Mining the Urban Environment: Rare Earth Magnets in ASR

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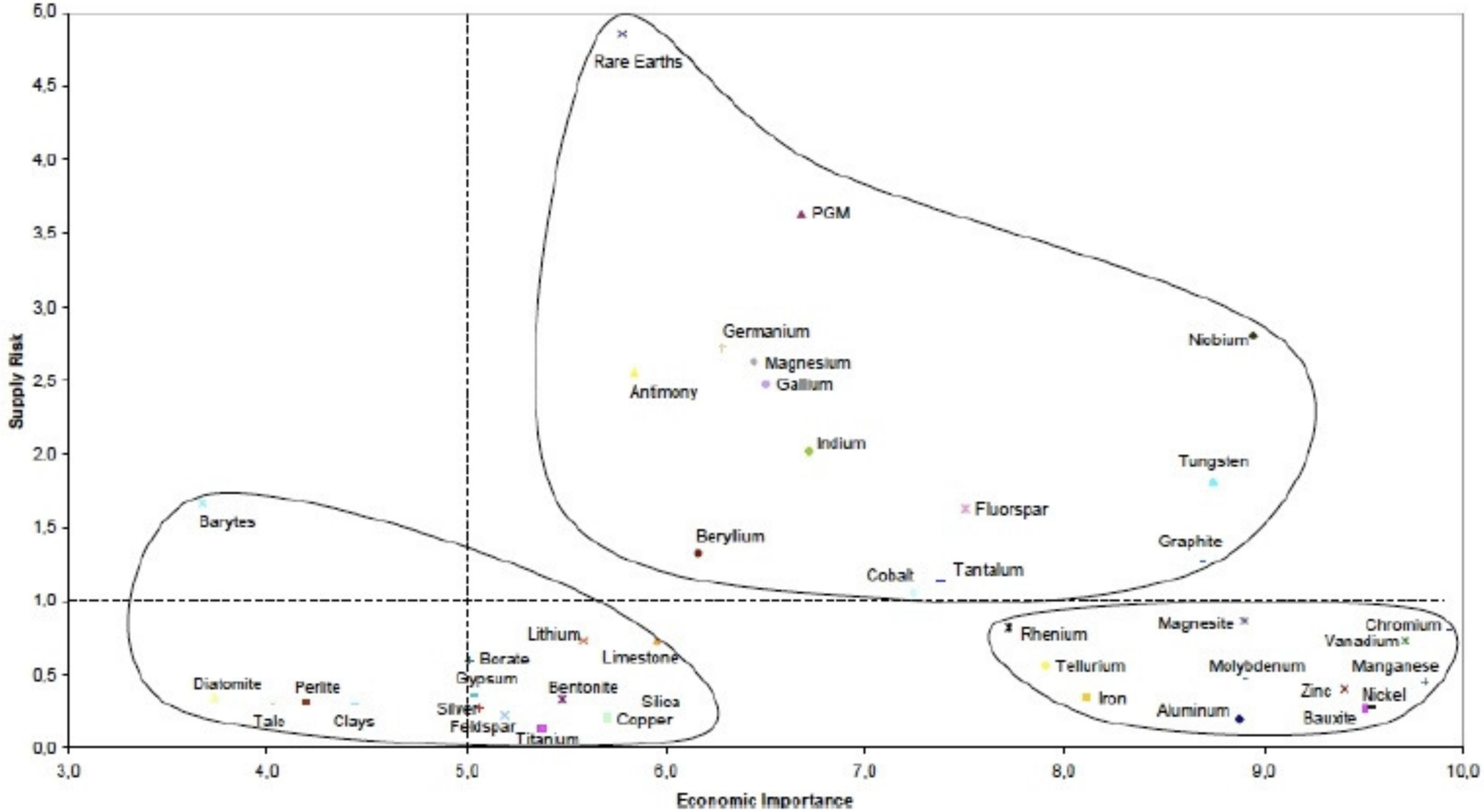
Why recycle?

Figure 2 shows where several elements and materials are placed in terms of supply risk and economic importance. The strategic metals being investigated are those in the upper right bubble on the graph. They are considered to be of high supply risk and economic importance.

Fig

Figure 2 Strategic metals[1]



Mining the Urban Environment?

- Examples:
- Recycling of Autocatalyst. (industry well established)
- Recovery of PGM"s from road dust.
- Recycling of specific items from cars: Battery(Pb), Autocat (Pt,Pd,Rh), Radiator (Cu).
- Processing of WEEE. (Cu+Ag+Au+PGM"s)
- Battery recycling (Li) +others.
- Plastic and glass recycling

Example :PGM from road dust

Case Study

- Pt,Pd.Rh can be produced from various urban wastes. Road dust, medical waste, recycled autocat.
- Road dust is collected from specific sites around UK.
- PGM level can be similar to South African mine.
- Dust processing via mineral processing techniques and pgms leached out.
- Plants running in UK. (Veiola).
- Research pioneered at UofB.

Primary Sources of REE

Significant ores:

- Steenkampskraal at 14%;
- Mount Weld at 10 %,
- Mountain Pass at 6 %
- Cut of grade 5% depending on mineralogy

- The Ion-Adsorption Clay deposits (Longnan, China) have the rare earth elements extracted by a completely different method from the classic processes for hard rock and their TREO contents vary from around 0.3% to 1.0%. The extraction process economics and the concentration of the scarcer elements change the feasibility judgement for these deposits.

Advantages of Urban Mining

For	Against
• Less processing • Lower carbon footprint • Higher grades • Less cost per tonne of material • Transport reduced • Sustainable production in light of increased demand for metals. • Allows strategic plan for country.	• Can de-stabilise metal markets and effect primary producers. (PGM). • Processing can occur in build up areas.

Mineral occurrence of REE

REE are found in almost all mineral groups including:

- silicates (e.g. eudialyte, allanite, zircon,),
- fluoro-carbonates (e.g. bastnaesite),
- oxides (e.g. euxenite, fergusonite, pyrochlore,)
- phosphates (e.g. xenotime, apatite).

Currently three mineral species, i.e.

- bastnaesite, a LREE fluorocarbonate (China and USA)
- monazite, a LREE/HREE phosphate (Australia)
- xenotime, a HREE yttrium phosphate (Malyasia)

as well as lateritic ore containing HREE rich ion adsorption clays in China are exploited commercially. Besides, loparite is processed in Russia to extract REE enriched in the Lovozero Complex.

Mine operations

Primary production

- There are two major REE ore minerals from which LREE can be extracted **bastnaesite** and **monazite**.
- **Bastnaesite**, a fluorocarbonate mineral and **monazite**, a phosphate, contain predominantly either cerium, lanthanum or yttrium.
- **Mountain Pass** (California, USA), operated by Molycorp, contains bastnaesite ore as part of a carbonatite body (8-12 % REO) intruded into gneiss.

Mineral Processing

- **The Mount Weld** (southern Western Australia) REE deposit shows generally high LREE/HREE ratios with locally enriched HREE and yttrium.
- Physical concentration of the REE minerals is performed at Mount Weld. The run of mine material is subjected to crushing, grinding and flotation to produce a concentrate with a grade of **40% REO**.

Typical Primary Monazite

Rare Earths: Mineralogy

Typical Chemical Composition and REO-Distribution in Monazite (Ce, La, Nd, Th) PO_4

Chemical composition	
SiO_2	1,00 %
Fe_3O_4	0,32 %
TiO_2	0,36 %
P_2O_5	27,03 %
ThO_2	10,50 %
U_3O_8	0,04 %
$(RE)_2O_3$	61,57 %

Rajendran et al. 2008

REO Composition	
Lanthanum	23,05 %
Cerium	31,74 %
Praseodymium	6,59 %
Neodymium	20,37 %
Samarium	6,95 %
Gadolinium	4,74 %
Yttrium	6,56 %
Dysprosium	
Europium	
Terbium:	*traces*

Soe et al. 2008

Monazite crystal

Worldwide Distribution

Rare Earth: Deposits

Major deposits world wide

Location No.	Location Name	Deposit Type	Location No.	Location Name	Deposit Type
1	Bayan Obo, China	Fe-REE-Nb deposit	11	Orissa, India	Monazite by-product, coastal placers
2	Weishan, China	Bastnasite-barite veins	12	Eneabba, Australia	Monazite by-product, coastal placers
3	Maoniuping, China	Bastnasite-barite veins	13	Capel and Yoganup, Australia	Monazite by-product, coastal placers
4	Xunwu and Longnan, China	Lateritic clay	14	Mount Weld, Australia	Lateritized carbonatite
5	Chavara, India	Monazite by-product, coastal placers	15	Dubbo, Australia	Altered alkaline complex
6	Perak, Malaysia	Xenotime by-product, tin placers	16	North Stradbroke Island, Australia	Monazite by-product, coastal placers
7	Mountain Pass, USA	Bastnasite-barite carbonatite	17	Elliot Lake, Canada	Uraniferous conglomerate
8	Lovozero, Russia	Loparite in peralkaline complex	18	Green Cove Springs, USA	Monazite by-product, placer
9	Aktyus, Kyrgyzstan	Polymetallic deposit	19	Camaratuba, Brazil	Monazite by-product, coastal placers
10	Northern Sri Lanka	Monazite by-product, coastal placers	20	Steenkampskraal, South Africa	Monazite-apatite vein

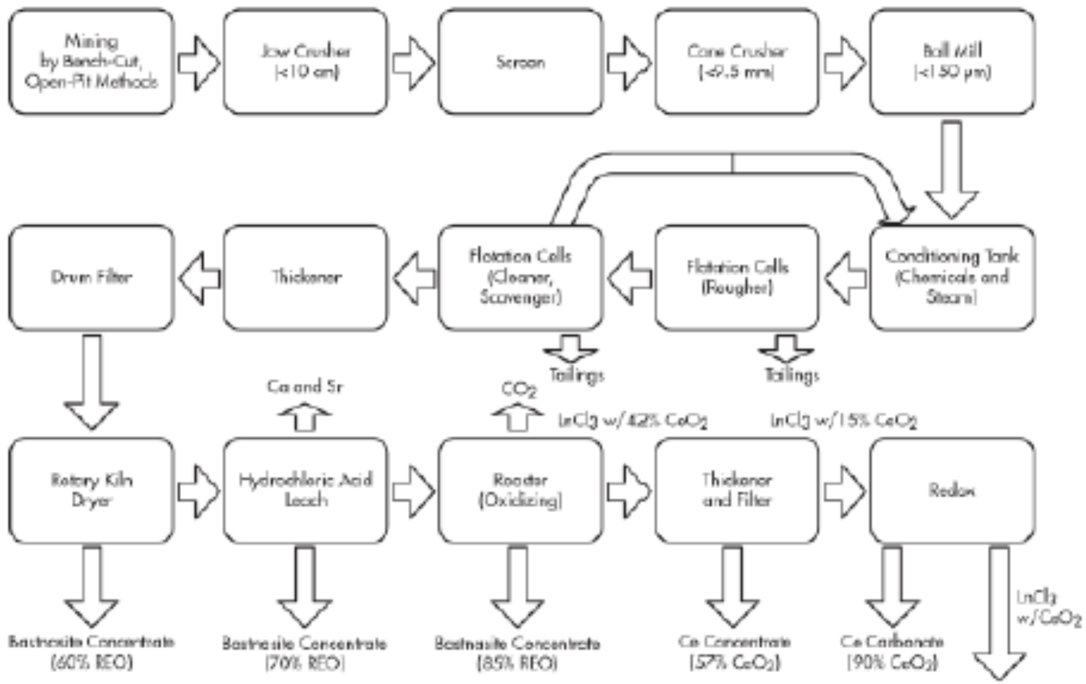
Source: Castor & Hedrick 2006

Processing routes

Rare Earths: Processing

Bastnasite: Minerals Concentration and REO Extraction (Mountain Pass, California)

- Mechanical Liberation
  crushing, milling, scrubbing, drying, screening
- Physical separation
  flotation, electrostatic, magnetic, gravity separation or processes
- Chemical extraction
  acid leaching, digestion, roasting, hot chlorination (loparite) or baking



Source: Castor & Hedrick 2006

Mix of REE"s in different deposits(Lehmann)

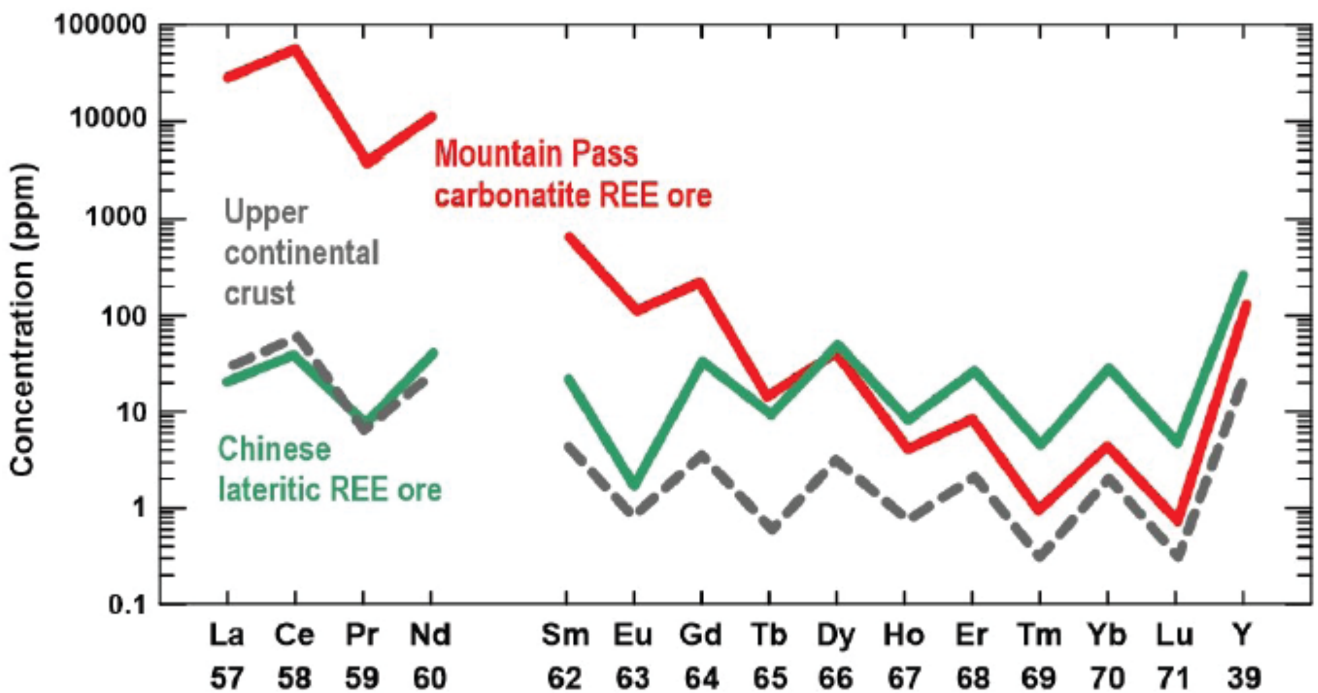
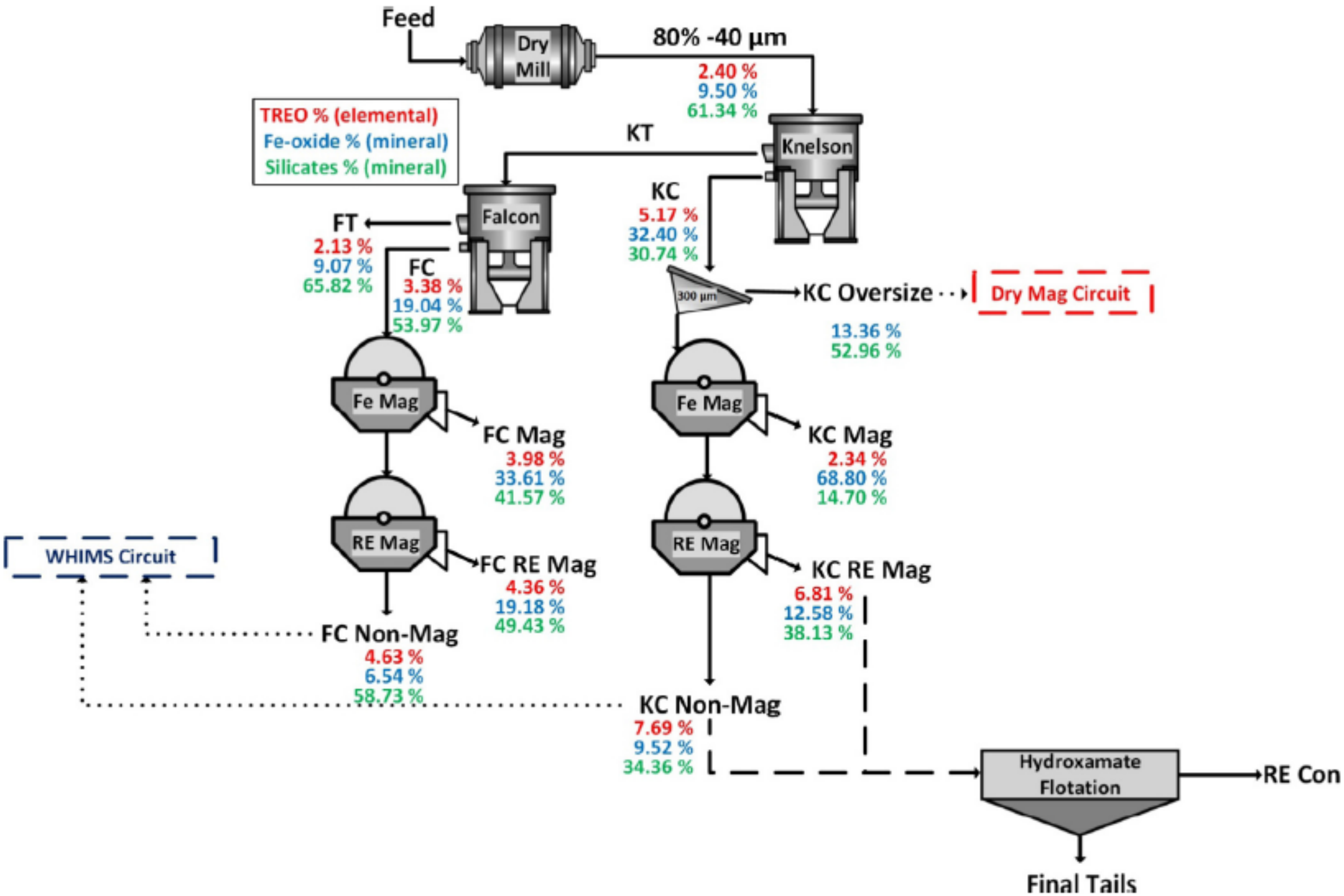


