European Pathway to Zero Waste
Demonstrating the route to zero landfill

Study into the feasibility of protecting and recovering critical raw materials through infrastructure development in the south east of England.

Summary Report

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Material change for a better environment

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1.0 Introduction

Purpose of this Study

The purpose of this study was to examine the applications for the EU's list of 14 critical materials, review existing practices associated with their recovery, and identify the end markets where increased recovery of these materials has the greatest potential for implementation. The issue of critical materials is strongly related to resource efficiency and waste minimisation: these have the possibility to reduce the demand for raw materials. Therefore there are links with the aims of EPOW, which are broader than simply the minimisation of waste, and extend into other related issues such as this.

One of the typical responses to material security issues is to increase the resource efficiency of the use of these materials, such as through improved design to minimise use, to increase longevity or to allow disassembly of the material-containing product. Another response may also be investing in new collection, disassembly and reprocessing methods and infrastructure. The aim of the report is to advise on recovery of these materials and implementation of new schemes or improve existing infrastructure to decrease the demand for these critical materials.

To the knowledge of the authors, this EU Life+ funded project is the first work to look at the issues of resource efficiency in detail for the EC critical materials list. It goes beyond the approach undertaken by other studies which have analysed a different set of metals and had a specific remit on the technologies and products considered. Those studies took a material-focussed approach in considering potential recycling options, whereas this report has taken a product-based approach.

This summary report provides a synopsis of the main sections of the full study; an extensive report and accompanying annexes are available, providing more detail and supporting information.

What are Critical Raw Materials?

There are justifiable concerns about the access of developed countries to raw materials which are critical to high technology or green economy applications. Existing issues around certain resources (for example rare earth elements), and the prospect of further problems led the EC to launch the Raw Materials Initiative, which identified a group of 14 'critical materials' (Table 1).[1]

Table 1: The 14 critical materials identified in the Raw Materials Initiative

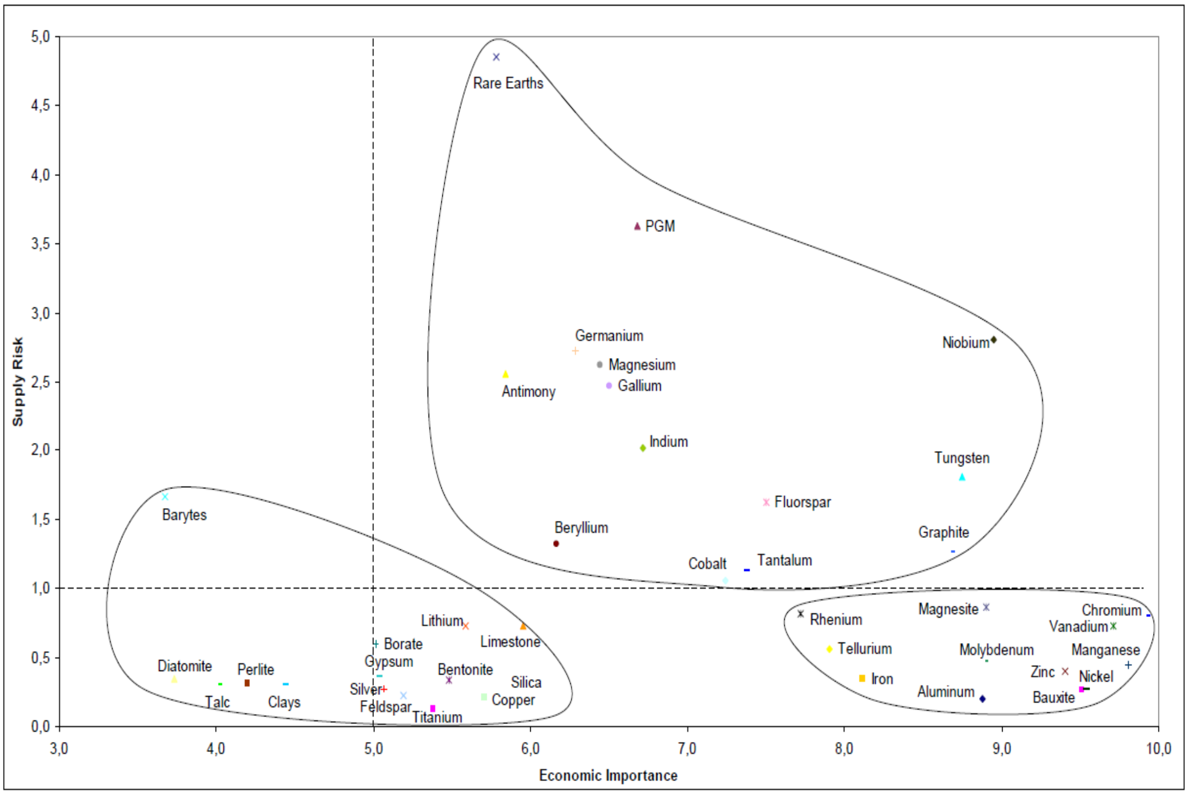
Antimony	**Beryllium**	**Cobalt**	**Fluorspar**	**Gallium**	**Germanium**	**Graphite**
Indium	**Magnesium**	**Niobium**	**Platinum Group Metals**	**Rare Earth Elements**	**Tantalum**	**Tungsten**

