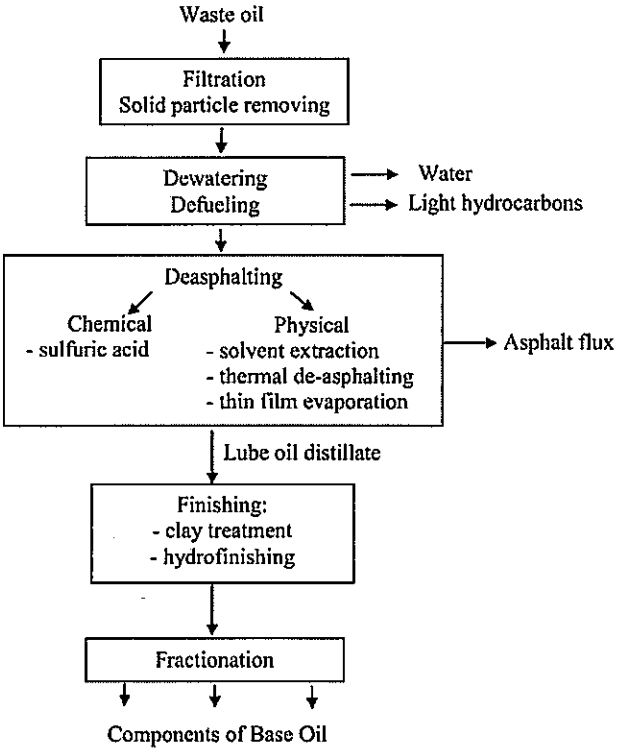


Fig. 1 The rerefining process of the used oil

- The recycling of waste oils can be accomplished with three methods: used oil reprocessing, reclamation and rerefining.
- reprocessing and reclamation → low quality → heating and fuel oils
- rerefining → high quality → base oils

[1] Kupareva A, et al. Journal of Chemical Technology & Biotechnology, 2013, 88(10):1780-1793.

⇒ Acid-clay Rerefining Process

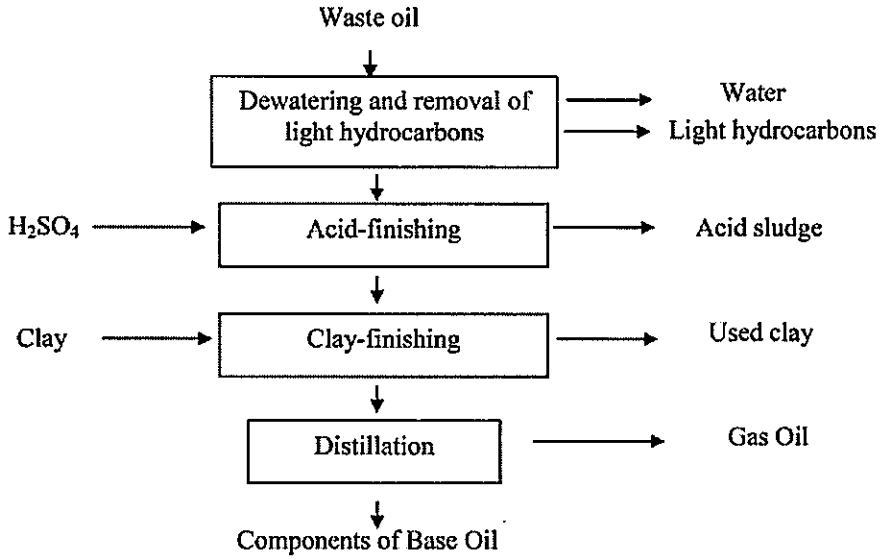


Fig. 1 Acid-clay rerefining process

- Low quality
- Low capital costs and simplicity of operations

[1] Kupareva A, et al. Journal of Chemical Technology & Biotechnology, 2013, 88(10):1780-1793.

⇒ Hylube Process

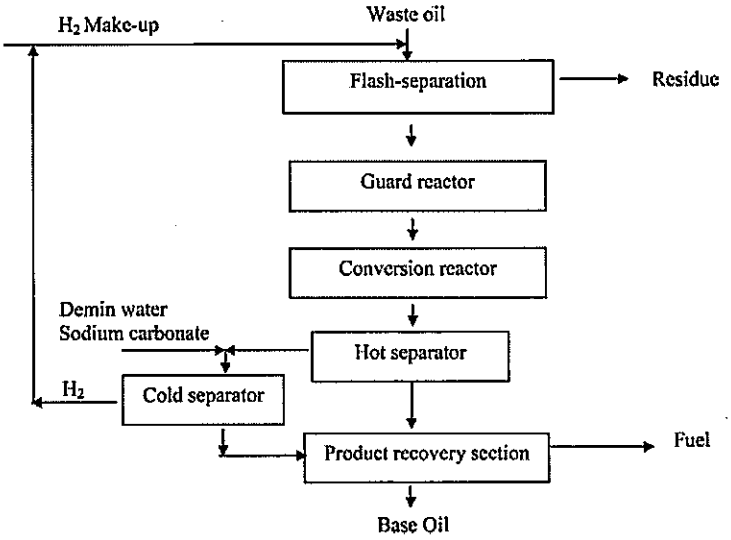


Fig. 1 Hylube process

- About 44% of the total used oil capacity goes to base oil production.
- Achieves more than 85% lube oil