Figure 2: Abundance patterns of the rare-earth elements in the average upper continental crust and in two representative REE ore types, i.e. high-grade carbonatite ore from Mountain Pass, USA, and lateritic ion-adsorption ore from southern China. The gap at atomic number 61 is due to the fact that promethium has no long-lived or stable isotopes and does not occur in natural materials. From Haxel et al. *(2002).*

Development flowsheet for deposit in Canada



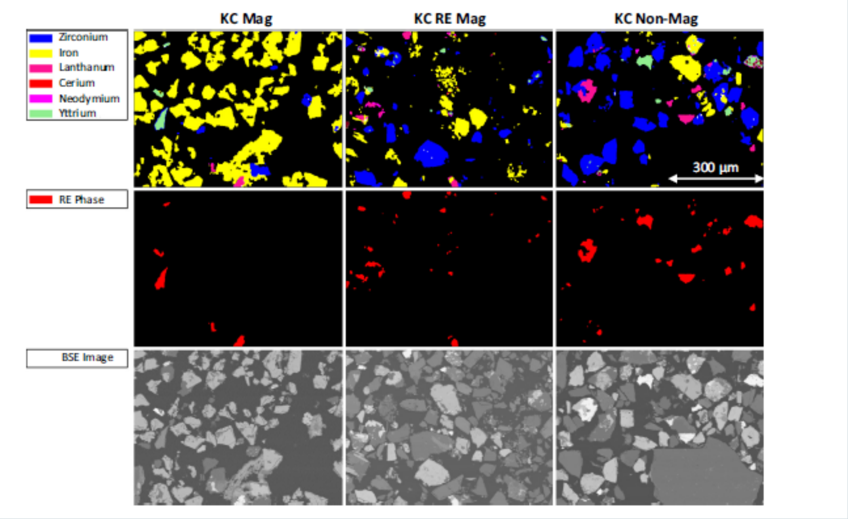
Canadian REE deposit

New deposit mineralogy

Table 1
Nechalacho deposit mineralogy (in wt%) as determined by QEMSCAN after Jordens et al. (2015).

Mineral name	Total	+20 µm	−20 µm
REM			
Zircon	7.14	9.47	5.47
Bastnäsite	0.93	1.23	0.71
Synchysite	0.55	0.27	0.75
Allanite	0.58	0.68	0.52
Columbite (Fe)	0.42	0.59	0.31
Fergusonite	0.22	0.13	0.29
Other REM	0.49	0.18	0.71
Silicate gangue			
K-Feldspar	21.84	23.39	20.73
Quartz	20.90	19.87	21.64
Plagioclase	18.59	25.62	13.53
Biotite	13.18	5.32	18.84
Other gangue			
Fe-oxides	9.50	9.37	9.59
Ankerite	2.87	1.58	3.80
Calcite	0.64	0.51	0.73
Fluorite	0.55	0.46	0.62
Other gangue	1.59	1.33	1.78

Distribution of REE



Primary versus Secondary ?

Primary	Secondary
• Majority of production in China. • Volatile metal prices. • Expensive development costs. • Unwanted minerals (Th, Ce)	• Local supply. • Lower start up costs • Recycle further up production process. • Other value added components (Al,Cu,)

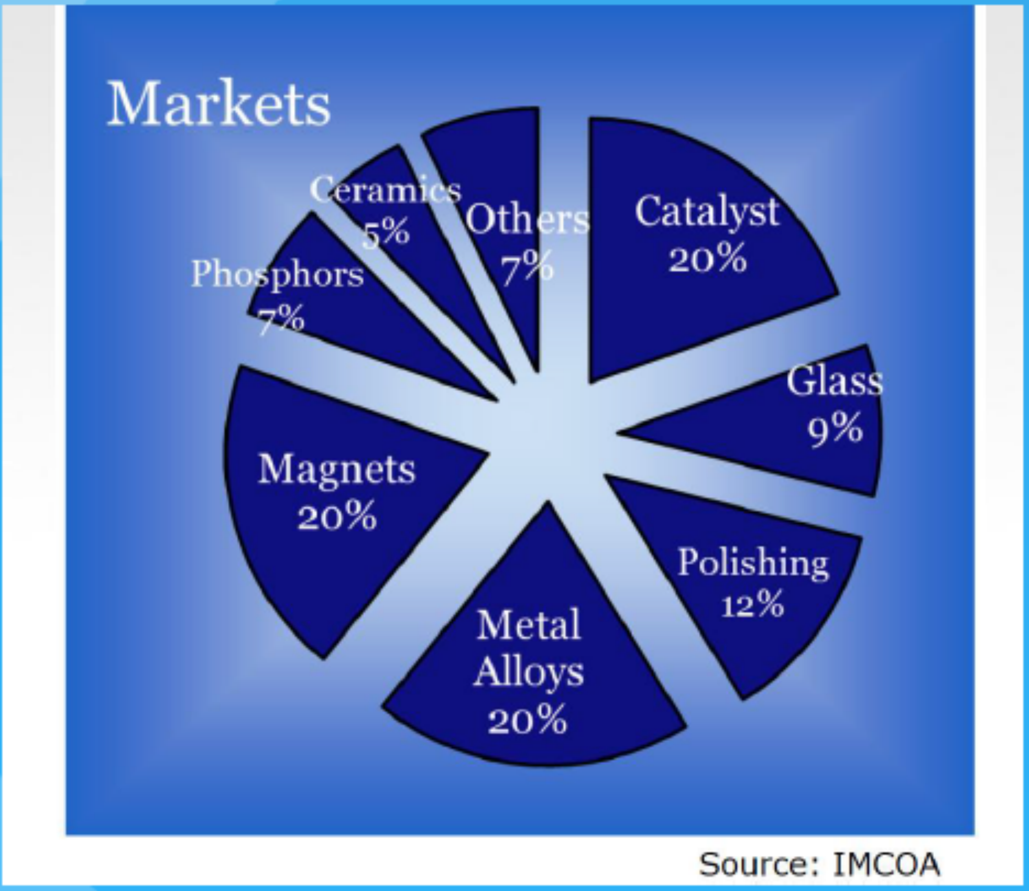
Environmental impact of REE processing

The lake of toxic waste at Baotou, China, which has been dumped by the rare earth processing plants in the background. Mail on-line, 10th Feb 2011

Mail on-line, 10th Feb 2011

Markets for REE

Rare Earth Metals -
Sc
Y
La
Ce
Pr
Nd
Pm
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu



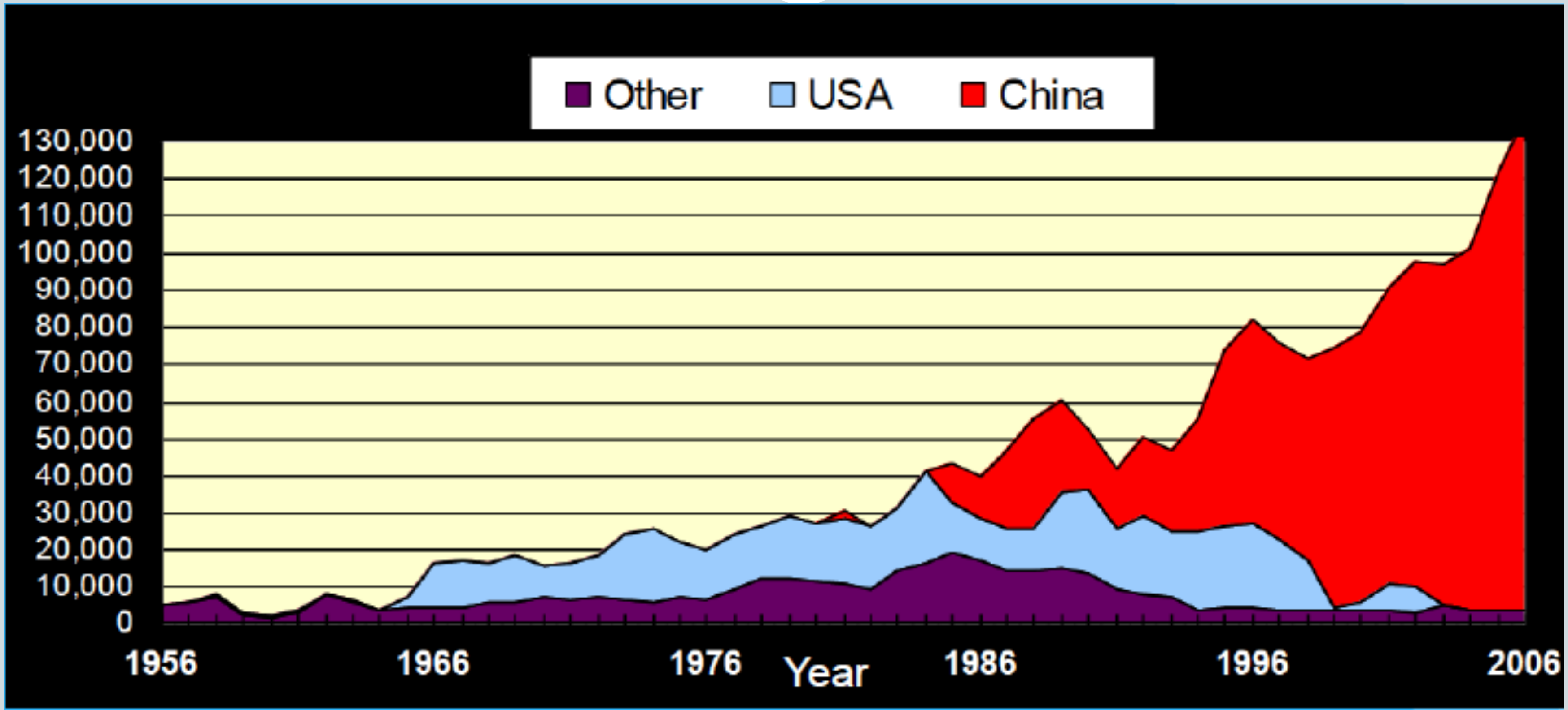
By value, magnets = 37% of world demand for rare earths

Typical Key REE for Magnets

	Current and Imminent	All Mines On List
Nd	13.6	14.4
Pr	4	4.1
Dy	3.1	3
Tb	0.5	0.5
Sm	2.1	2.5
Totals	**23.3**	**24.5**

Data is from 11 working mines. There are 20 mines listed by USGS with chemistries.

Production Changes Historical Perspective



Source – Stan Trout, Molycorp, from presentation at UK Magnetics Society

Car Scrap processing

- In nearly all areas of scrap metal processing, standard minerals processing unit operations are used to liberate the “values” and separate them from the “gangue”. A car scrap processing plant is a typical example as there is a large amount of cheap (£23/tonne) raw material available inmost of the UK and in all areas of the USA.

Preparation and analysis of raw materials

Prior to processing, the scrap yard would remove the following:

•Radiator – high in copper so would be sold on to IMI for example.

•Catalytic converter – contains precious metals (Platinum, Palladium etc.) which would go to Johnson Matthey for example.

•Tyres – for reuse, retreading or recycling.

In addition the petrol tank should be removed as this poses a safety risk. What is left is cubed and consists of:

Ferrous metal	75%
Aluminium	3%
Copper	1%
Copper wire	0.2%
Zinc	0.1%
Glass/stone/ Non-combustible waste	10%
Plastic/Rubber/Combustible waste	10%

If recycled at 100% efficiency this would yield a profit of approx. £20 per car (i.e. 90% profit)

Processing of the cars.

1. Comminution

The first stage of processing is to liberate the various materials by comminution. This is usually carried out in a shredder/ large scale hammer mills which shear the metals, plastics and rubber into fragments of 10cm to 4mm in size. Glass and stone are shattered and as such are generally finer. If used, with screening, the feed can immediately be upgraded.

https://youtu.be/lXfitusZ9qY

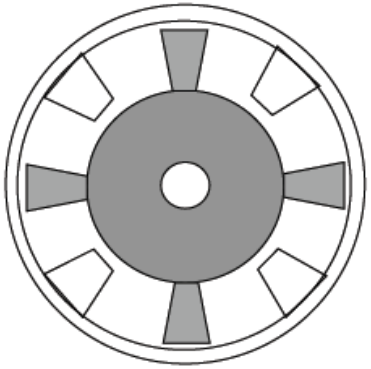
Shredders can process up to 300 tonnes per hour and are the major investment in the plant costing in excess of 1 million pounds.

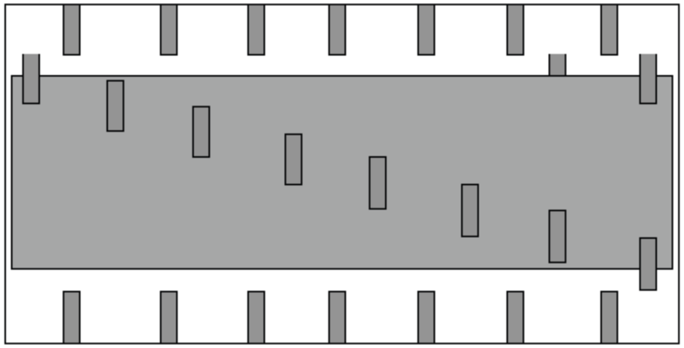
Size Reduction

Processing Methods – Comminution.