Source: European Commission

1 Critical raw materials for the EU, European Commission, July 2010

This group consists of mainly speciality metals which experience a combination of high economic importance to the EU and a high risk of potential disruption to or interference in supply. The EC study quantitatively analysed 41 metals and minerals, and assessed the stability of the producing country, diversity of supply, substitutability and recycling as key factors. Figure 1 gives the overall results of the EC study, with the critical raw materials circled in the top right corner of the chart.

Figure 1: Overall criticality results of the Raw Materials Initiative study



Source: European Commission

A number of different studies have attempted to evaluate the relative criticality of minerals, with different materials identified depending the specific focus and criteria.[2,3,4,5,6,7] This present study differs from these earlier reports in that rather than seeking to identify critical materials, it will identify measures which can be taken to protect and recover them.

2 Assessing Metals as Supply Chain Bottlenecks in Priority Energy Technologies, Oakdene Hollins for EC Institute of Energy, 2011

3 Critical Materials Strategy, US Department for Energy, 2010

4 Minerals, Critical Minerals, and the US Economy, Committee on Critical Mineral Impacts of the U.S. Economy, 2008

5 Material Security: Ensuring resource availability for the UK economy, Oakdene Hollins, 2008

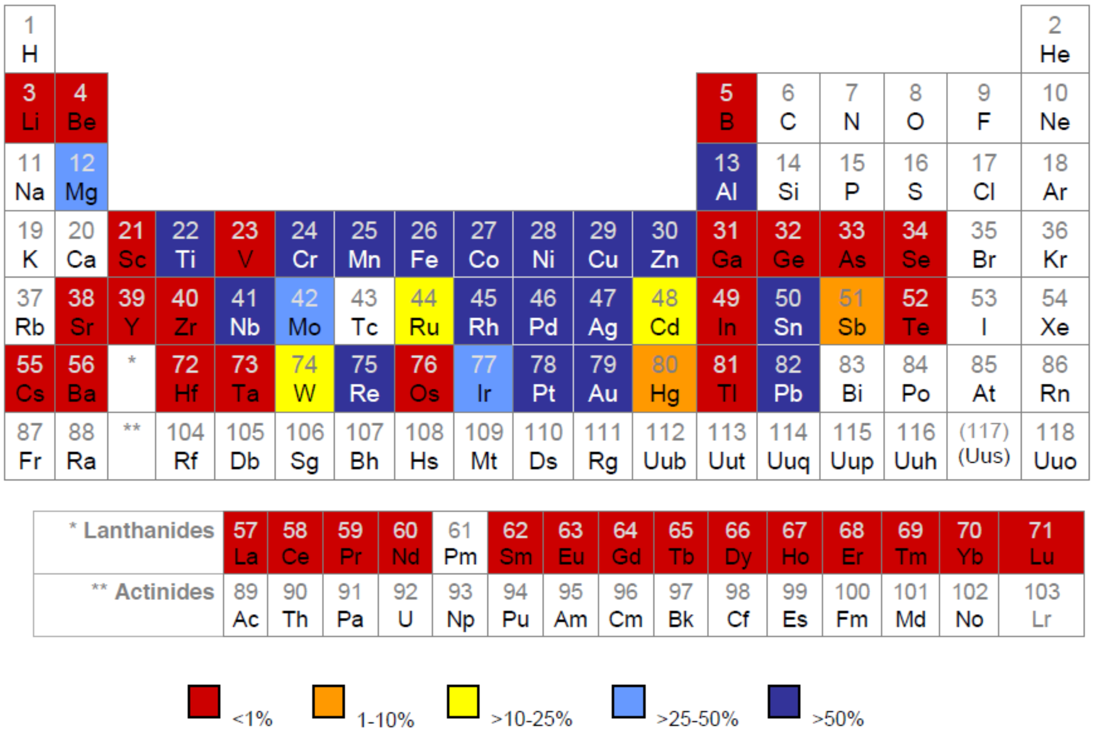
6 Les nouveaux métaux stratégiques, BRGM, 2008