[1] Kupareva A, et al. Journal of Chemical Technology & Biotechnology, 2013, 88(10):1780-1793.

⇒ Solvent Extraction Process

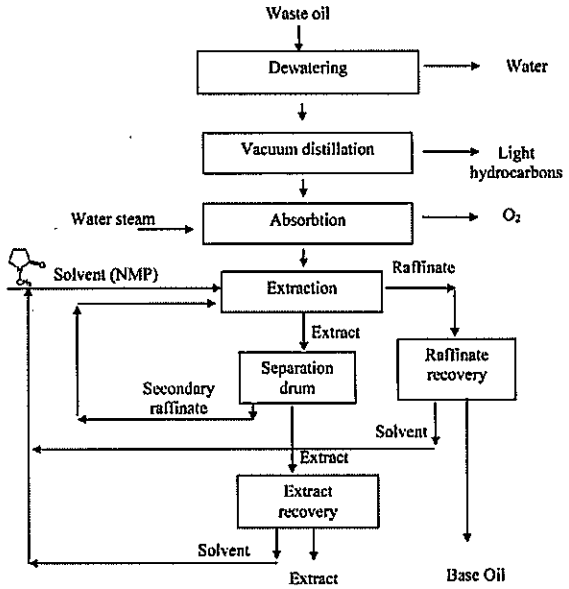
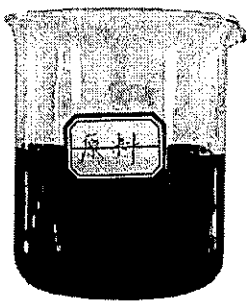


Fig. 1 MRD solvent extraction process using N-methyl-2-pyrrolidone

- High quality
- The average base oil yield within the process is about 91%.

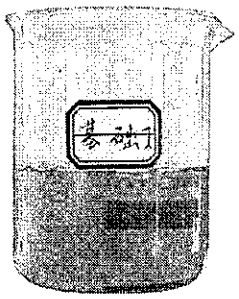
[1] Kupareva A, et al. Journal of Chemical Technology & Biotechnology, 2013, 88(10):1780-1793.

⇒ Demo——Dongying Guo'an Chemical Co., Ltd.