Hammer mills.

A hammer mill consists of a cylinder covered in hardened steel "hammers" which rotates causing impact and shearing actions on the media to be treated. Often the casing has fixed hammers to increase shearing action.





Hammer mill/Shredder

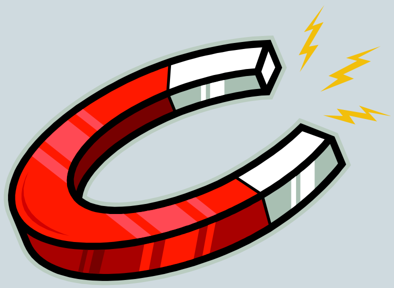
Processing of the cars.

2. Magnetic separation

Magnetic separation is the second stage in the plant.

It can be carried out as a wet process to help remove dirt and fluff and suppress dust from shredding. However normally dry: over-band and conveyour pulley separators : Removes mild steel.

75% of stream is ferromagnetic and is removed here therefore further processing is on a much smaller scale.



Processing of the cars.

3. Screening

This stage is important for both sizing the material for further processing and for the removal of waste. Trommel screens are used as they rotate and are less susceptible to blinding.

Typical fractions removed are:

+100mm	High in metallics – hand sorted
-100mm+16mm	High in metallics dense media separation
-16mm +4mm	~40% metallics –jigging
-4mm	high in stone, glass, fluff, plastic :small metallics

As most of the ferrous metals have been removed density separation is used to upgrade the non ferrous metals.

Size separation of auto shredder residue

Vibratory screen

Trommel screen

Processing of the cars.

4. Density separation methods

To remove non ferrous metals from waste material. Higher density than plastic, stone, rubber and glass.

Ballistic separation –Material is thrown from a conveyor and air jets blow the light material into one hopper while heavier more dense materials are carried further.

Jigging – Can remove plastics, rubber, glass, and stone from the materials. Usually carried out in stages.

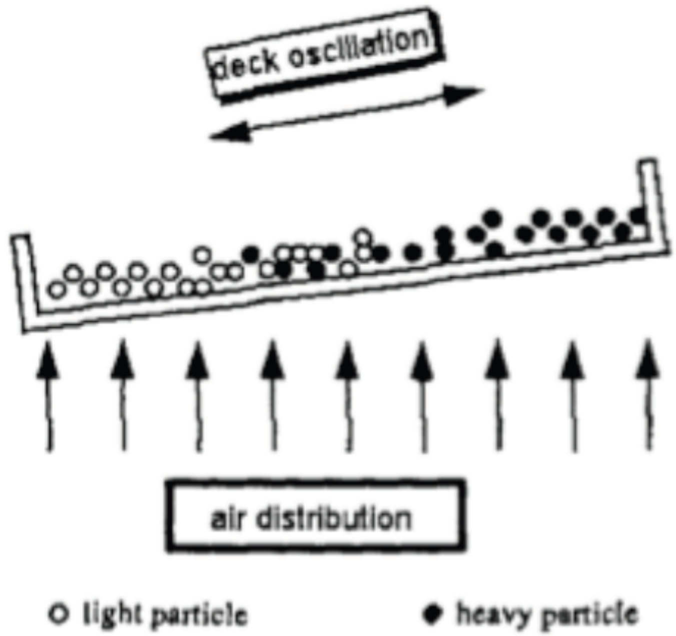
Elutriation – Material is dropped into a rising current of water or air. Heavy more dense materials sink to the bottom while lighter materials are carried over the top.

Dense media separation – Drum type separators used to separate copper rich fraction. Main method of non-ferrous metal upgrading. Magnetic fluid dense media separation is being developed which involves using magnetic media in a high magnetic field. Simulated media densities of up to 10 can be achieved allowing separation of lead from copper.

Disadvantage is loss of aluminium to lights waste stream.

Gravity Separation: Air Table

Processing Methods – Gravity Separators.



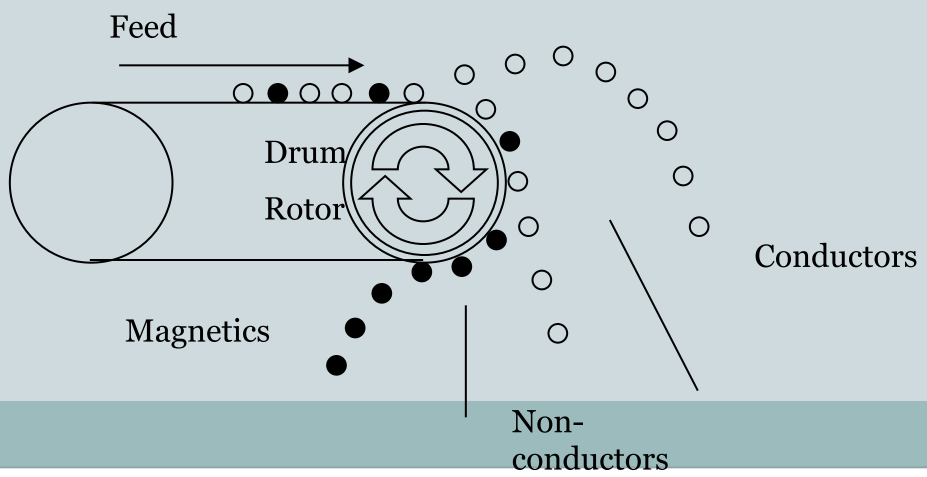
Pneumatic Table

Source: Resource Recovery & Recycling from Metallurgical Wastes, by Rao

Processing of cars.

5. Eddy current separation

Based on the conductivity/density ratio of non-magnetic materials. The separators consist of a conveyor with a rotating high intensity magnetic drum in the end pulley. This induces a current in the conductive material on the conveyor which causes the particles to act as similar pole electro magnets and as such repel the drum magnet. As a result, the conductors “jump” from the end of the pulley whilst non-conductors simply drop of the end. Any magnetic material that sticks to the pulley is brushed off.



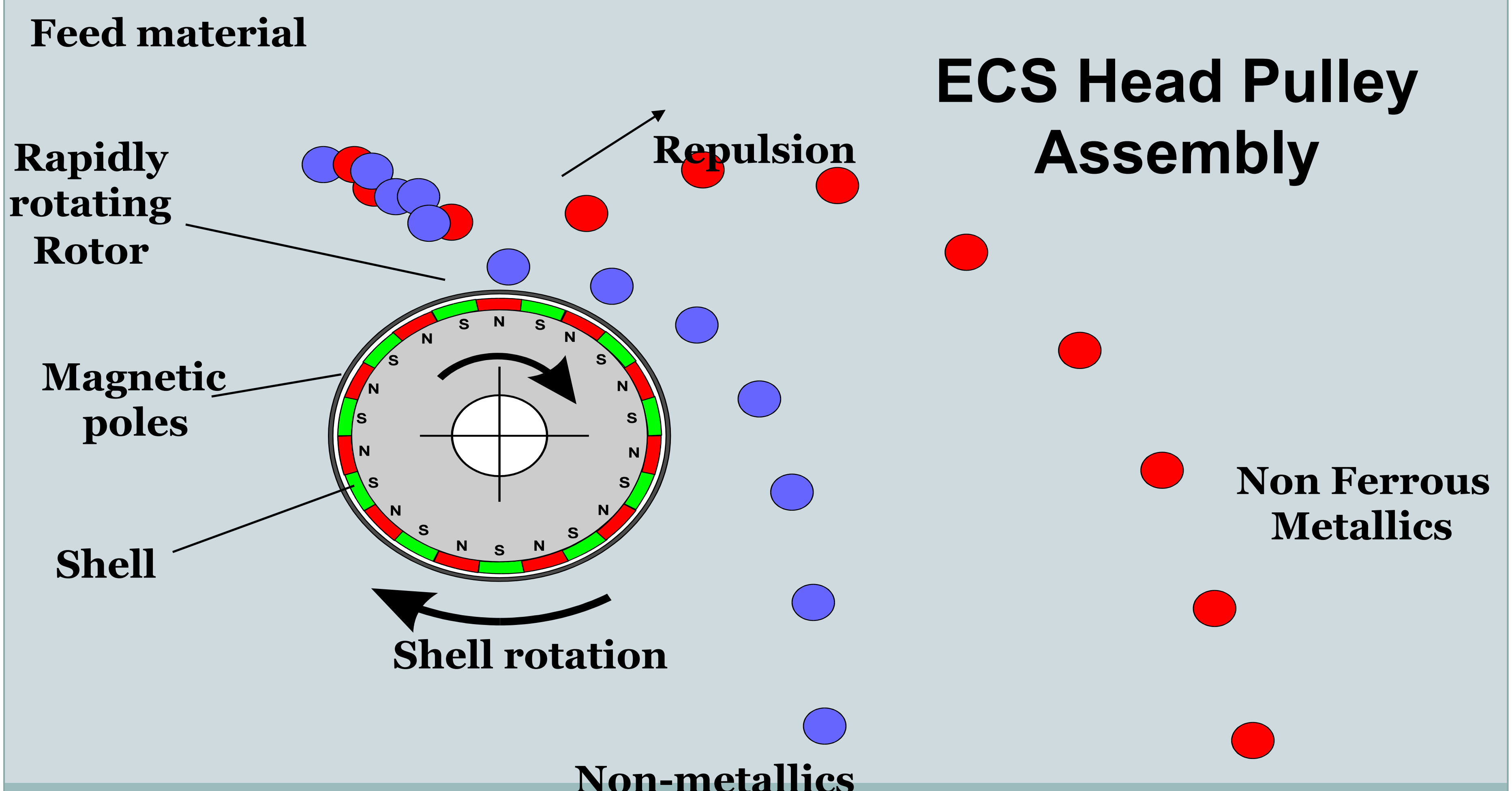
Aluminium particularly well suited to separation by this method due to its high conductivity/density ratio.

Processing of the cars.

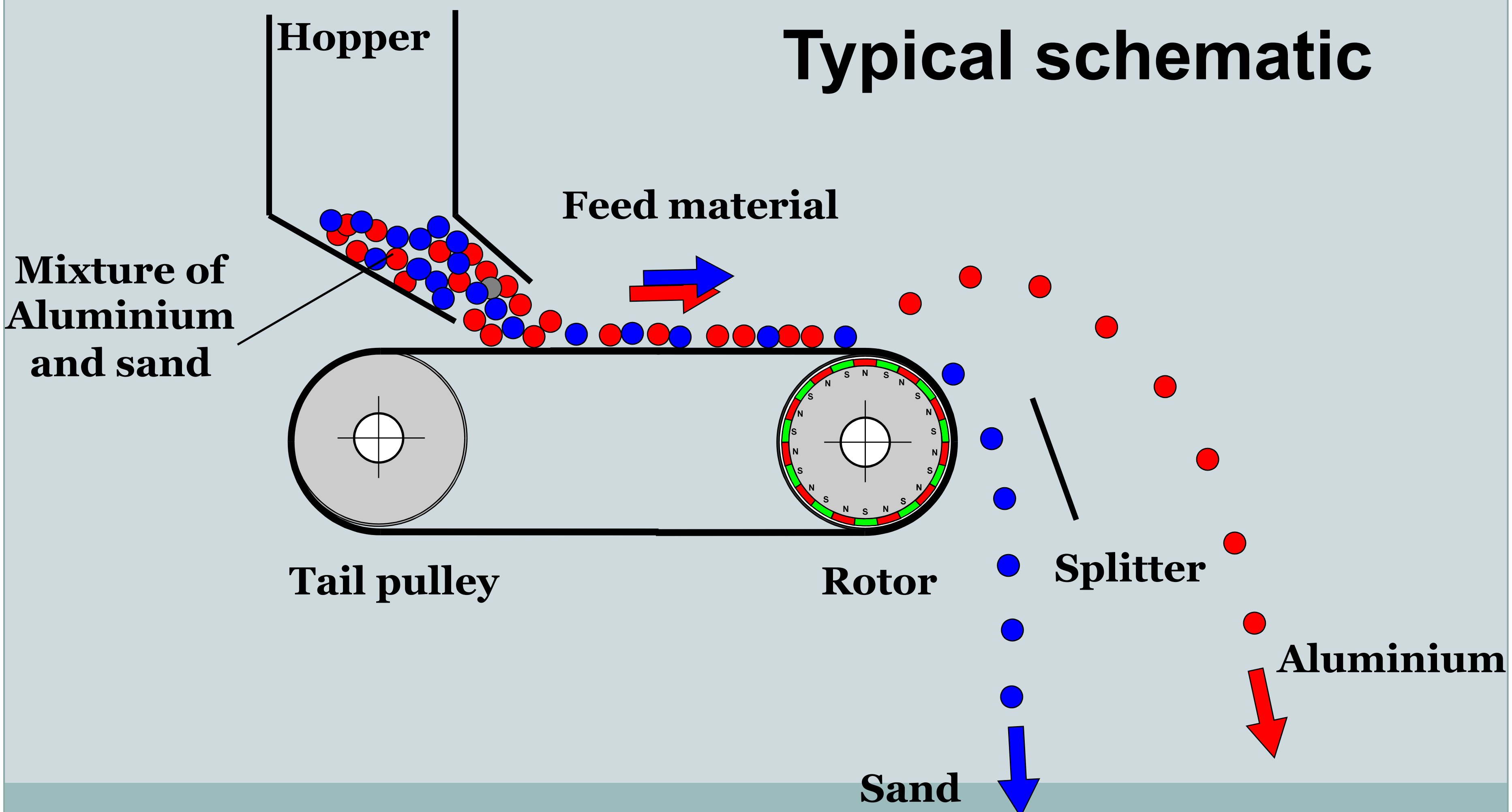
Conductivity density ratio of certain materials.