7 Review of the Future Resource Risks Faced by UK Business and an Assessment of Future Viability, Defra, 2010

The Recovery of Critical Raw Materials

The rate of recovery and recycling for different metals varies considerably (Figure 2). Amongst the critical raw materials, many have very low recycling rates; beryllium, gallium, germanium, indium, rare earth elements and tantalum all have recycling rates less than 1%. In contrast cobalt, niobium and some of the platinum group metals are all reported to have a recycling rate above 50%. Antimony, magnesium and tungsten have intermediate recycling rates.

Figure 2: Recycling rates of metals



Source: UNEP/EU Working document

There are numerous challenges associated with recovering critical raw materials. Some of these are inherent to recycling in general. The OECD, in their study *Improving Recycling Markets,* identified the main sources of market inefficiency for recycling as:

- transaction costs and information failures between buyers and sellers
- externalities where the actions of individuals or companies affect other organisations, e.g. between the designer and recycler
- the market power in the primary or secondary markets.

The interactions between different actors and the associated market power have been shown to be particularly important within critical metal recycling. For example, for electronic waste in the EU there are 10,000s of different actors involved in collection, 1,000s in dismantling and 100s in pre-processing, but only three major smelters or refiners.[8] Research by the Centre for Remanufacturing and Reuse (CRR) established that

8 Opportunities & limits to recycle critical metals for clean energies, Mark Caffarey, Umicore, December 2010

these market inefficiencies also tend to carry over in the remanufacturing and reuse of products. However both government policy and market-led initiatives can be successful in overcoming these inefficiencies and promoting recycling, reuse and remanufacture.[9]

It should be noted that within this report a distinction is drawn between recycling rates and a reduction in the use of virgin raw materials. This is important as a high recycling rate for a critical raw material does not necessarily imply a reduction in the use of virgin raw material. For example, niobium contained within high strength steel grades is commonly recycled along with a larger pool of steel scrap, and is hence much diluted within the secondary steel. The recycled niobium is consequently not available as an alternative to virgin raw material. This use also highlights that the degree of dispersion and value of material is a further key issue of importance for the recycling of critical raw materials. A greater degree of dispersion implies that the cost of collecting, sorting, recycling and refining is likely to be higher than if the raw material were concentrated within a single product or in large piece. For recycling to be economic these costs need to be favourable when compared with value of the material that can be recovered.

Structure and Methodology of this Study

The full study is divided into five main sections with accompanying appendices and conclusions:

- applications, future supply and demand issues for the critical raw materials
- resource efficiency best practice for critical materials
- identification of principal end uses
- resource efficient use of critical raw materials
- conclusions and recommendations.

This summary report broadly follows this structure, however much of detailed discussion has been omitted to provide an outline of this work.

In addition to the main report, annexes have also been produced which include discussion of key applications and potential future substitution of the critical materials, as well as their reserves, output prices; and supply and demand forecasts.

2.0 Applications and Future Supply and Demand Concerns for the Critical Raw Materials

The critical raw materials identified by the EC Raw Materials Initiative are diverse in a number of senses. By way of background, this section provides an overview of the different critical raw materials, summarising the supply, demand and pricing data in Table 2. More information on each critical raw material can be found within the individual material reports located in the main report and Annex A, including summaries of applications, substitution and recycling, and further detailed data for supply, demand and pricing. Some general observations about the supply and demand of the critical materials are made below.

9 Market Failures in Remanufacturing, Centre for Remanufacturing and Reuse, 2010

Supply

The critical raw materials fall into three groups in terms of the volumes produced:

- The largest annual production is of fluorspar and graphite (the two minerals), and magnesium, which have world supply at 5,100,000, 1,130,000 and 760,000 tonnes respectively.
- The middle group has a production in the range of 62,000 to 187,000 tonnes, and includes antimony, cobalt, niobium, REEs and tungsten.
- The group with the lowest annual production has a range of 118 to 1,200 tonnes, and includes beryllium, gallium, germanium, indium, platinum group metals (PGMs) and tantalum.