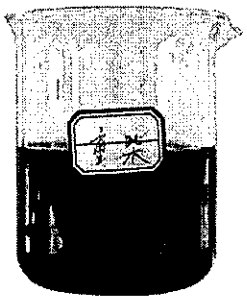


Used oil

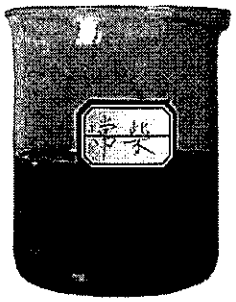
Asphalt oil



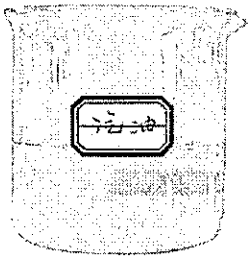
Based oil



Heavy oil



Diesel oil

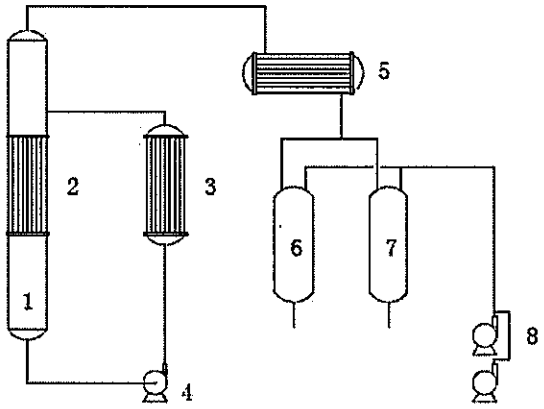


Petrol

- Technologies: solvent extraction, thin film evaporation, hydroprocessing……

[1] http://www.sdguoan.cn/

⇒ Three Steps of Hydroprocessing



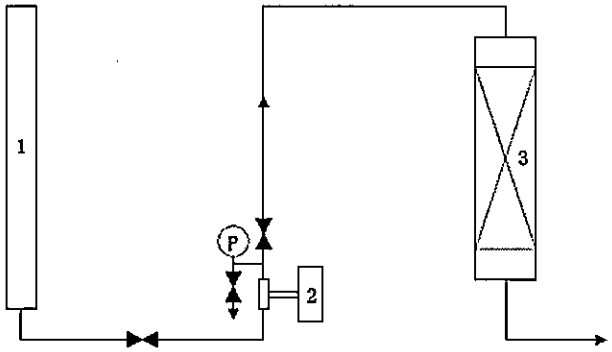
1. Distillation column 2&3. Evaporator 4. Circulating pump

5. Condenser 6&7. Product receiving tank 8. Vacuum pump

Fig. 1 Distillation flow chart

- Removing water, metals and mechanical impurities

⇒ Three Steps of Hydroprocessing

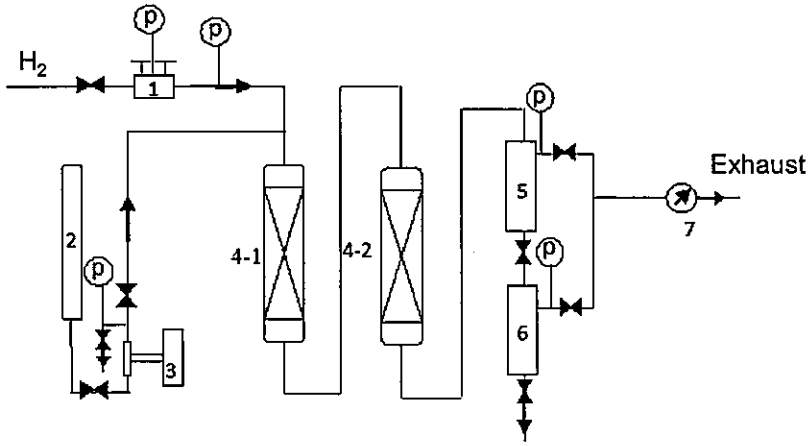


1. Metering tube 2. Metering pump 3. Adsorptive Reactor

Fig. 1 Adsorption flow chart

- Removing most asphaltene and a few metals remained after distillation.

⇒ Three Steps of Hydroprocessing



1. Pressure regulator 2. Metering tube 3. Metering pump 4. Reactors
5. High-pressure separator 6. Low-pressure separator 7. Gas flowmeter

Fig. 1 Hydroprocessing flow chart

- Removing sulfur, oxygen and nitrogen in base oil.
- Saturating alkenes and arenes.

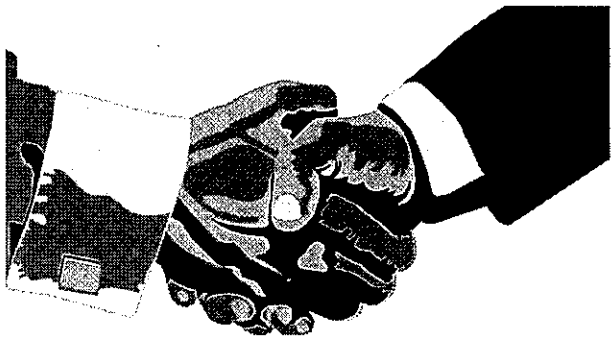
⇒ Summary

➢ Compared with the large amount of waste oil, recycled lubricants is still very few. It is necessary to develop new technology to dispose waste oil.

➢ Various technologies have been applied to regenerate waste oil, such as solvent extraction process, hydroprocessing and thin film evaporation.

➢ Among these technologies, hydroprocessing is one of the most attractive method, giving product oils of high quality. It can achieve the highest oil conversion and yield and has been successfully used in industry.

Thank You for Your Attention!



IN TOUCH WITH TOMORROW

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Increasing complexity in autocat recycling

Thierry Van Kerckhoven, Elwin Meng, Dennis Fontijn, Colton Bangs
Electronics & Cars Recycling WRF
November 14 – 17, 2017, Macau, China

Introducing Umicore

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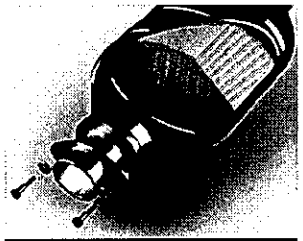
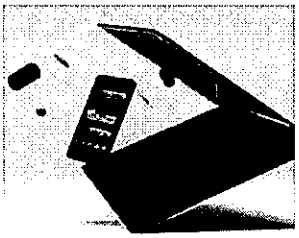
Precious Metals Refining