Material	Conductivity/ density ratio
Aluminium	13
Copper	6.7
Silver	6.0
Zinc	2.4
Brass	1.7
Tin	1.2
Lead	0.4
Stone/glass	0

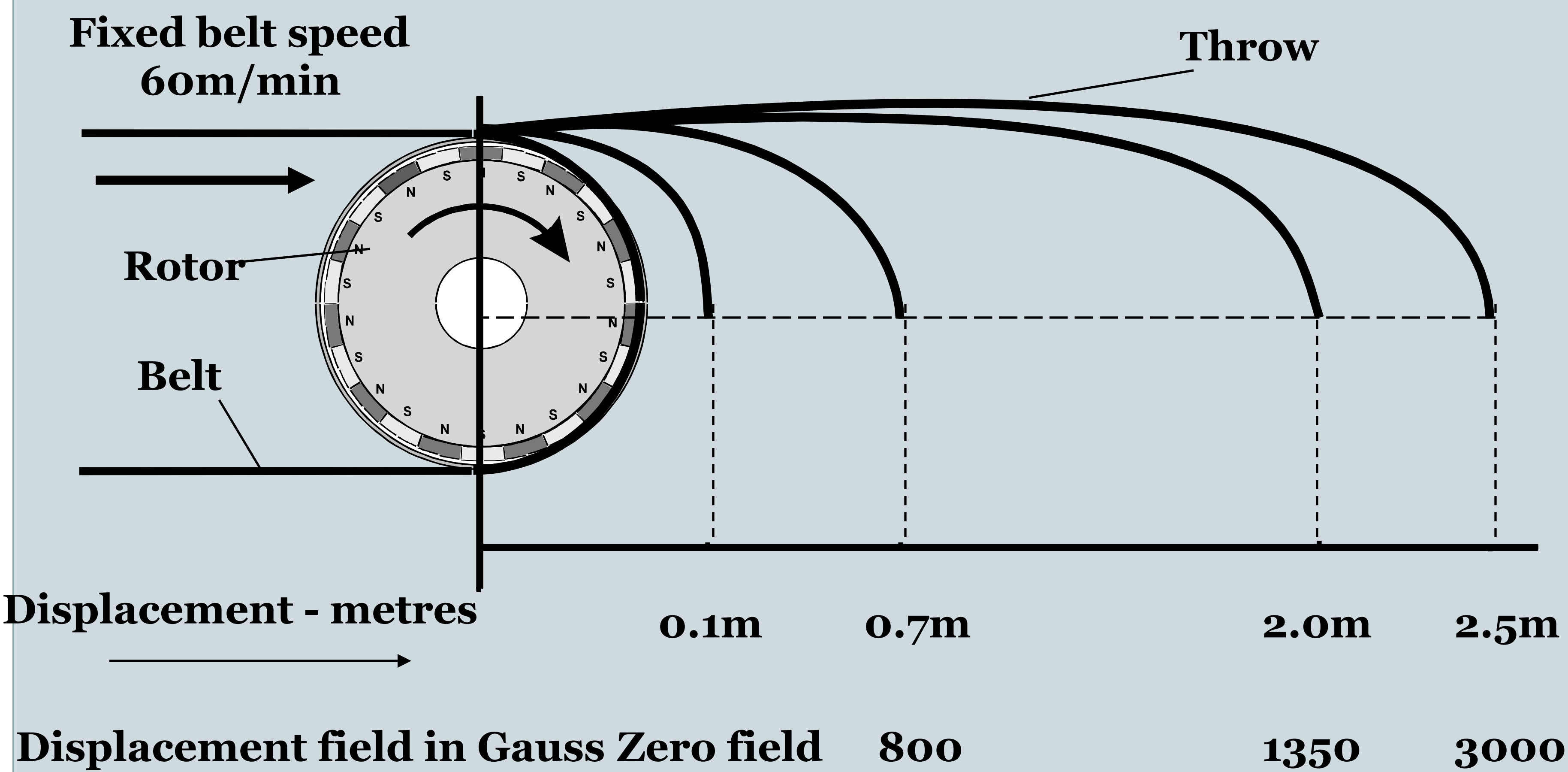
Eddy Current Rotor Design



Conductors thrown from rotor



Stronger magnets in rotor give larger throw



Future trends for car processing

Optimise: Eddy Current Separator

- Rotor Design (Magnet Size/Strength)
- Rotor Speed/Direction
- Aspect Ratio of Metallics (-2 mm issues)
- Feed Presentation to Separator.

Develop sensor based sorting options

- Optical, Near I.R. ,Microwave Detection

Secondary Processing Techniques

Processing Methods – Hand sorting

This is applicable to a wide range of operations, from simple removal of non-recyclable waste (polystyrene packing) to highly skilled operations in which trained operators select components with high precious metal content for special attention.

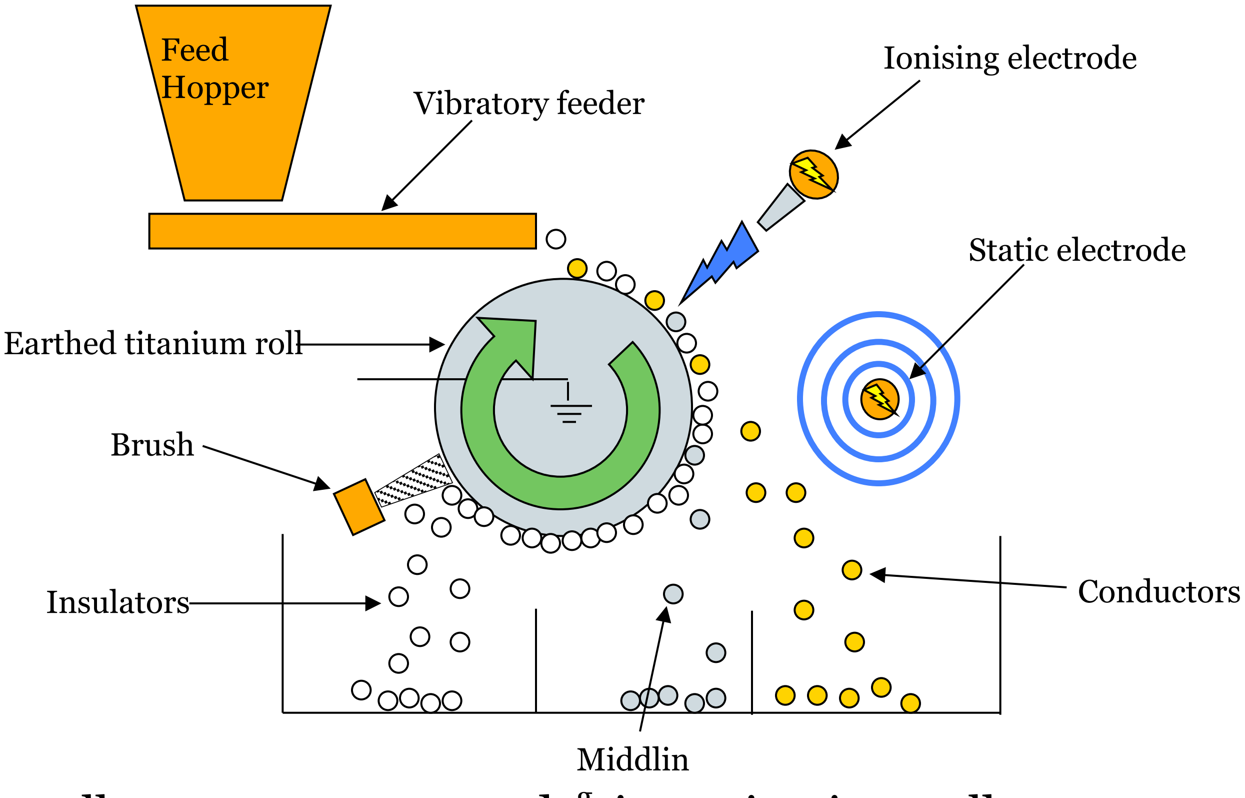
Often electronic items are partially disassembled e.g. plastic case is removed to allow access to circuit board.

Source: http://www.constructionphotography.com/

Source: http://www.mhwmagazine.co.uk

Electrostatic Separation

Electrostatic separations separate one material from another by exploiting the difference in electrical conductivity.

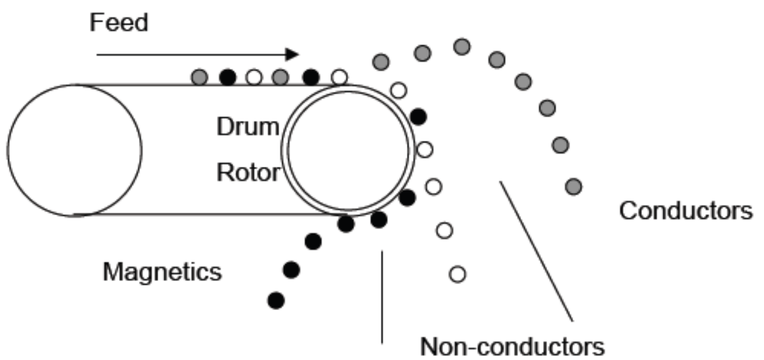


High Tension roll separator was tested using a titanium roll set at 100rpm set at 0.2mA and 20kV

Eddy Current Separation

Processing Methods –Eddy current separation.

Separators of this type function on the principle that whenever a conductive object is subjected to a changing magnetic field, an eddy current within the object is induced, which in turn produces a magnetic field opposing the original change. A tin can, for example, subjected to an increasing magnetic field becomes a magnet of opposite polarity and is repulsed. This forms the basis of separation of non-ferrous metals from other materials.

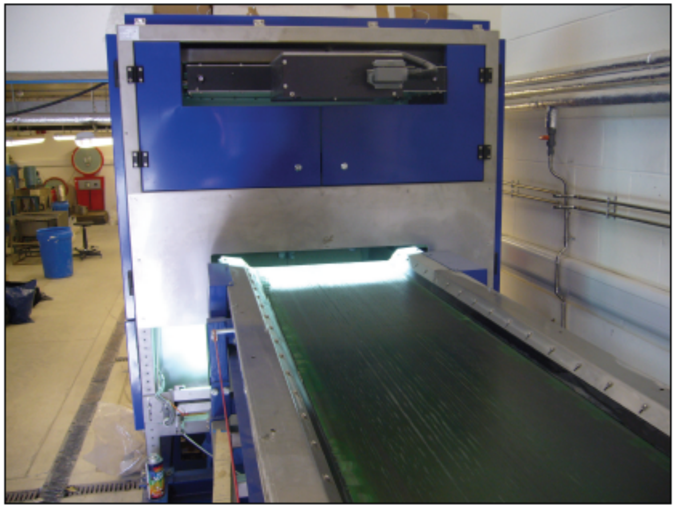


Eddy Current Principle

www.youtube.com/watch?v=rHemCWkjnB4

Sensor based Sorting

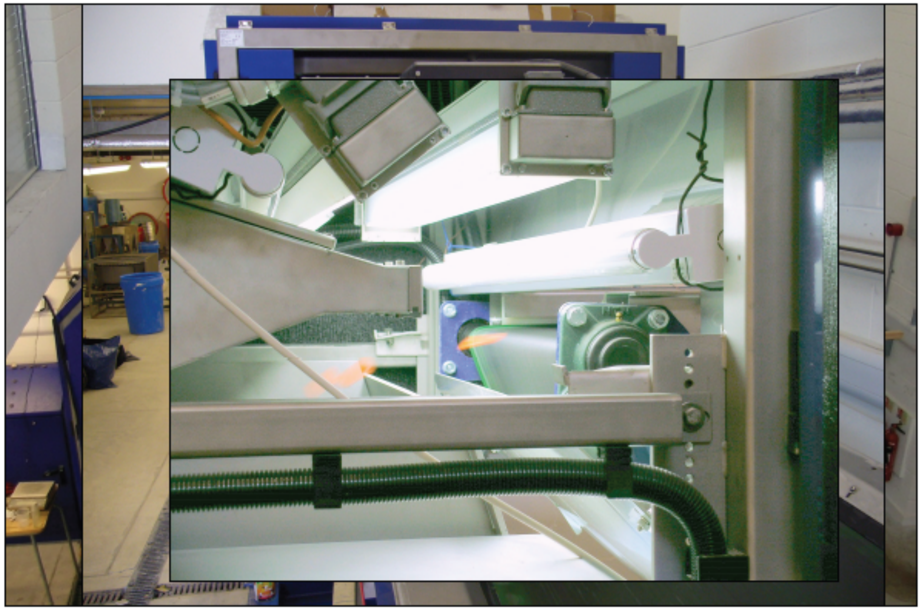
Sensor Based Sorting of Wastes



Potential Applications of the MikroSort© Sorting Control System for Waste Recycling Research at Birmingham

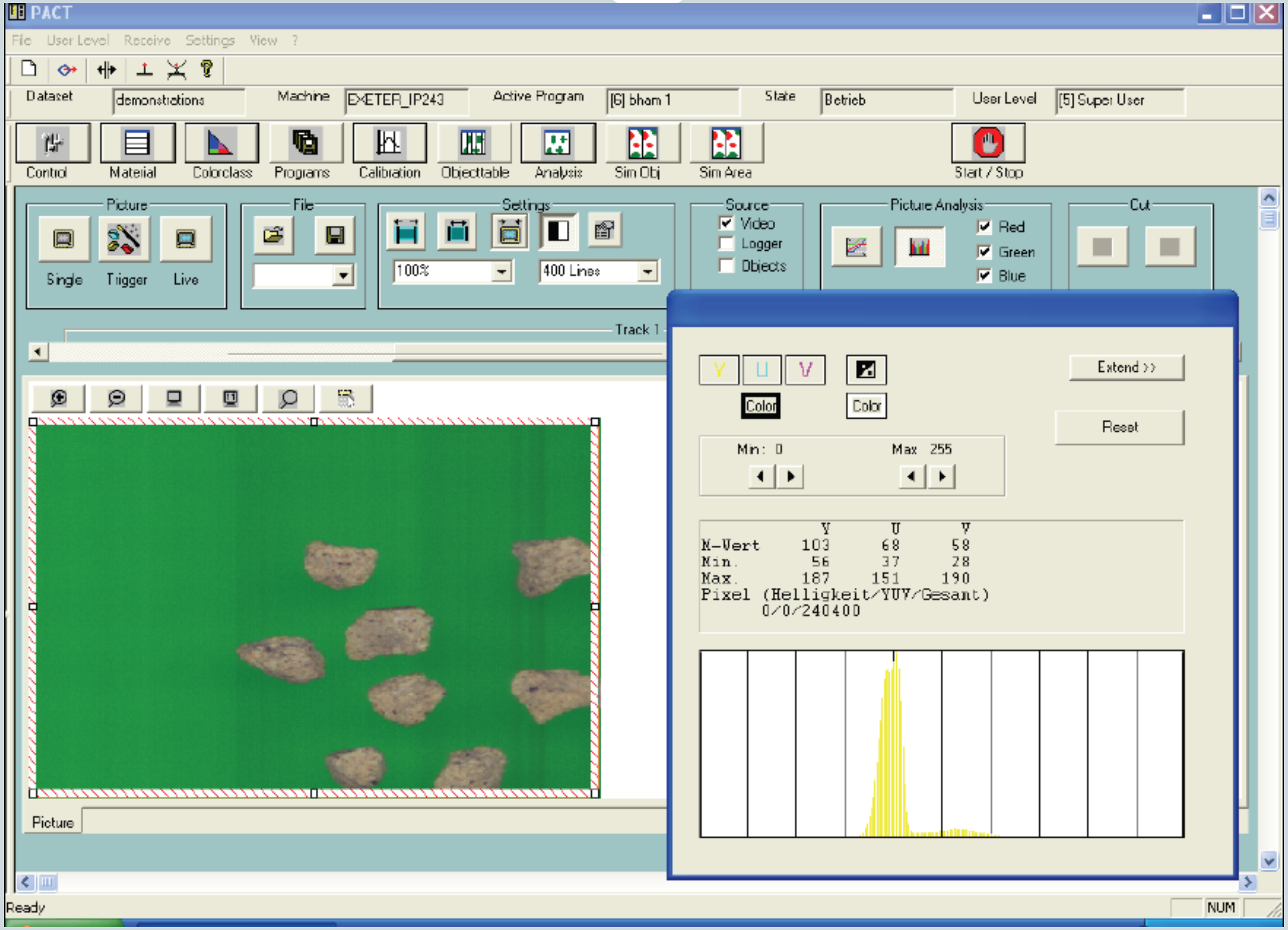
Optical Sorter

MikroSort© Sorting Control System



A high capacity system that has the potential to control complex sorting tasks. It can link signals from several sensors in order to classify and separate different components of a waste stream.