The major primary producing countries are all outside the EU (except Germany for gallium):

- China is the leading producer of nine of the raw materials: antimony (91%), fluorspar (59%), gallium (32%), germanium (71%), graphite (71%), indium (50%), magnesium (77%), REEs (97%) and tungsten (81%), and is in the top three largest producers of two other critical raw materials: beryllium (14%) and cobalt (10%).
- Brazil: niobium (92%), tantalum (16%), graphite (7%) and REEs (1%).
- United States: beryllium (86%), magnesium (7%) and germanium (3%).

Demand

There is a diverse number of applications for these critical raw materials ranging from automotive end-uses to electronics and chemicals to construction. For seven of the critical raw materials, a single application accounts for over half of the consumption. From Table 2 it can be observed that a number of different critical raw materials are contained in the same products. It is this cross-mapping, over different applications, which was used in the screening process to obtain a short list of product groups for resource efficiency review. Demand growth is forecast to be strong for a number of the critical raw materials, with seven having forecast demand growth rate at around 5% or above (significantly above forecast global GDP growth, 3.6%[10]) and three (gallium, niobium and REEs) with growth rates forecast at or around 10% per year. Strong demand growth for particular emerging technologies such as electric vehicles and wind turbines will alter the composition of consumption and could lead to some shortages.

Although there is a broad range in prices, these map relatively closely to production levels In terms of prices for each of the critical raw materials. The most expensive critical raw materials are those among the lowest levels of production: PGMs ($31,847/kg), germanium ($1,151/kg) and indium ($506/kg); the cheapest being those with the largest levels of production: fluorspar ($0.42/kg), graphite ($1.16/kg) and magnesium ($3.29/kg). Assessment of the price trends of these materials highlight the volatility associated with the commodity boom and economic downturn, or government intervention as with REEs.[11]

10 World Bank World GDP Forecast for 2010-2012, available at URL: http://web.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTDECPROSPECTS/EXTGBLPROSPECTS/0,,contentMDK:20675180~menuPK:615470~pagePK:2904583~piPK:2904598~theSitePK:612501,00.html accessed 02/03/11

11 Graphs are shown are available in the main report and Annex A

Table 2: Summary of supply, applications, price and demand for the critical materials

Critical Raw Material	World Supply 2009 (tonnes)*	Primary Producing Countries (%)	Major Applications (%)	Forecast Demand Growth p.a. (%)	Price – 3yr Ave ($/kg)
Antimony	187,000	China (91%) Bolivia (2%) Russia (2%)	Flame retardants (72%) Batteries (19%) Glass (9%)	4.2%	$6.58
Beryllium	140	United States (86%) China (14%) Mozambique (1%)	Electronics/it (20%) Electric equipment (20%) Final consumer goods (15%)	3.0%	$165#
Cobalt	62,000	Congo Kinshasa (40%) Australia (10%) China (10%)	Batteries (25%) Superalloys (22%) Carbides/tooling (12%)	2.5%	$57.45
Fluorspar	5,100,000	China (59%) Mexico (18%) Mongolia (5%)	Hydrogen fluoride (60%) Steel (20%) Aluminium (12%)	3.4%	$0.42
Gallium	118	China (32%) Germany (19%) Kazakhstan (14%)	Integrated circuits (66%) Laser diodes & led (18%) R&d (14%)	10.2%	$499
Germanium	140	China (71%) Russia (4%) United States (3%)	Fibre optic (30%) Infrared optics (25%) Catalyst polymers (25%)	3.4%	$1,151
Graphite	1,130,000	China (71%) India (12%) Brazil (7%)	Foundries (24%) Steel industry (24%) Crucible production (15%)	3.0%	$1.16
Indium	1,200	China (50%) South Korea (14%) Japan (10%)	Flat panel displays (74%) Other ito (10%) Low melting point alloys (10%)	6.5%	$506
Magnesium	760,000	China (77%) United States (7%) Russia (5%)	Casting alloys (50%) Packaging (16%) Desulfurization (15%)	7.3%	$3.29
Niobium	62,000	Brazil (92%) Canada (7%) Others (1%)	Structural (31%) Automotive (28%) Pipeline (24%)	10.1%	$62.05
Platinum group metals	445	South Africa (61%) Russia (25%) Canada (4%)	Autocatalysts (53%) Jewellery (20%) Electronics/electrics (11%)	2.7%	$31,847
Rare earth elements	124,000	China (97%) India (2%) Brazil (1%)	Catalysts (20%) Magnets (19%) Glass (12%)	9.8%	$29.83
Tantalum	1,160	Australia (48%) Brazil (16%) Congo Kinshasa (9%)	Metal powder (40%) Superalloys (15%) Tantalum carbide (10%)	5.3%	$352
Tungsten	94,009	China (81%) Russia (4%) Canada (3%)	Cemented carbides (60%) Fabricated products (17%) Alloy steels (13%)	4.9%	$41.21