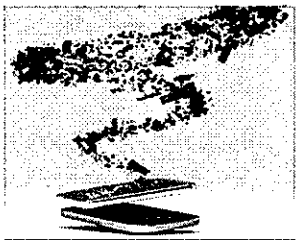
A global materials technology and recycling group



One of three global leaders in emission control catalysts for light-duty and heavy-duty vehicles and for all fuel types



A leading supplier of key materials for rechargeable batteries used in portable electronics and hybrid & electric cars



The world's leading recycler of complex waste streams containing precious and other valuable metals

Agenda

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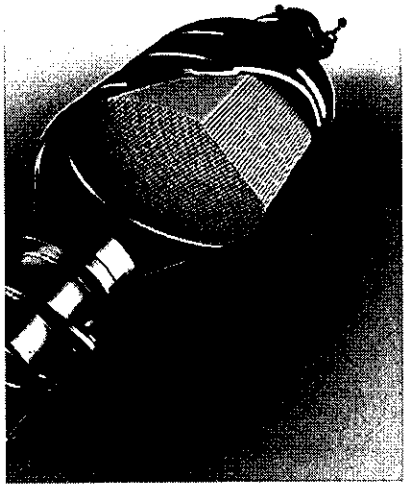

- **Diesel Particulate Filters (DPFs)**
- DPF market size
- DPF recycling at Umicore
- Conclusions

Developments in EU light duty diesel

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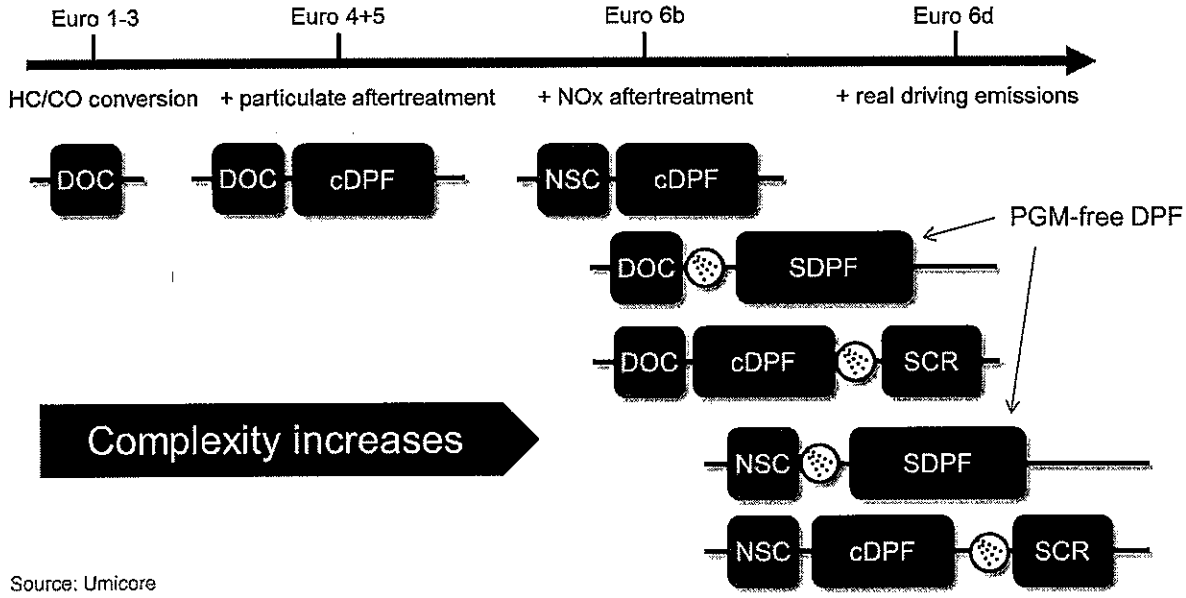
Exhaust systems are becoming more complex



Source: Umicore

Focus on Diesel Particulate Filters (DPFs)

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Material characteristics depend on vehicle class

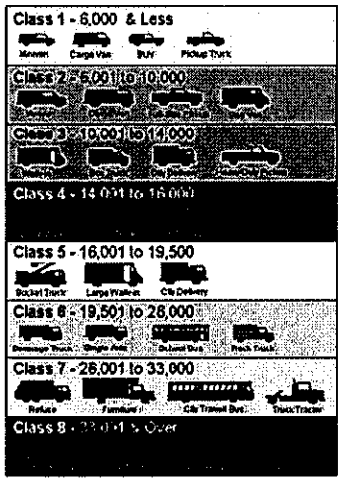

Photo source: FHWA

Vehicle class	Substrate	Unit weight	PGM loading
Light Duty (Class 1-2a)	• SiC • AT	2-3 kg	>10g/ft3
Medium Duty (Class 2b-3)	• SiC • AT	~8 kg	~5 g/ft3
Heavy Duty (Class 2b-8)	• Cordierite • AT • SiC	10-13 kg	~1 g/ft3