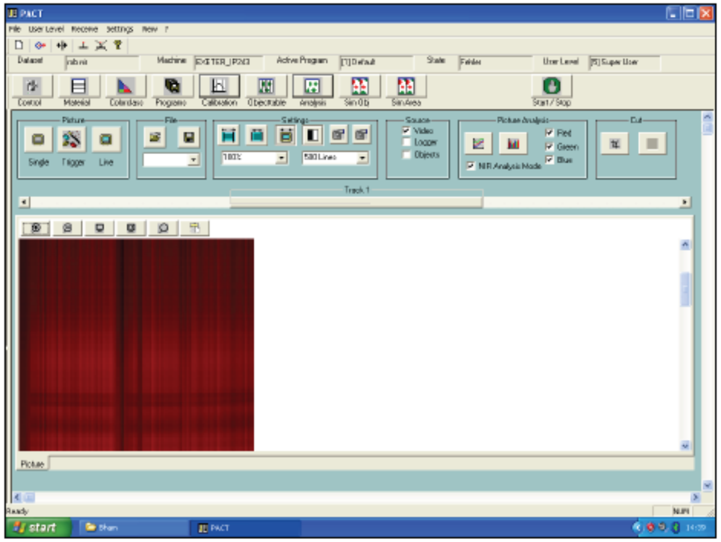
Refractory lining PGM

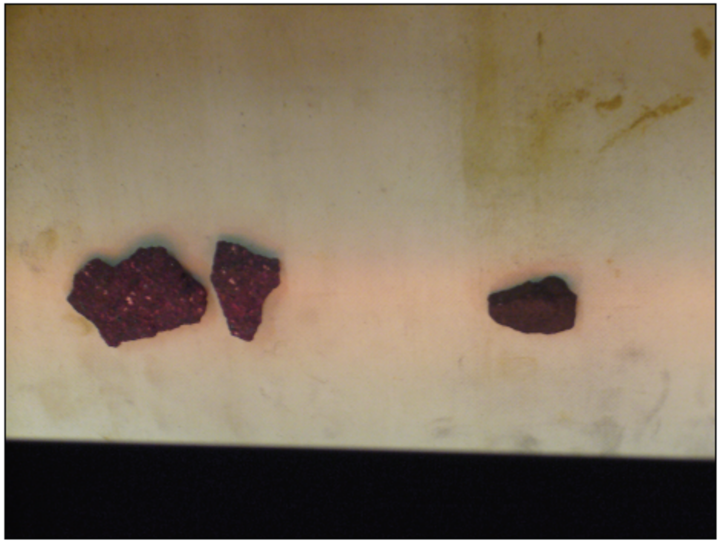


Refractory lining PGM

Near Infrared Sensor (NIR)

- Near Infrared sensor scans particles and measures IR reflectance
- There are 80 pixels spread across the width of the belt
- A wavescan from 1293-2476nm is performed for each of the pixels
- This produces an IR spectra across the belt





Potential ....

Advantages of Sensor Based Sorting

- High processing capacity
- Complete recording and analysis of material flow
- Material-dependent rejection
- Multisensor ability
- Real image display and tools for image analysis

Potential Research Applications

- Segregation of plastics
- Recovery of metals from electronic scrap
- PGM recovery from furnace lining

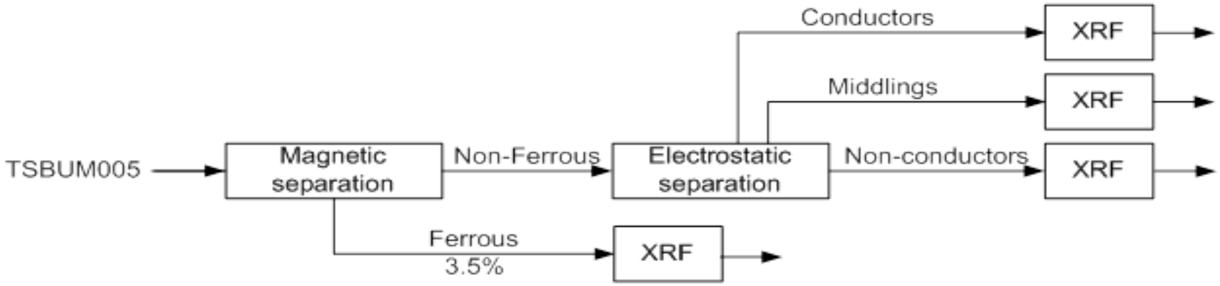
Secondary Occurrences of REE

- TSB Project looking at auto shredder residue.
- Occurrence of RE magnets
- Recovery of RE Metals (plus other critical metals)

Recovery of high value metals from ASR

TSB funded project with Axion Consulting +MIRO.

Final report March 2013



The remaining body of the ELV is passed to a scrap metal processing plant where the material is shredded and ferrous

and non-ferrous metals are recovered. The waste fraction which contains glass, fibre, rubber, foam and plastic is known

as auto shredder residue (ASR). ASR can be differentiated into heavy and light fractions dependent on how it is

removed from the process. Traditionally the majority of ASR (~25% of the initial vehicle weight) is landfilled; representing

a significant cost to the processor and a waste of valuable resources and landfill space.

Dismantlers de-pollute the ELV
and remove reusable items for reconditioning or reuse and specific high value items for direct recycling (catalytic
converters, fuel tank batteries, bumpers,tyres etc.).

Axion Recycling has developed and now operates an innovative Shredder Waste Advanced Processing Plant (SWAPP)

capable of recovering a range of materials from each ASR fraction that are saleable products, suitable for recycling

which also results in diversion from landfill. The plant is capable of processing 200,000 tonnes ASR per annum. The

SWAPP is the one of the most advanced facilities of its type in Europe and the World, with only a handful of similar

facilities operating or under development elsewhere. 1.

Determine an accurate measure for the arisings of high value, strategic metals in these material streams; and
2. Examine options for further processing of the material streams for the recovery of these metals and then
produce an assessment of economic viability.

Car Strategy

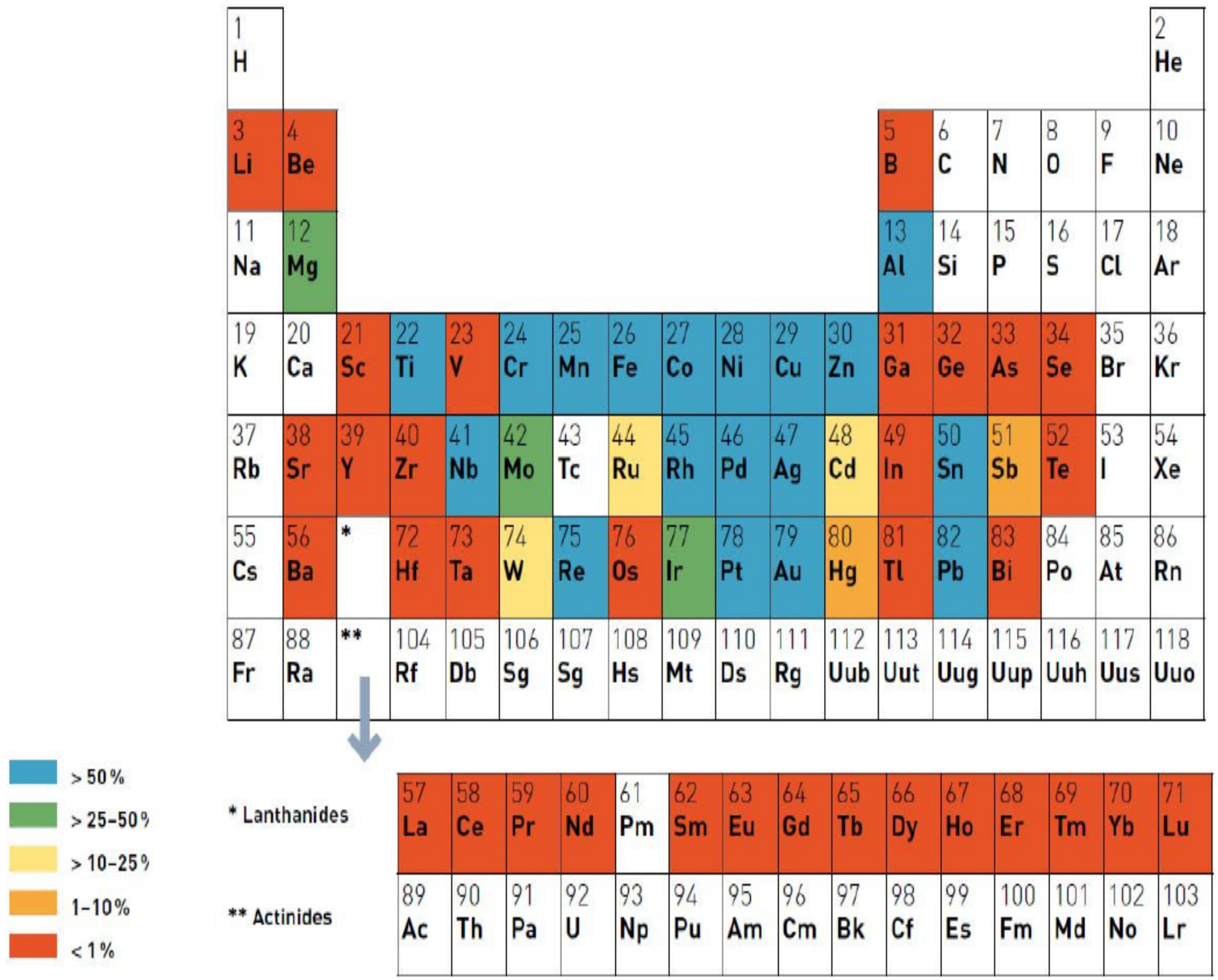
- Some of the strategic elements listed above are used in the automotive industry. Most notably is neodymium, a REE, which is used in magnets for motors. In the past magnets were largely strontium or barium ferrite magnets..
- A typical rare earth magnet would have the composition Nd15Fe77B8 and would also be likely to include other REE such as niobium and dysprosium. It is a continuing trend that Nd magnets are being used in these types of vehicles as they are more lightweight.
- Electric and hybrid cars currently entering the market (from 2013) contain about 12 -20 kg of REE primarily from magnets. Petrol and diesel cars entering the market contain about half this amount at 5-8 kg of REE.

Recycling of ELV is becoming more complex and rigorous.

Any added value components that can be recovered economically can enhanced the overall profitability.

Electric and hybrid cars currently entering the market (in 2013) contain about 12 kg of REE primarily from magnets.

Petrol and diesel cars entering the market contain about half this amount at 5 kg of REE.

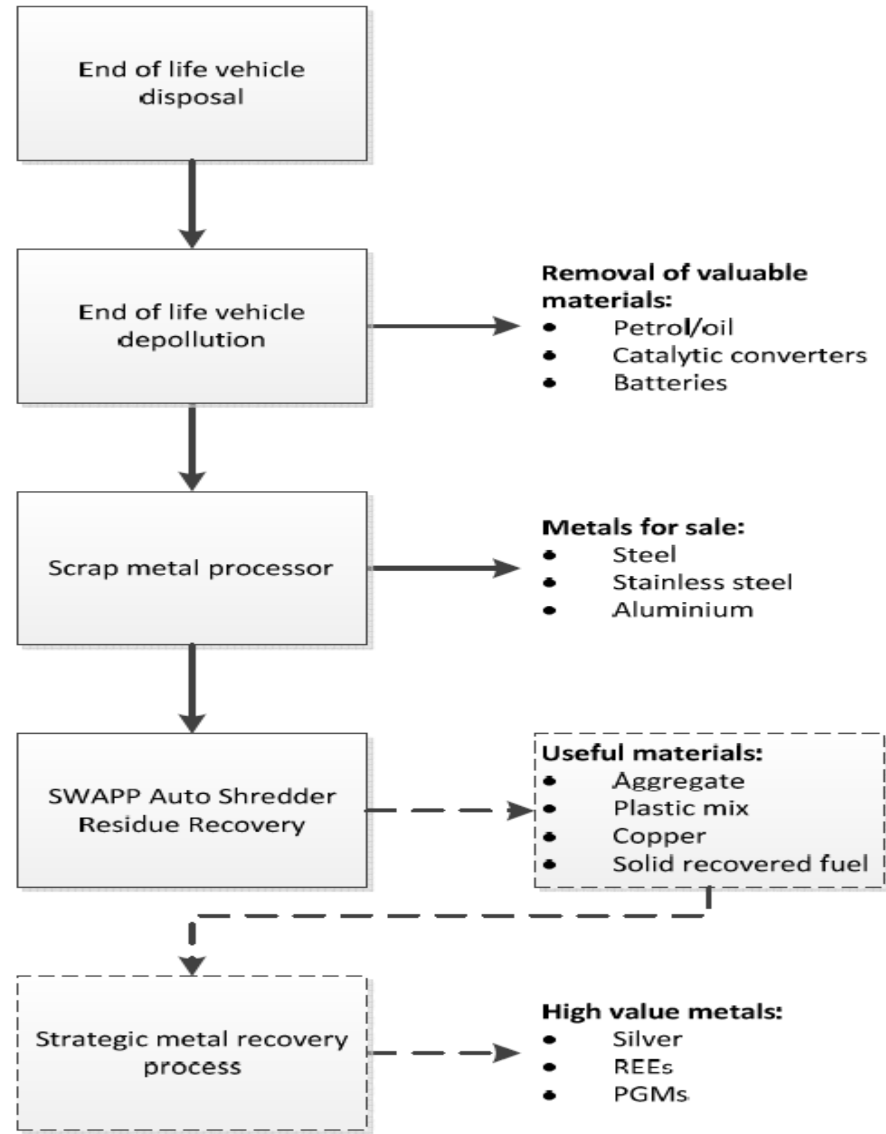


Recycling rates for key elements

Recovery of metals from ASR

SWAPP Trafford

- Capacity 200,000 t/y
- 600,000 cars per year
- Sophisticated plant allows recovery of plastics; solid recovered fuel and base metals.
- Designed and built by Axion



Project took place over a 9 month period:3 stages

1.Sampling and mass balance across plant.

2.Characterisation of each product stream

3. Further processing of streams to identify and isolate added value metals.

Recovery of high value metals from ASR

TSB funded project 2012-2013

Plant performance

2015 ELV targets achieved for all fragmentiser waste supplied to SWAPP

Plant gives:

- Metals
- Inert materials for construction
- Fuel for power generation
- Mixed plastic for upgrade

Axionpolymers

Product Information Sheet

Solid recovered fuel 01

Doc Ref: MS05 SRF01

ISSUE REF: 2.0 13/07/2011

Solid recovered fuel SRF01 unshredded

Description:
SRF01 unshredded is a mix of textiles, fibre-board, fluff, plastics and rubber derived from an advanced materials sorting facility in Manchester, UK. Will contain some wood, cable and other minor contaminants.

SRF01 unshredded is a consistent and reliable material with repeatable physical and chemical properties.

Origin:
Solid recovered fuel SRF01 is derived from automotive shredder residue by a unique sorting process.

Availability:
Solid recovered fuel SRF01 is available for delivery in bulk loads.

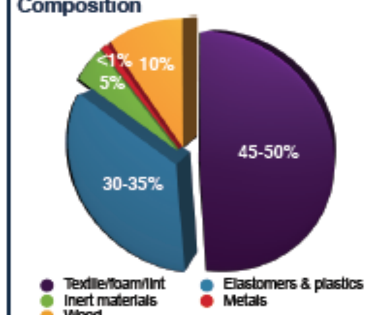
Size range	Mass %
less than 2mm	0%
2 to 3mm	0%
3 to 8mm	1%
8 to 25mm	5%
25 to 40mm	20%
40 to 100mm	42%
>100mm	32%

Additional analytical data can be provided on request.

Parameter	Unit	Properties
Net CV	MJ/kg	15-17
Ash	%	23-25
Moisture	%	5
Chlorine	%	0.3-0.8
Copper	%	0.1-0.3

Disclaimer:
Numerical data are provided in good faith based on measurements and analysis using samples produced using newly commissioned process equipment. Actual readings may vary from that shown.

Composition



Axion Polymers
Langley Road South, Salford M6 6HQ
Telephone: (+44) 161 737 6124
info@axionpolymers.com

Chemicals Awards 2010 WINNER

Plastics Industry Awards 2010 Finalist

Awards for innovation and excellence 10 Winner

Recycled Aggregate

AGG03 +20mm particle size aggregate.
87% of mass between 20-100mm.

Description:
Recycled aggregate for use in a wide range of civil engineering applications such as embankments, fill materials, capping and sub-base for paving areas.

Origin:
Recovered from automotive shredder residue by a unique sorting process. Very clean aggregate material of a controlled and regular particle size, with low fines and dust content.

Benefits:

- Free of aggregate tax
- Regular particle size
- Low fines
- Good drainage properties
- Large volumes available
- Budget cost
- Stock located in central Manchester - low transport costs to urban sites.