Notes: Supply includes estimates of recycling where available; # Beryllium price is 2 year average of US export prices (not publicly traded)*

Source: Annex A

3.0 Identification of Principal End Use Applications

The 'EU Critical 14' minerals and metals are used in a wide variety of products. In addition two of the fourteen are themselves groups of metals: rare earth elements (REEs) and platinum group metals (PGMs). Hence it was not possible to consider the resource efficiency opportunities for each combination of element and end use within the scale of this project. Research on the materials identified 40 end uses. Screening was undertaken to identify the most relevant groups for the purposes of the study, with the aim of identifying around 10 markets or applications for further study of potential resource efficiency measures. Screening criteria were developed based on consumption levels, economic value and carbon impact of the critical materials associated with each group. In total 12 markets were selected using this methodology (Table 3).

Table 3: Final matrix of selected markets and materials

	Antimony	Beryllium	Cobalt	Fluorspar	Gallium	Germanium	Graphite	Indium	Magnesium	Niobium	PGMs	REEs	Tantalum	Tungsten
Automotive/Aerospace		■	■				■		■	■			■	
Batteries			■				■					■		
Catalysts			■			■					■	■		
Cemented carbide tools			■											■
Chemicals				■										
Construction									■					
Electrical equipment					■		■	■	■			■		
Electronics/IT	■	■			■	■		■			■	■	■	
Flame retardants	■													
Optics					■	■								
Packaging									■					
Steel & steel alloys				■			■		■			■		

Whilst care was taken to ensure that distinct end uses were chosen, the nature of this work and the data available on the use of these materials meant that there was some overlap between them when investigation into the market took place. For example, superalloys were represented as a separate group, but have been discussed within the aerospace sector where appropriate.

4.0 Resource Efficient Use of Critical Raw Materials

Within the study each market was researched, as well as submarkets where appropriate. In total 40 applications of the critical materials were investigated; these are listed in Appendix 1 of this report. Each of these applications were studied in detail to assess existing supply chains, current end of life practice and assess potential for reducing critical raw material demand through improved recovery. Each of these markets and applications is discussed in detail within the main report. Over all the applications, ten were identified as having high potential for recovery, and eleven as having medium potential.

Summary of Opportunities and Recovery of Critical Materials

Table 4 outlines the ten applications identified as having high opportunity to implement critical material recovery.

Table 4: Summary of 'high' opportunities from all markets, with estimated consumption and value associated with each[12]

Market/ Submarket	Application	Raw Material(s)	Current Total Consumption (Tonnes)	Current Total Consumption ($Millions)	Estimated Carbon Impact	Timeframe
Aerospace	Superalloys	Cobalt	10,639	$611	N/A	Short
		Niobium	4,960	$308		Short
		Tantalum	58	$20		Short
	Landing gear	Beryllium	21	$3	N/A	Short
	Aluminium alloys	Magnesium	54,900	$180	Medium	Short
Portable Batteries	Li-Ion	Cobalt	11,594	$666	Medium	Short
		Graphite	39,776	$46		Short
Catalytic Converters (PGMs)	Vehicles	PGMs	232	$7,398	Low	Short
Wind Turbines	Wind Turbines	REEs	6,126	$183	Medium	Long
Screens	Used as ITO in LCD screens	Indium	444	$225	Low	Medium
Hard Disk Drives	80% of ruthenium produced is used in hard disks	PGM (ruthenium)	10	$327	Medium	Short
	Neodymium is used in magnets for HDD	REEs	7,304	$218	Medium	Short
Beverage Cans	Aluminium Alloys	Magnesium	97,600	$321	High	Short

For each of these applications the current consumption in tonnage and value associated with each critical material has been estimated using data from Annex A. It should be

12 It was assumed that 5% of tantalum consumption was used for aerospace alloys

noted that these values include material that is already recycled and assume 100% recovery, therefore will likely overestimate the true scale of the opportunity. However, they do provide an indication of the potential materials saving and value associated with each application.

According to these estimates, catalytic converters have the highest potential market value for critical material recovery, even if it is assumed that recovery of half already occurs. Two values are comparatively low: tantalum in aerospace superalloys (however this application includes larger values of cobalt and niobium) and beryllium used in landing gear. The timeframes for implementing the measures discussed in the individual sections have also been estimated, with ‘short’ being 0-5 years, ‘medium’ 5-10 years and ‘long’ 10 years or more. This assessment indicates that most of these opportunities are likely to be feasible in the short term.