Info source: Umicore estimates

SiC = Silicon Carbide, AT = Aluminium Titanate, Cordierite = Aluminium Silicate

DPFs introduce recycling challenges

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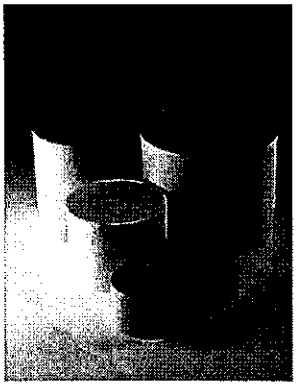
Linked to substrate material and PGM-content

1. DPFs use **different substrates**
   - Traditional autocats (TWC, DOC): cordierite
   - DPFs: SiC, AT, cordierite
2. SiC-DPFs are **2-3x heavier**
3. SiC-DPFs can complicate the smelting process in recycling due to **high carbon content**
4. Not all DPFs are **PGM-coated**, examples:
   - Early DPFs in EU
   - More recently SCR-DPFs in EU and US



SiC (top), cordierite (others)
Photo source: Umicore

DPF technologies and PGMs

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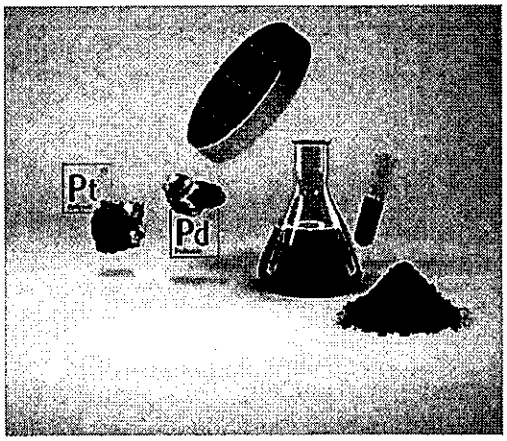
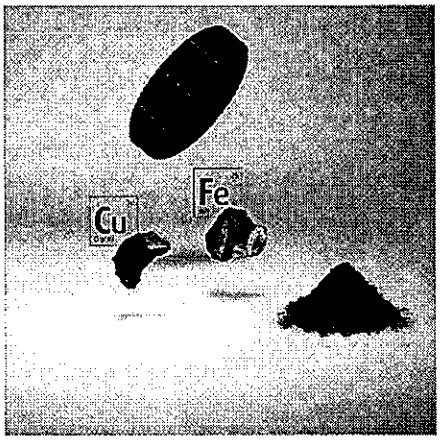
Catalyzed DPFs are PGM-containing (left)
SCR-DPFs used for NOx control are not PGM-containing (right)





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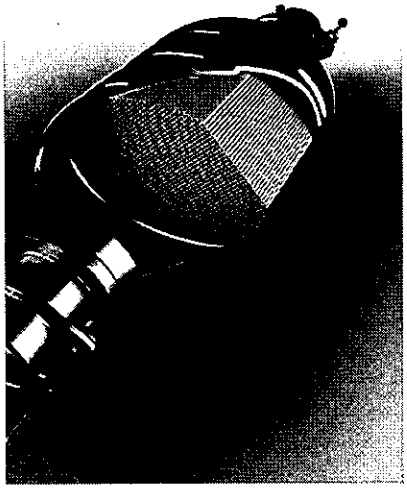

- Diesel Particulate Filters (DPFs)
- **DPF market size**
- DPF recycling at Umicore
- Conclusions