PARAMETER	TYPICAL PROPERTIES
Stone & glass content	94%
Metal content	2%
Plastic & rubber content	3%
Wood content	1%

Value of metals at time of survey

	Value (£/te)	Source
Sc	£1,000,000	Low side estimate
La	£16,013	HEFA Rare Earth, metalpages.com
Ce	£16,340	HEFA Rare Earth, metalpages.com
Nd	£68,627	HEFA Rare Earth, metalpages.com
Er	£187,908	HEFA Rare Earth, Alibaba
Ru	£1,767,712	Nothernminer, infomine
Rh	£27,424,255	Northernminer, metalpages.com
Co	£17,268	LME, metalprices.com
Mg	£1,791	Northernminer, metalprices.com
Sb	£7,379	Northernminer, metalprices.com
Sr	£2,614	Alibaba
Ba	£718	Alibaba (based on Braium Nitrate)
Pt	£38,422,601	Mineralprices.com, metalprices.com
Ag	£617,154	Mineralprices.com, metalprices.com

Streams sampled from site

Sample identifier number	Material description
TSBUM001	Dust waste from the copper recovery process
TSBUM002	Dust from air filter
TSBUM003	Fines from light fraction processing
TSBUM004	Fines from heavy fraction processing
TSBUM005	Copper rich product
TSBUM006	Copper rich product – larger size than TSBUM005 and lower purity
TSBUM007	Solid Recovered Fuel (3 - 8 mm)
TSBUM008	Solid Recovered Fuel (8 - 20 mm)
TSBUM009	Solid Recovered Fuel (20 - 100 mm) – not analysed by the University of Birmingham
TSBUM010	Magnetic process build up
TSBUM011	Aggregate
TSBUM012	Slurry collected from shredder cyclone
TSBUM013	Waste from Eddy Current Separators – not analysed by the University of Birmingham
TSBUM014	Build up inside shredder
TSBUM015	Eddy Current Separator feed
TSBUM016	Motors and Fuel pump

Processing options for ASR

The samples were separated into fractions using a variety of methods which were likely to contain higher strategic metal content than the original sample as a whole. Treatment options were selected based on the following criteria:

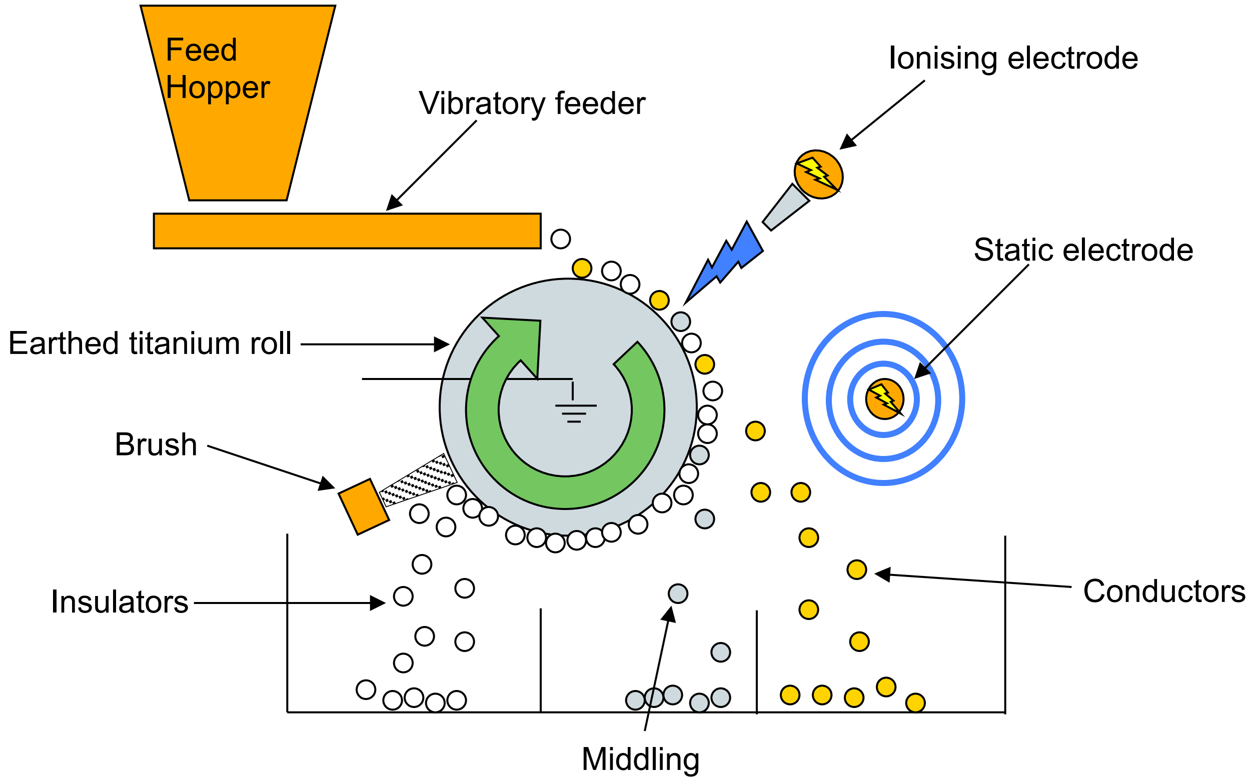
- Moisture content of sample;
- Particle size distribution;
- Metallic content;
- Fibrous nature of sample (bird nests); and
- Density of sample.

The separation options considered were:

- Size reduction of the larger material carried out at Axion laboratories;
- Sieving to concentrate fractions of different morphology;
- Magnetic separation (Low and High Intensity) (400 gauss, 10,000 gauss);
- Electrostatic separation (High Tension Separation);
- Air table separation (Fluidised Bed Separator based on density and shape) - Kipp Kelly Air Table;
- Density separation (Knelson Concentrator); and
- Froth flotation (surface chemistry separation): Denver Cell: 5 litre vessel.

Electrostatic Separation

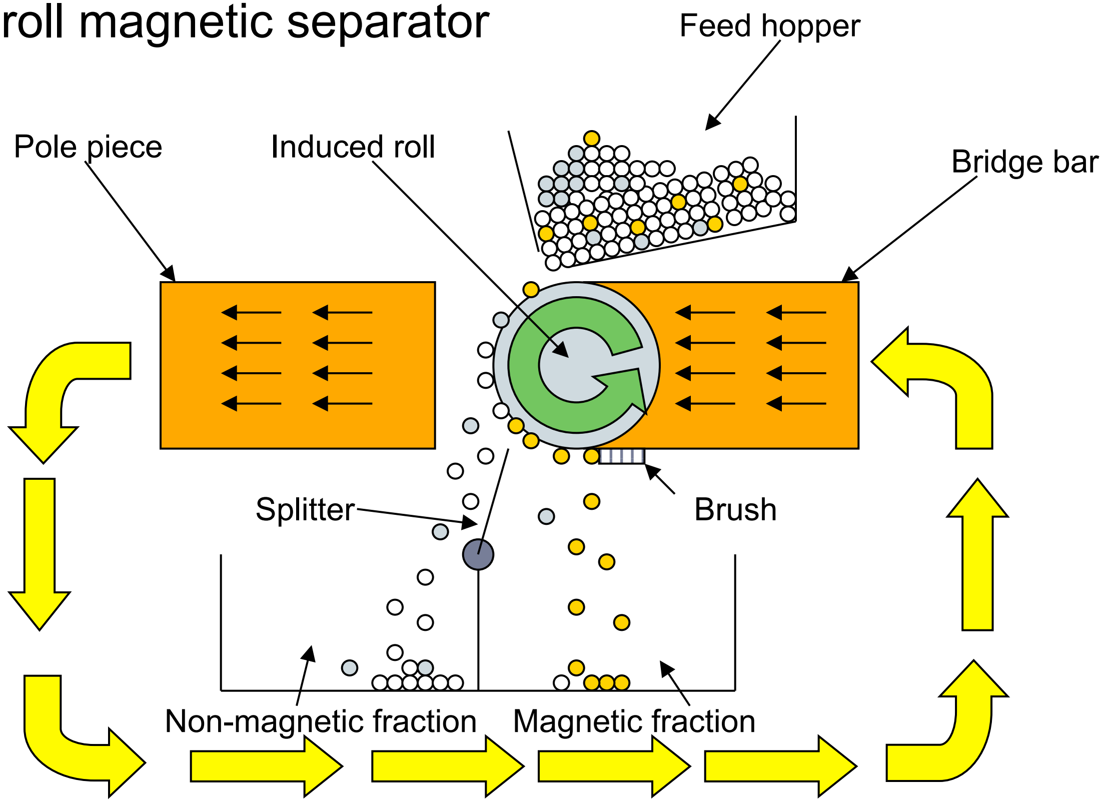
Electrostatic separations separate one material from another by exploiting the difference in electrical conductivity.



High Tension roll separator was tested using a titanium roll set at 100rpm set at 0.2mA and 20kV

Magnetic Separation

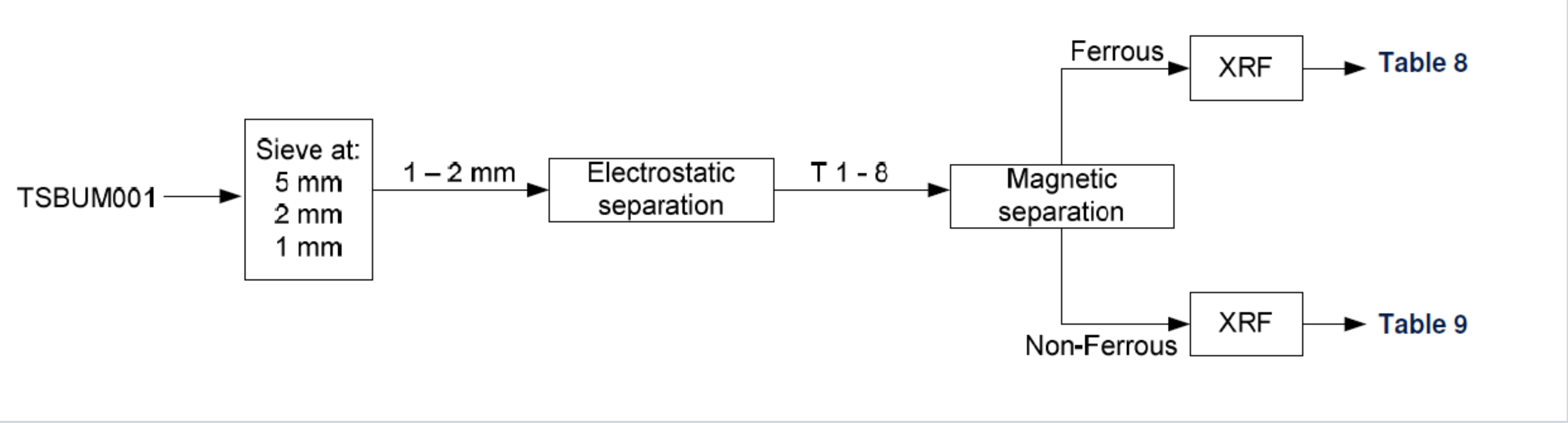
Induced roll magnetic separator



Processed streams TSBUM 001

Feed material: +2mm	From Cu recovery process
	

TSBUM 001 flowsheet: Cu recovery waste



Conducting fraction

TSBUM 001Electrostatic Separation _tray1-8_(+1,-2mm)			
Element	**% of sample**	**Element**	**% of sample**
Fe	26.69%	Cl	0.73%
Si	25.12%	Ti	0.73%
Ca	15.33%	P	0.66%
Br	8.42%	Mn	0.49%
Al	7.91%	Cu	0.32%
Mg	3.43%	Pb	0.28%
S	2.83%	Sr	0.15%
Na	2.57%	Ni	0.09%
Zn	1.99%	Sc	0.04%
Sb	1.19%	Zr	0.02%
K	1.02%		

TSBUM 001

Magnetics

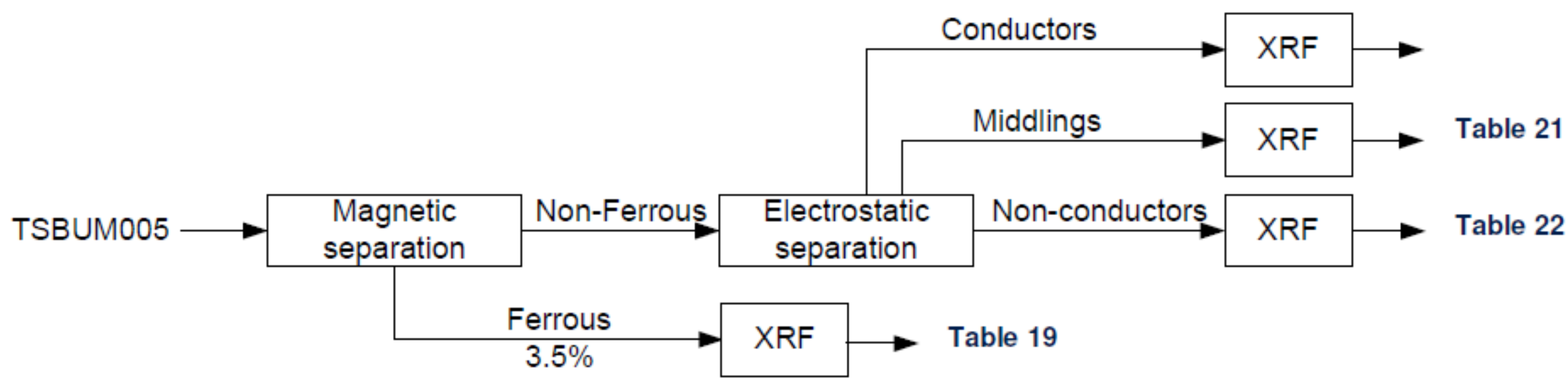
TSBUM 001 Conductors magnetic fraction			
Element	**% of sample**	**Element**	**% of sample**
Fe	69.74%	Ba	0.54%
Ca	8.50%	Na	0.51%
Si	6.52%	Ti	0.49%
Ni	3.00%	Nd	0.49%
Al	2.79%	Cr	0.37%
Mg	1.47%	Cl	0.28%
Zn	1.29%	Pb	0.15%
Cu	1.11%	Sr	0.09%
S	0.93%	Sc	0.03%
Mn	0.63%	As	0.01%

Non magnetics

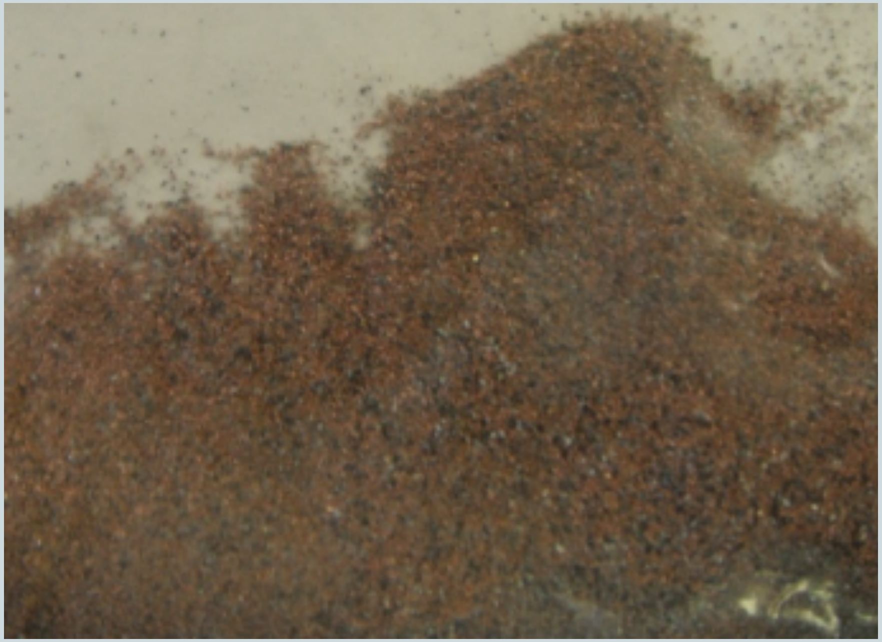
TSBUM 001: NON-MAGNETICS FRACTION -400 gauss			
Element	**% of sample**	**Element**	**% of sample**
Fe	27.27%	Ti	1.40%
Si	21.21%	Sr	1.15%
Ca	16.32%	Mn	1.02%
Cu	9.88%	Cl	0.83%
Al	6.41%	P	0.54%
Zn	3.02%	Na	0.47%
Pb	2.61%	Cr	0.33%
S	1.86%	Sn	0.28%
K	1.71%	Zr	0.23%
Ba	1.69%	Ni	0.12%
Mg	1.60%	Br	0.05%