Eleven further opportunities were identified as having medium potential for future implementation, (Table 5). These opportunities may still be viable; however, there are greater barriers to implementation, which are discussed within individual market sections.

Table 5: Summary of medium opportunities from all markets, with estimated consumption and value associated for each[13]

Market/ Submarket	Application	Raw Material(s)	Current Total Consumption (Tonnes)	Current Total Consumption ($Millions)	Estimated Carbon Impact	Timeframe
Automotive	Aluminium alloys	Magnesium	259,250	$852	Medium	Medium
Portable Batteries	NiMH	REEs	4,266	$127	Low	Short
		Cobalt	2,046	$118		Short
(H)EV Batteries	Li-Ion/ NiMH	Cobalt	1,860	$107	Low/ Medium	Long
		Graphite	5,424	$6		Long
		REEs	5,654	$169		Long
Catalytic Converters (REEs)	Vehicles	REEs	7,548	$225	Low	Short
Process Catalysts	General	REEs	17,252	$515	Medium	Short
Cemented Carbide Tools	Tooling	Cobalt	7,440	$427	Medium	Short
		Tungsten	34,800	$1,434		Short
Permanent Magnets	(H)EVs	REEs	5,654	$169	Medium	Long
Solar PV	Solar PV	Gallium	4	$2	Low	Long
		Indium	12	$6	Low	Long
Flame Retardants	Flame retardant in plastics	Antimony	134,640	$886	Low	Short
Steel Production (Graphite)	Raise carbon content of steel (recover losses)	Graphite	27,120	$31	Low	Short
Steel Production (Others)	Pickling	Fluorspar	61,200	$25	Low	Short

13 It was assumed that 5% of graphite losses could be recovered from steel, and 2% of hydrogen fluoride was used in stainless steel production

Potential Recovery of Critical Materials

To provide an indication of the materials which lack potential recovery opportunities, the consumption and values associated with the high and medium opportunities have been summed together, and an assessment of each material performed (Table 6).

Table 6: Summary of high and medium opportunities associated with each critical material

	Current total consumption of material (tonnes)	Consumption associated with High/Medium opportunities (tonnes)	Proportion attributed to High/Medium opportunities (%)	Value of current consumption ($Millions)	Value associated with High/Medium opportunities ($Millions)
Antimony	187,000	134,640	72%	$1,231	$886
Beryllium	140	21	15%	$23	$3
Cobalt	62,000	33,579	54%	$3,562	$1,929
Fluorspar	5,100,000	61,200	1%	$2,118	$25
Gallium	184	4	2%	$92	$2
Germanium	140	0	0%	$161	$0
Graphite	1,130,000	72,320	6%	$1,307	$84
Indium	600	456	76%	$304	$231
Magnesium	610,000	411,750	68%	$2,004	$1,353
Niobium	62,000	4,960	8%	$3,847	$308
PGMs	445	232	52%	$14,172	$7,398
REEs	124,000	53,804	43%	$3,699	$1,605
Tantalum	1,160	58	5%	$409	$20
Tungsten	58,000	34,800	60%	$2,390	$1,434

From this analysis it is clear that the materials fall into two distinct groups: those which have a large potential for recycling to reduce the demand for raw materials (antimony, cobalt, indium, magnesium, PGMs, REEs and tungsten) and those for which recovery and recycling appear unlikely to significantly reduce the demand for primary production (beryllium, fluorspar, gallium, germanium, graphite, niobium and tantalum). This indicates that whilst recovery and recycling can have an impact on demand for certain materials, other measures such as substitution, reuse or elimination may be necessary to reduce the demand for these raw materials in the future.

5.0 Conclusions and Recommendations

Conclusions

The recycling industry in the UK and EU has been found to be efficient at targeting new opportunities for recovering valuable materials from emerging waste streams, whether they are critical materials or other recyclates. Pre-consumer recycling is efficient for almost of all of the critical materials, and often accounts for a large proportion of the overall supply. By contrast, the levels of post-consumer recycling of the critical materials are more variable as many of the 14 critical materials fall outside more common recycling activities. For example high recycling rates are achieved for magnesium in beverage cans due to its link with aluminium, but almost no recovery occurs for the materials used in electronic equipment. When entering EU-based processing, unrecovered critical materials typically end up in waste slags or landfill or are lost during incineration. However, many end of life products containing critical materials are sent outside the EU, therefore excluding them from EU- or UK-based supply chains. It was also found that not all activities which are considered to be 'recycling' reduce demand for raw materials. For example in steel alloy recycling, the critical material niobium is retained through recycling. However its concentration is diluted due to the presence of different steel grades, and its properties are lost; hence no primary niobium production is avoided. Therefore care is needed when assessing recovery and recycling rates of these materials.