Light duty diesel production

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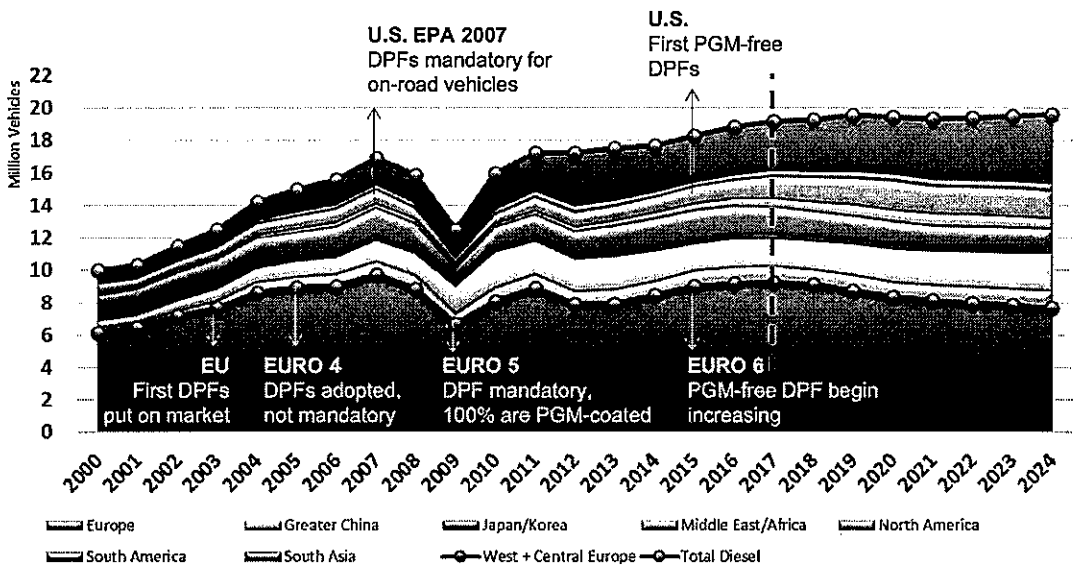
Growing DPF market driven by vehicle production and regulation



Source: IHS (April 2017), Umicore

SiC-substrate autocats put on market

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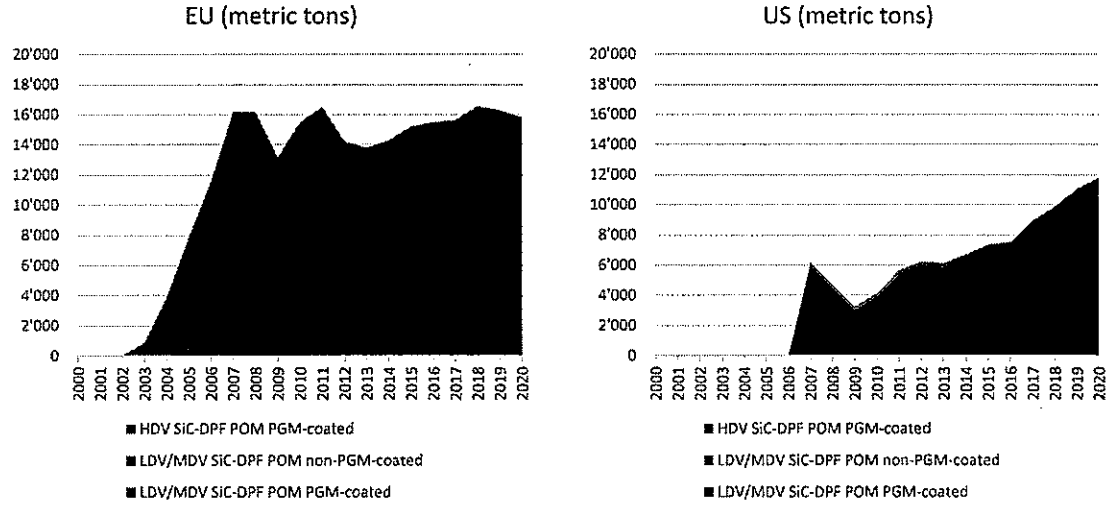
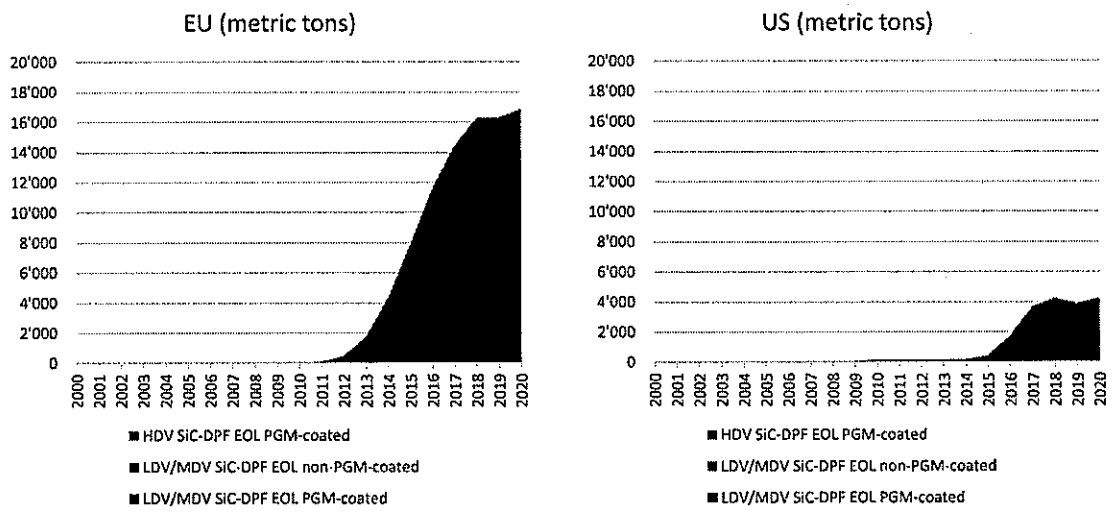
Metric tons SiC-DPF in EU and US