Sub processing of individual streams 005

Figure 22 TSBUM005 v2 analysis



Feed TSBM 005



- Cu rich fraction from Eddy current separator.
- Not very effective under 2mm

TSBUM 005 v2 feed			
Element	**% of sample**	**Element**	**% of sample**
Cu	55.15%	K	0.41%
Si	16.49%	Ti	0.40%
Al	7.44%	P	0.29%
Ca	6.08%	Cr	0.29%
Fe	5.78%	Br	0.18%
Zn	1.68%	Sr	0.18%

Magnetic fraction analysis

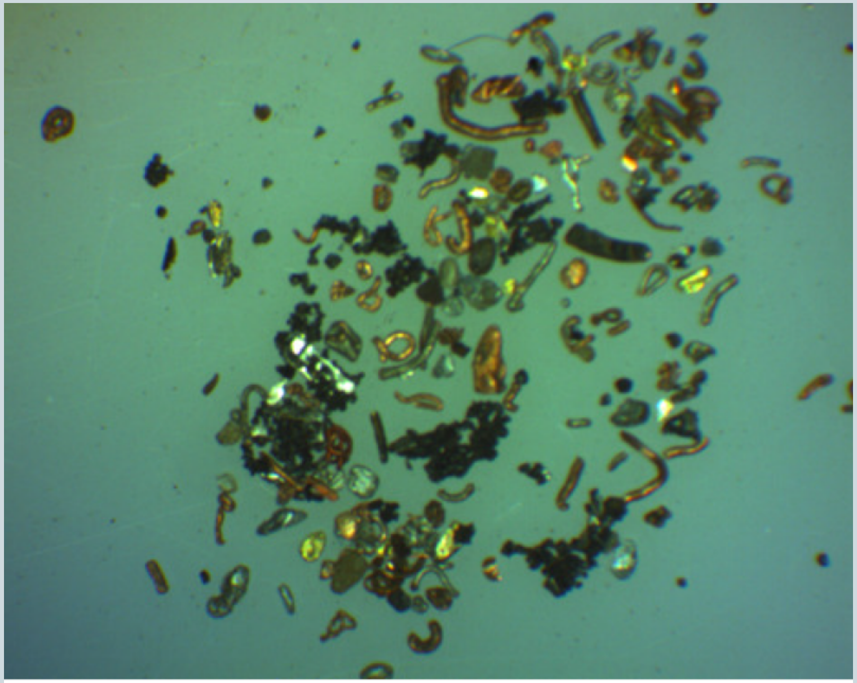
TSBUM 005V2 Magnetics 400 Gauss
Mass fraction 3.5% by mass of feed

Element	% of sample	Element	% of sample
Fe	47.06%	S	0.44%
Si	20.74%	P	0.37%
Ca	14.08%	Cu	0.34%
Al	4.93%	Nd	0.34%
Zn	2.16%	Cr	0.31%
Na	1.72%	Ni	0.20%
Mg	1.59%	Cl	0.18%
K	1.30%	Zr	0.12%
Ba	1.19%	Mo	0.02%
Pb	1.18%	Sn	0.02%
Ti	0.75%	Br	0.01%
Mn	0.68%	Co	0.00%
Sr	0.58%		

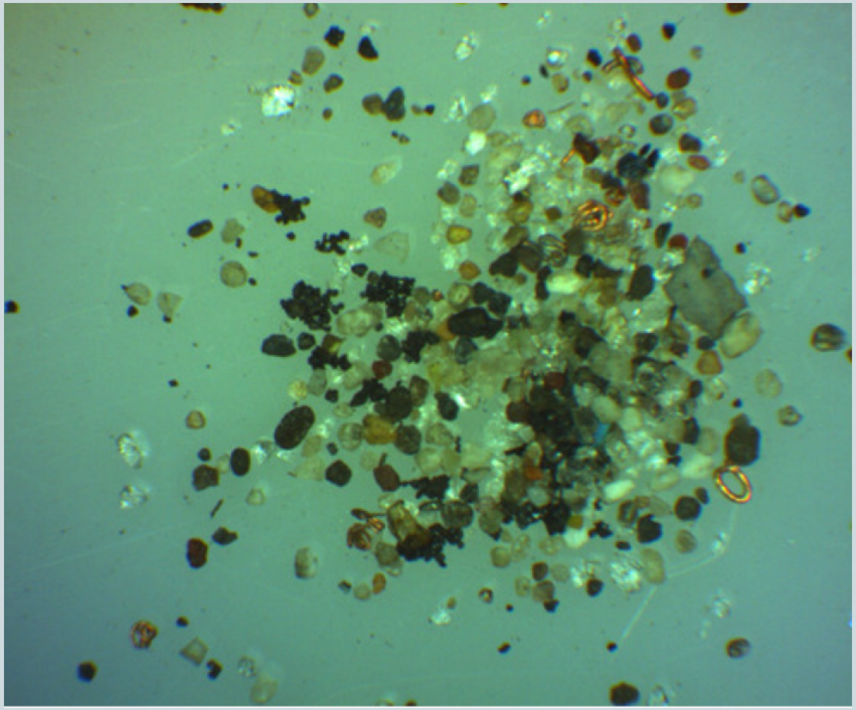
Comments
High iron- to be expected
Nd detected at 0.34%

Stream TSBUM 005

Conductors



Non conductors



Stream TSBM 005

Conductors

TSBUM 005 Electrostatic Separation Trays 1-5 conductors			
Element	**% of sample**	**Element**	**% of sample**
Cu	81.57%	Er	0.16%
Fe	8.21%	Cl	0.14%
Zn	2.57%	S	0.11%
Pb	1.96%	K	0.09%
Si	1.25%	Ti	0.07%
Ca	1.08%	Mn	0.06%
Sn	0.96%	Br	0.05%
Cr	0.67%	V	0.02%
Al	0.50%	Sr	0.02%
Ni	0.25%	Mo	0.01%
Mg	0.20%	Zr	0.01%
Comments:			

Non conductors

TSBUM 005 Non conductors			
Element	**% of sample**	**Element**	**% of sample**
Si	48.12%	Zn	0.67%
Al	13.81%	Sn	0.58%
Ca	12.09%	Pb	0.57%
Mg	4.10%	Br	0.48%
Cu	3.38%	Sr	0.48%
Fe	2.81%	P	0.46%
Ba	2.68%	Zr	0.37%
Na	2.46%	Cr	0.08%
Cl	1.80%	La	0.08%
Ti	1.61%	Mn	0.07%
Ce	1.48%	Pt	0.07%
S	0.88%	Ni	0.03%
K	0.85%	Co	0.00%

Windscreen wiper

Contains Barium ferrite magnet

Some removed and exported.

Windscreen Wiper Motor			
Element	**% of sample**	**Element**	**% of sample**
Fe	72.43%	Sr	0.18%
Ba	23.90%	Mg	0.13%
Si	1.15%	S	0.09%
Na	0.60%	Zn	0.09%
Al	0.47%	K	0.03%
Ca	0.40%	Sc	0.02%
P	0.27%	Ti	0.02%
Mn	0.22%		
Comments			
Barium Ferrite Permanent Magnet Recovered			

Fuel pump petrol car

Electrical Contacts from Fuel Pump

Element	% of sample	Element	% of sample
Cu	65.09%	Ca	0.05%
Zn	33.85%	K	0.05%
Si	0.26%	Fe	0.04%
Al	0.22%	Sc	0.04%
Ce	0.09%	Rh	0.04%
Cl	0.09%	Ni	0.03%
Ti	0.06%	Ru	0.03%
S	0.05%	P	0.01%

Conclusions

Existing levels of Cu and Al recycling efficiency was high

Some Ag,Au and,PGM detected in specific process streams.

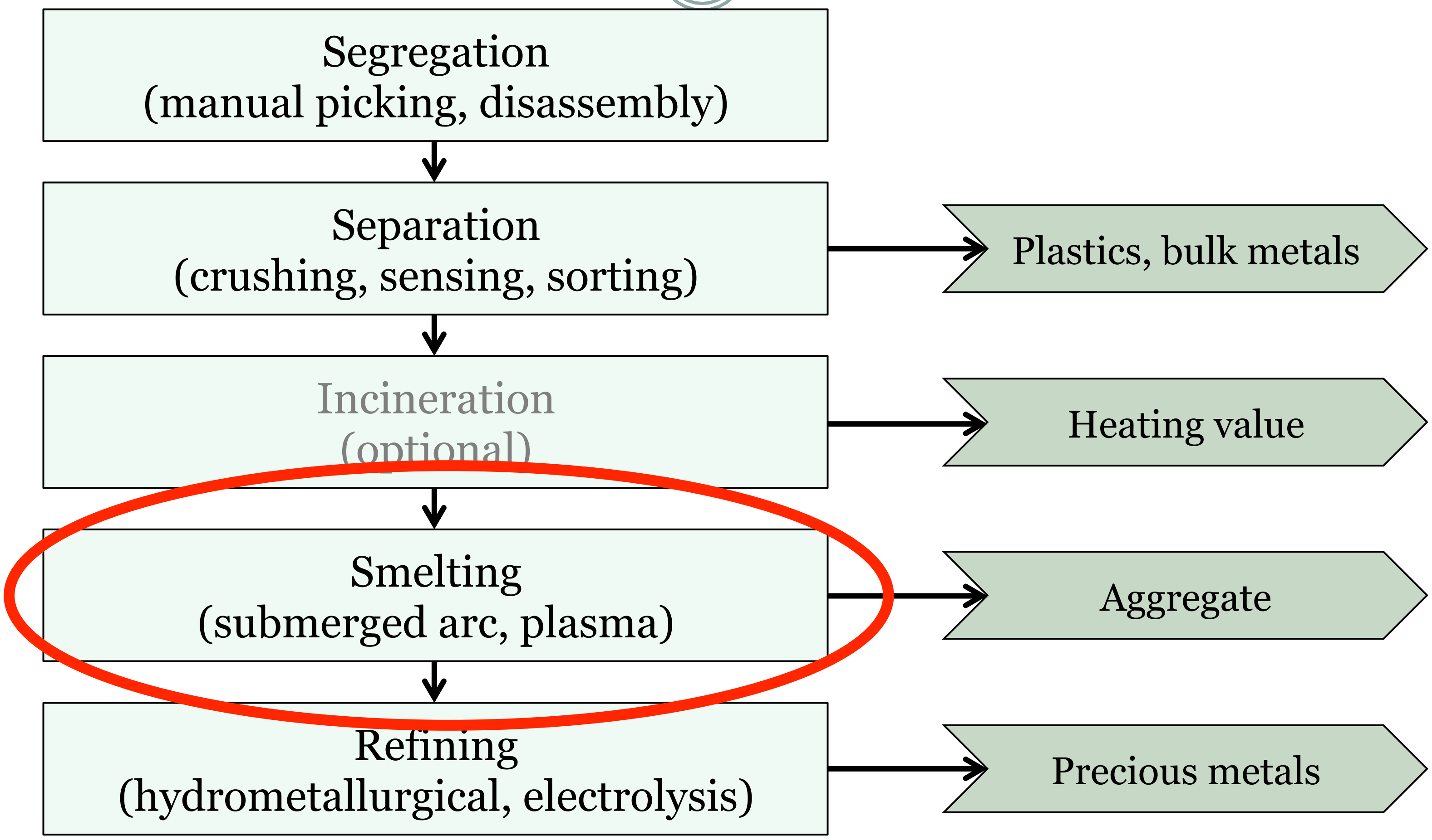
Strategic metals such as barium ,magnesium and strontium present.

Rare Earth Elements :Cerium,Erbium, Neodymium and Scandium detected in very low levels.

Very little evidence of RE motors arriving as feed to plant.

Sample	REE	Concentration
TSBUM001	Nd	0.01%
TSBUM005	Er	0.15%
	Nd	0.1%
	La	0.03%
TSBUM007	La	0.004%
TSBUM012	Ce	0.45%

Next Generation – Metal Recovery from E-Waste/ELV

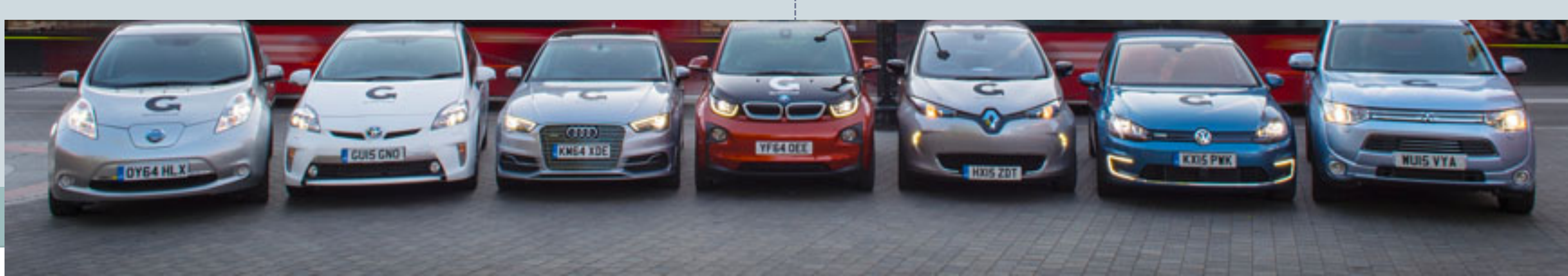


Processing of EV

- Current status in UK

Current EV Sales in UK

- Uptake of plug-in electric cars has reached a record high in the UK with more than 115 electric vehicle registrations every day during the first quarter of 2016.
- Representing the best period of sales since the Plug-in Car Grant was first introduced by Government in January 2011.
- The registration figures from the Society of Motor Manufacturers and Traders (SMMT) show plug-in car sales this year are already ahead of schedule to exceed 2015's record total – when 28,000 new plug-in cars were registered, more than the previous five years combined and a 94% rise compared to 2014



January –April 2016

- There were a further 19,000 petrol-electric and diesel-electric hybrids registered in the same period, up from 15,750 in the same period of 2015
- Over the past 12 months, the UK ranks as the biggest major market and second only to the Netherlands in total EV registrations, with 28,715 new plug-in cars representing one fifth of the European Union’s collective EV sales