There is technology available for recycling of almost all of the 14 critical materials on at least on a demonstration level (with some uses of REEs and fluorspar being the main exceptions). However, the availability of these technologies does not enable material recovery, and several other factors were found to hinder recovery:

- **Collection:** Recovery of the product does not take place, therefore the materials never enter recycling streams. This is common for batteries, beverage cans, and vehicles.
- **Separation:** The material or component containing the critical material may be difficult to separate or may be contaminated. Therefore extra processing and costs are associated with recycling. This is typical of integral batteries, hard disk drives and flame retardant containing plastics.
- **Dispersion:** The properties of many critical materials mean that they are often found in low concentrations, and large volumes of waste provide only small quantities of material. This is true for niobium-containing steels and metals used in PCBs.
- **Uncertainty:** Implementation of large scale recycling requires significant investment; this is increasingly true for critical materials. Uncertainty about future quantities and qualities of waste streams, legislation and the value of materials can discourage the establishment of recycling activities.

With these factors in mind, and considering existing and future uses of the critical raw materials, ten opportunities for markets with high potential for increased recovery of critical materials were identified, summarised below.

	Market	Application
Growth	Catalysts	Catalytic converters
	Packaging	Beverage cans
Implementation	Aerospace	Superalloys
		Landing gear
		Aluminium alloys
	Batteries	Portable Li-Ion
	Electronics and ICT	Hard disk drive magnets and layers
Future Prospect	Electronics and ICT	LCD screens
	Electrical Equipment	Wind turbine magnets

These classifications distinguish between:

- those opportunities which are well established but have potential for **growth** through development of infrastructure
- opportunities which will arise in the short term that will require **implementation** of new infrastructure or technology
- opportunities which are **future prospects.**

A further eleven applications were found as having medium potential for increased recovery. These opportunities may also be viable: however there are greater barriers to their implementation. A gap analysis of all high- and medium-potential opportunities identified two groups within the critical materials: those for which end of life recovery has the potential to reduce demand for raw materials, and those for which this will have little impact.

Critical Raw Materials	
Reduction from recovery	**Low impact from recovery**
Antimony	Beryllium
Cobalt	Fluorspar
Indium	Gallium
Magnesium	Germanium
PGMs	Graphite
REEs	Niobium
Tungsten	Tantalum

Therefore, though recycling presents one option for reducing the demand for raw materials, other activities such as remanufacturing and reuse, substitution or elimination will be necessary to meet projected demands for some critical materials. Some of these activities are already in place; remanufacturing already plays a large role for automotive components and electronic equipment. Substitution, either of material or product, is possible; however, the replacement of many critical materials simply adds to the demand for different critical materials. Care is needed when considering this strategy.

Overall Recommendations

In addition to identifying the ten most promising markets for critical material recovery, the following recommendations, applicable to the UK and EU, are made for increasing the recovery of critical raw materials:

- **Improved collection:** Several of the recycling activities highlighted above are already in place, but their impact is limited by poor recovery. Developing more efficient collections schemes for consumer (e.g. beverage cans) or industrial (e.g. aircraft or cemented carbide tools) waste will increase recycling rates. This may also help enable other end of life options such as remanufacturing and reuse.
- **Advanced sorting techniques:** Existing business models using practices such as ‘shred and sort’ are poor at isolating small, high value items containing critical materials. Therefore, high value materials may be lost or dispersed into large quantities of generic shredded waste. Implementation of more sophisticated sorting, which distinguishes between items containing critical materials, will help encourage the recovery of these raw materials, and produce ‘higher value’ waste streams.
- **Implementation of new technology:** New technologies, such as that for the recovery of magnets from hard disk drives, are becoming available. With the implementation of improved collection and sorting, these will become viable as larger volumes of isolated waste types become available.
- **Linking of agents within the supply chain:** The design and use of many products prevents separation of components such as batteries. Linking together designers, producers and waste management firms will aid understanding of the challenges of separation at end of life.
- **Design for disassembly:** Existing sorting of materials is often held back by product design lowering the ease in which parts can be separated, for instance using epoxy resins or non-standard screw types for connecting components. Adopting design practices which enable disassembly will improve the efficiency of sorting. The EU Ecolabel scheme has already adopted this approach through specification in the electrical equipment criteria. This action will also help remanufacturers and refurbishers extend the life of products.
- **More sophisticated waste recovery targets:** Existing targets are often weight-based, leading to an emphasis on the recovery of materials in bulk whatever their specification; this often causes further dispersion of critical materials. Investigating and implementing measures which would motivate separation based on critical material content would help prevent this occurring.
- **Alignment and enforcement of regulations:** Implementation and enforcement of headline policy to specific market regulations will provide recyclers with greater certainty over future waste streams.