Source: Umicore estimates

SiC-substrate autocats at end-of-life

Metric tons SiC-DPF in EU and US



Source: Umicore estimates

Market sizing observations

End-of-life DPFs are growing rapidly

- We are in a period of steep growth for SiC-DPF recycling with increasing tonnages reaching end-of-life (though not all are available for recycling)
- EU end-of-life tonnage of light duty SiC-DPF should eventually peak at around 15 kt/y (33 Mlbs/y) and then PGM-coated material for recycling will decline due to the current switchover to SCR-DPF
- US end-of-life tonnage will be significant but lower in PGM-content because it is mainly driven by medium duty, however less PGM-free DPFs are expected compared to EU
- Gasoline particle filters have just entered the market and so will become available for recycling in a decade

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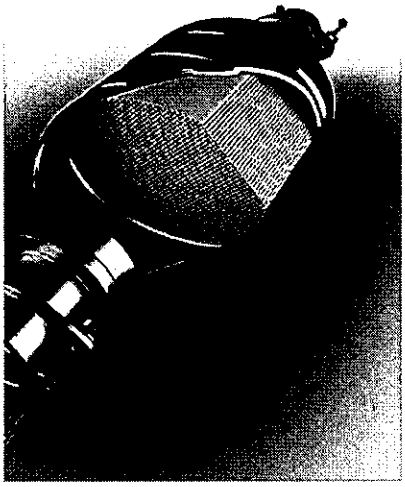

- Diesel Particulate Filters (DPFs)
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- **DPF recycling at Umicore**
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Umicore's refining offer for DPF catalysts

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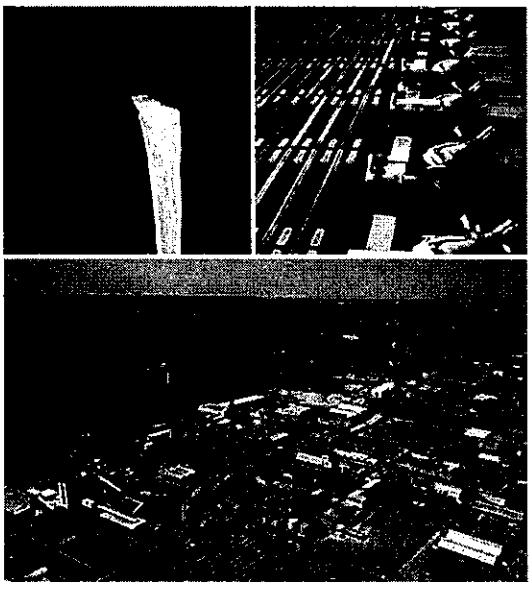
Our process flexibility allows for significant SiC intake

- Umicore Precious Metals Refining has been refining spent automotive catalysts for decades
- Our high flexibility in processing complex materials is now increasingly applied to SiC-DPFs
- Umicore's suppliers benefit from:
  - High tolerance for carbon content
  - Acceptance of mixed autocat lots (no pre-separation required)
  - No change in recovery rates, sampling & assaying and environmental performance



Refining @ UPMR

Our process in a nutshell

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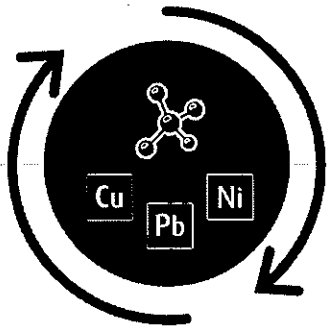
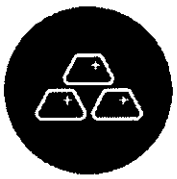
Recyclables

Industrial by-products

Collector metals



17 different metals



Refining @ UPMR

Recyclables

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Electronic Scrap

e.g.
mobile phones
printed circuit boards

Spent Automotive Catalysts

end-of-life car catalysts

Spent Industrial Catalysts

industrial catalysts from oil refining & petrochemical industry

Other precious metal bearing materials

e.g.
fuel cells
photographic residues

Refining @ UPMR

Industrial by-products

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	Pb Zn	Cu	Ni PGM	Precious Metals
WET	e.g. lead sulphate	e.g. electrolysis slimes	e.g. hydroxide	e.g. filter cake
LUMPY/ METALLIC	e.g. drosses	e.g. mattes	e.g. slags	e.g. impure bullion
DUSTY/ FREE-FLOWING	e.g. fine drosses	e.g. complex concentrate	e.g. flue dust	& many more