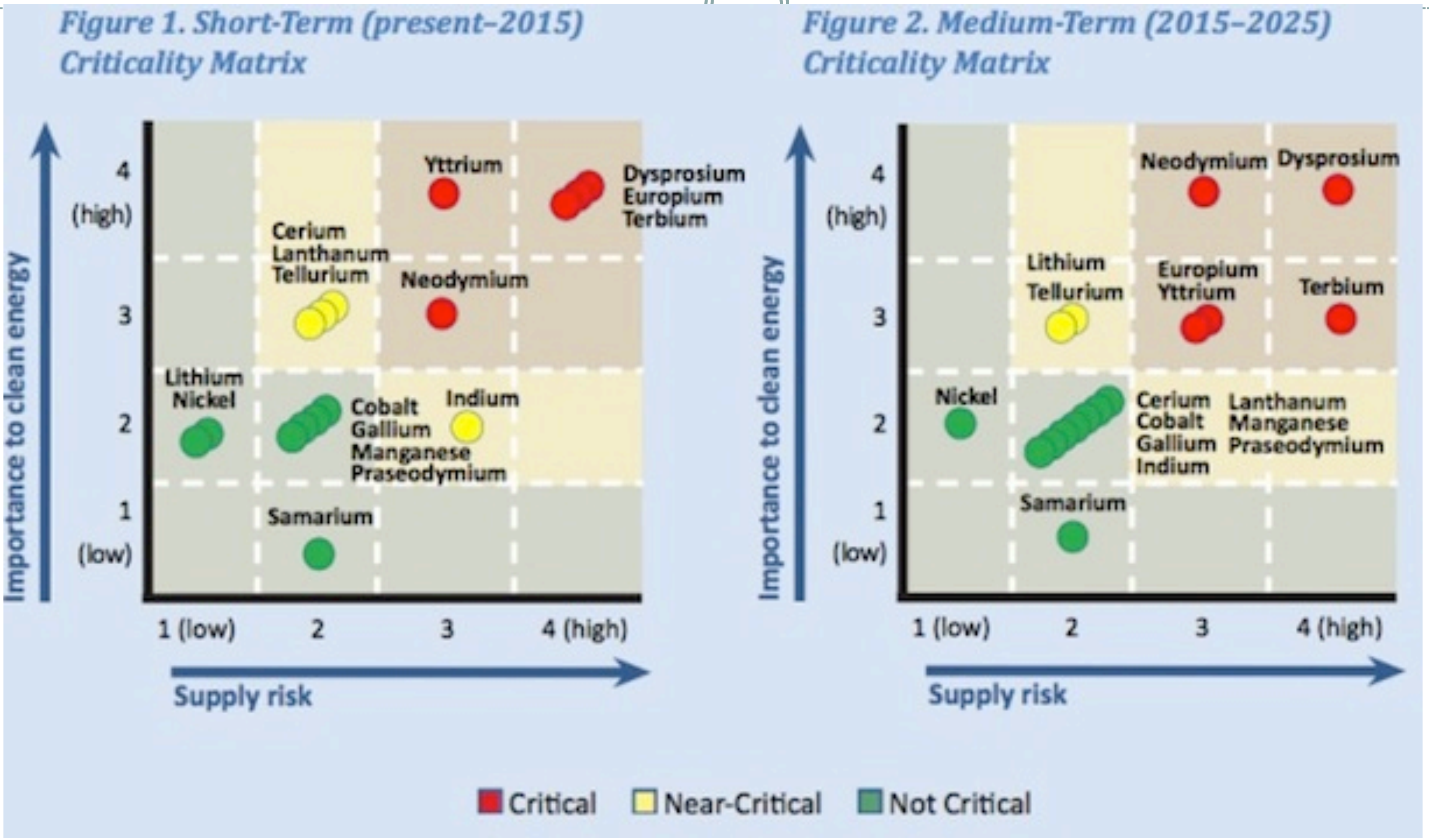
Scrap rates July 2016

- 950,000 cars scrapped in UK annually
- Pure electric and hybrid vehicles as well as their ages at one major operator (5% of market)
- **2014: 11 pure electric vehicles** Age, years: 9 (1 car), 8 (1 car), 7 (1 car), 3 (8 cars)
- **2014: Hybrids: 6 :**14 (1 car), 13 (2), 12 (1), 11 (1)
- **2015: No pure electric vehicles recorded**
- **2015 hybrids 7:** 14 (1), 13 (1), 12 (3), 10 (1), 8 (1)

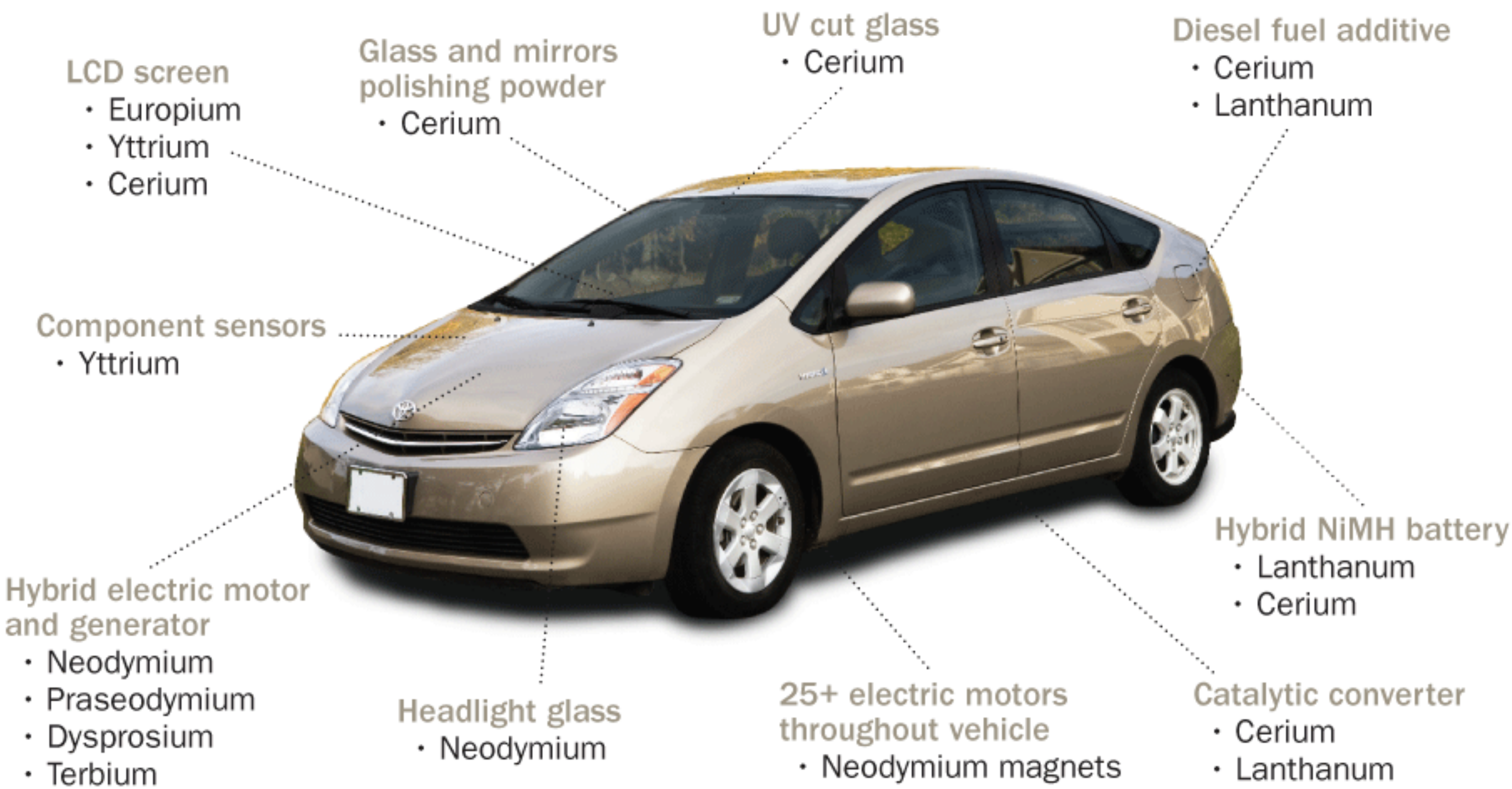
- 2014: 220 pure electric cars (uk total figure)
- 2014: 120 hybrid cars(total uk figure)
- 2015: 140 hybrids scrapped (total uk figure)

RE in Electric and Hybrid cars

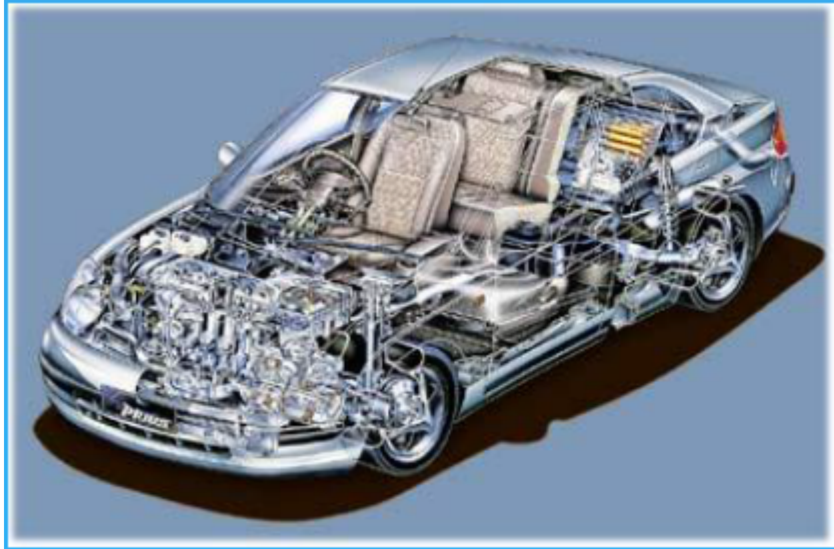
2013 Critical Materials Strategy (Doe)



Various sources of REE in cars



Toyota Prius Hybrid



Gasoline Engine: Inline 4-cylinder DOHC Displacement: 1,496 cc. Output: 76HP with a max of 5,000 rpm

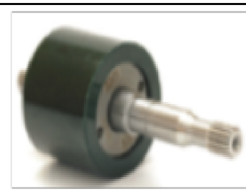
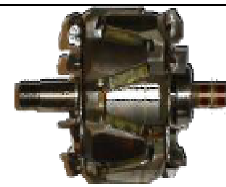
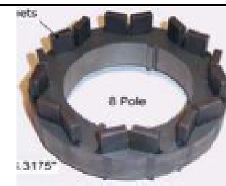
Electric Motor: Permanent Magnet (1.3kg of NdFeB) .

Max. Power: 50kW / 67 HP (940-2,000 rpm) operating at 500V

Braking: Front Disc/Rear Drum (Hydraulic, with Power Assist) with Integrated Regenerative System (0.7kg of NdFeB)

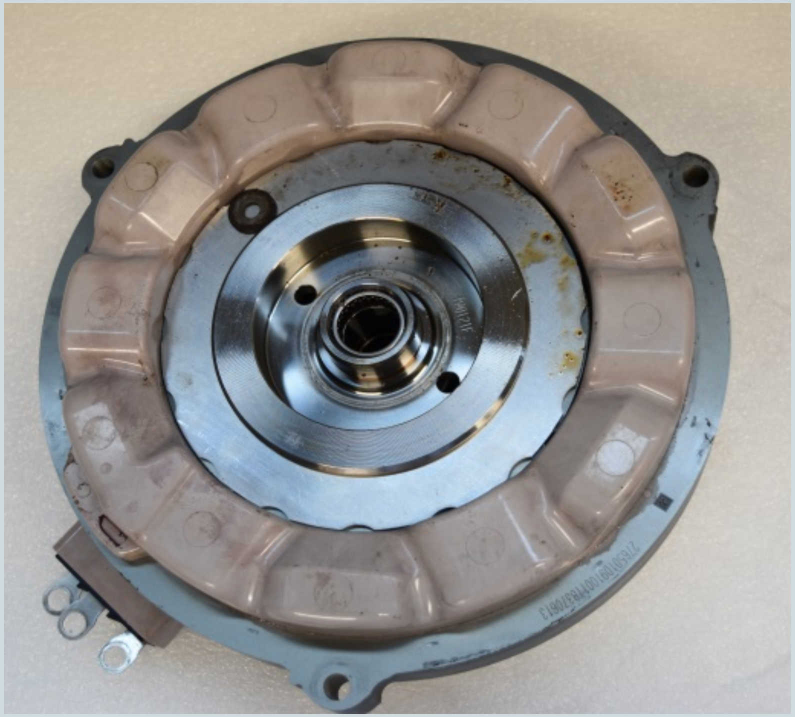
Occurrence of permanent(RE) magnets in Electric Vehicles.

Table 1. Overview of permanent magnets in (H)EVs and Advanced ICEVs. DEMETER focuses on the larger permanent magnet machines (motors and generators) in the present and future (H)EVs and, in second instance, Advanced ICEVs.

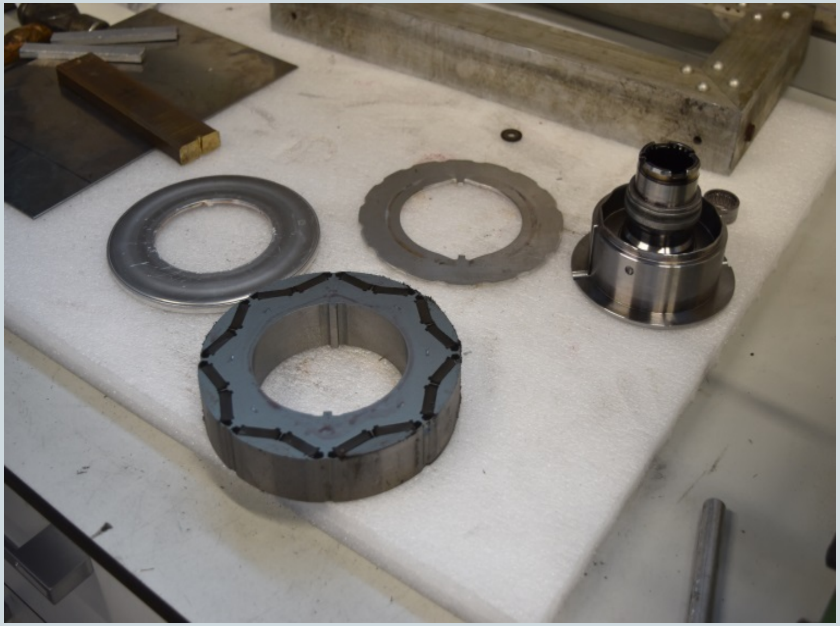
						
Magnet and alloy type and typical weight	Drive motor: NdFeB, 1-1.5 kg; or SmCo in the future	Power-steering motor: NdFeB, 30-100 g	Stop-start motor NdFeB, 200 g; or SmCo in the future	Regenerative braking generator: NdFeB, ~0.7 kg; or SmCo in the future	Range Extender generator: SmCo, 0.8-1.5 kg alloy	Small magnets (loudspeakers and tiny motors): NdFeB, < 30 g
EV	YES	YES	YES	YES	In some models	YES
HEV	YES	YES	YES	YES	NO	YES
Advanced ICEVs	NO	YES	YES	YES	NO	YES
	Scope DEMETER (main focus on (H)EVs, secondary focus on Advanced ICEVs)					

Motor from Toyota Prius

Cu, Neo magnets, Al,Stainless steel



20 kg Cu

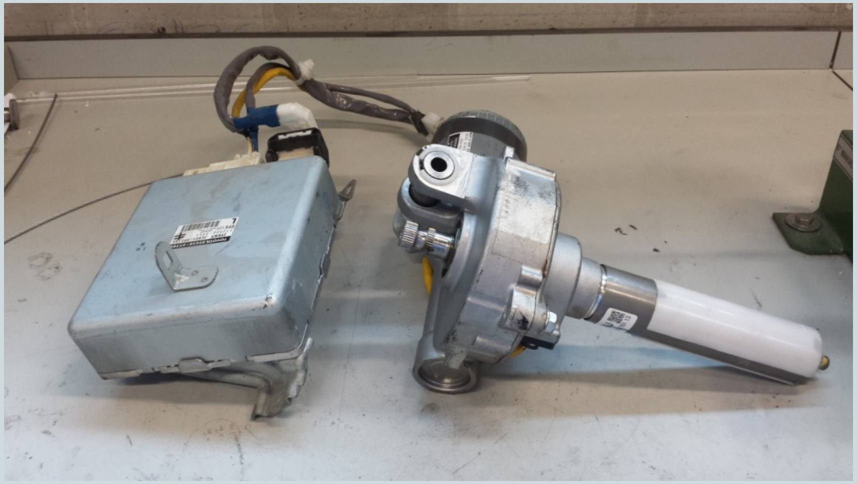


Generators

Al,Stainless steel, RE magnets

RE magnet plates slide in

Power steering

Stainless steel,Al,Cu,Nd +	Magnet assembly at centre
	

New site survey

- Due to start autumn 2016
- Logging EV and hybrid cars at major UK dismantler.

Acknowledgements

Thanks to Allan Walton, Axion Recycling, Tetronic Ltd, Muhammad Awais.