- **Remanufacturing and reuse:** Remanufacturing and reuse activities can help resource efficiency through product life extension. These activities are already established with the aerospace and automotive industries, however wider implementation would increase their impact.

Recommendations for the South East of England

The recommendations and opportunities described above on a wider scale also apply to the South East of England. However, the existing infrastructure and regional scale should be borne in mind; for certain materials there may only be enough material arising in Europe to reasonably supply one refiner.

At present the infrastructure in the South East of England is mainly focussed around collection, sorting and processing with companies such as Light Brothers acting as focus for these activities. Once products are processed the recycling of the materials typically happens outside the region for example at Johnson Matthey's plant in Royston, Hertfordshire, and a few other large sites in the EU; alternatively they are sent to outside the EU. No refiners of these materials were identified within the region.

The most likely short term opportunities of improving the recovery of critical materials in the South East of England through infrastructure development lie within the improvement of existing collecting and sorting infrastructure, through the recommended measures above. Opportunities for implementing new recycling technologies for potential future waste streams also exist, however the lack of smelters may inhibit the extent to which these can be implemented.

Therefore, providing the availability and concerns over these critical raw materials continue, and prices remain high, conclusions about changes required to the South East's infrastructure can be made, particularly for those opportunities identified above:

Post-Consumer Waste:

- WEEE - More sophisticated WEEE recycling facilities, including
  - Greater disassembly prior to shredding
  - Greater segregation of a larger number of material streams.

This would enable the recovery of critical material containing components within many of the uses described above. For example, Hitachi has developed technology to isolate and recover the REE magnets used in hard disk drives. Technologies are also available for the recovery if indium from LCD screens, antimony from plastics and both Li-Ion and NiMH batteries.

- Packaging – Improved collection of "on-the-go" recycling for beverage, for example through increased numbers of recycling facilities in public spaces, are required as recycling technology is well established

Post-Industrial Waste:

- A larger number of distributed post-industrial collections schemes (or expansion of existing) will lower critical material demand. For example, collections systems for cemented carbide tools, though actual recycling taking place outside the South East.
- The recovery of aerospace components is a growing theme, as manufacturers and organisations are increasingly seeking to investigate this end of life option. Locations for strip down facilities will be required, although given space requirements it is likely that expansion will occur outside the South East.
- Recovery of wind turbine magnets is a long term prospect, likely to be most viable near large wind farms. Development of dismantling and recovery specific to wind turbines will be necessary, as well as recycling technology and substantial investment in infrastructure.

6.0 Appendix 1 – Summary of Markets and Applications

Market	Submarket	Application		
Aerospace and Automotive	Aerospace	Aluminium alloy parts	Landing gear	Super alloys
	Automotive	Aluminium alloy parts	Steel alloy parts	Brake linings
Batteries	Portable Batteries	Lithium-Ion	Nickel Metal Hydride	
	Electric Vehicle Batteries	Lithium-Ion	Nickel Metal Hydride	
Catalysts	Vehicles	Catalytic Converters		
	Process Catalysts	Plastic	General	Petrochemical
Cemented Carbide	Tooling	Tooling		
Chemical	Fluorocarbons	Refrigerants	Blowing Agents	Fluoropolymers
	Aluminium fluoride	Flux agent		
Construction	Aluminium alloys	Wrought Products		
	Low alloyed steel	Pipelines	Structural	
Electrical Equipment	Permanent Magnets	Electric Vehicles	Wind Turbines	Small Domestic Appliances
	Solar Panels	CIGS type	CdTe type	
Electronics and ICT	---	Circuit Boards	Flat Panel Displays	Hard Disk Drives
Flame Retardants	Antimony Trioxide	Plastics		
Optical Equipment	---	Fibre optics	Lenses	LED lighting
Packaging	Aluminium alloys	Beverage Cans		
Steel and Steel Alloys	Steel Production (Graphite)	Carbon content	Electrodes	
	Steel Production (Others)	Flux agent/pickling	Desulfurization	Stainless Steel

Would you like to find out more about European Pathway to Zero Waste?

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