Refining @ UPMR

Sampling & assaying

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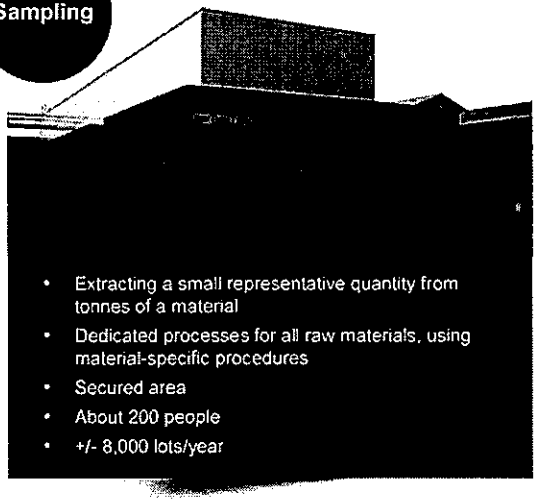
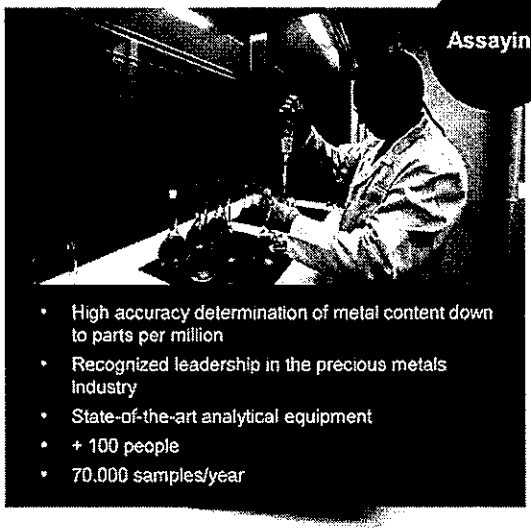
Sampling



- Extracting a small representative quantity from tonnes of a material
- Dedicated processes for all raw materials, using material-specific procedures
- Secured area
- About 200 people
- +/- 8,000 lots/year

Assaying



- High accuracy determination of metal content down to parts per million
- Recognized leadership in the precious metals industry
- State-of-the-art analytical equipment
- + 100 people
- 70.000 samples/year

Refining @ UPMR

We support throughout the process

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- **Logistical** and **tax** assistance
- Clear **individual metal accounts** reflecting all results of the metal transactions
- **Physical return** or **repurchase** of refined metals
- **Risk management** through forward pricing, limit orders and other solutions
- **Special services** such as regular metal statement, metal account transfers, ...

Umicore key strengths

For autocat recycling and more...

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Flexibility	**Material compositions & complexity –** our flexible process allows us to treat the widest range of materials in the industry and respond to market conditions
Sampling & assaying	**Accuracy & transparency –** our robust process for determining customer return is trusted throughout the industry and is used to optimise processing
High metal recovery	**Efficiency & impurity management –** our unique and complex flowsheet enables a highly efficient recovery of PGMs from both primary and secondary sources
Innovation	**Technology & environment –** our focus on continuous optimisation and new process innovation opens doors to the recycling markets of tomorrow

Agenda

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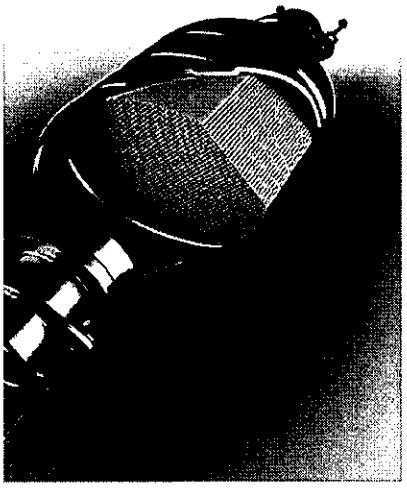

- Diesel Particulate Filters (DPFs)
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Conclusions

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Increasing complexity requires specialized refiners

- The market for DPF recycling is expected to grow sharply in the next 3-4 years
- DPFs will "contaminate" the autocat recycling stream for years to come, bringing new materials such as SiC into recycling processes
- In the longer-term, PGM-free DPFs will increasingly enter the recycling chain bringing additional challenges to recyclers
- Umicore is well-equipped to handle the added complexity that DPF brings to the autocat stream and will continue to offer its competitive refining terms

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Precious Metals Refining

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Thank you