A report by

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RESEARCH & CONSULTING

Critical Materials

Examining the Materials that are Critical to our Sectors and Economy

For Scottish Enterprise, March 2014

Critical Materials

Examining the Materials that are Critical to our Sectors and Economy

Resource efficiency

Clean technologies

Sustainable products and services

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Glossary

AHWG	EU Ad hoc Working Group (on Defining Critical Raw Materials)
BGR	Federal Institute for Geosciences and Natural Resources (Germany)
BGS	British Geological Survey
BIS	(Department of) Business Innovation & Skills
BMBF	Federal Ministry of Education and Research (Germany)
BRGM	Geology and Minerals Research Institute (France)
CFRC	carbon-fibre reinforced composite
CRM	critical raw material
Defra	Department for Environment, Food & Rural Affairs
DG	EC Directorate General
DSTL	Defence Science and Technology Laboratory
EEE	electrical and electronic equipment
EIP	European Innovation Partnership
EPSRC	Engineering and Physical Sciences Research Council
EV	electric vehicle
FP7	Seventh Framework Programme
FRP	fibre-reinforced polymer composite
GDP	gross domestic product
GE	General Electric
GVA	gross value added
HEV	hybrid electric vehicle
HIE	Highlands and Islands Enterprise
IAG	Industry Advisory Group
IOM3	Institute of Materials, Minerals, and Mining
ITO	indium tin oxide
JOGMEC	Japan Oil, Gas and Metals National Corporation
KTN	Knowledge Transfer Network
LCA	life cycle analysis
Li-ion	lithium ion
METI	Ministry of Economy, Trade and Industry (Japan)
MEXT	Ministry of Education, Culture, Sports, Science and Technology (Japan)
MoD	Ministry of Defence
NERC	Natural Environment Research Council
NiMH	nickel metal hydride
NIMS	National Institute for Materials Science
OEM	original equipment manufacturer
PGM	platinum group metal
PV	photovoltaic
REACH	EU Regulation for the Registration, Evaluation, Authorisation & Restriction of Chemicals
REE	rare earth element
RES	Resource Efficient Scotland
RMI	Raw Material Initiative
SEPA	Scottish Environment Protection Agency
SFTT	Scottish Forest and Timber Technologies
SIP	Strategic Implementation Plan
SME	small to medium sized enterprise
SNBTS	Scottish National Blood Transfusion Service
TSB	Technology Strategy Board

US DOE	US Department of Energy
USGS	US Geological Service
WEEE	waste electrical and electronic equipment
WRAP	Waste & Resources Action Programme
WTO	World Trade Organisation
ZWS	Zero Waste Scotland

Units

Conventional SI units and prefixes used throughout: {k, kilo, 1,000} {M, mega, 1,000,000} {G, giga, 10^9} {kg, kilogramme, unit mass} {t, metric tonne, 1,000 kg}

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1 Executive summary

Access to raw materials is of growing concern globally amongst Governments and businesses alike. Of particular concern are the potential economic, social and environmental impacts that may result from supply disruptions. As a result, five Scottish Government agencies[1] have identified material supply issues as a potential threat to the Scottish economy, particularly in the context of the Scottish Governments' Economic Strategy. However, these issues may also act as a driver toward the development of a circular economy within Scotland, and achieving zero waste targets.

This study outlines the risks and issues to businesses in Scotland associated with raw materials, identified through surveying industry stakeholders. Therefore, this survey has sought to monitor directly the impact that raw materials have on the Scottish Economy, the implications of these impacts to growth strategies, and possible responses. Conclusions and recommendations have been informed by an analysis of international responses, to define possible actions for Scotland.

A sectoral approach has been taken, with nine priority industry sectors selected:

- Aerospace, Defence and Marine;
- Energy – Oil & Gas, and Renewables;
- Construction;
- Food and Drink;
- Forest and Timber Technologies;
- Life and Chemical Sciences;
- Manufacturing Sector;
- Technology and Engineering; and
- Textiles.

From the in depth responses gathered from across industry, **70% identified the importance of raw materials risks to their business to be high or very high** when compared to other supply chain issues such as utility costs, variability of downstream demand, and operational risks**.** The significance of raw materials is further underscored by the fact that 80% of businesses considered raw materials to be vital or very important.

For each sector, material inputs, issues and responses were identified (see Sectoral Summary on following page). The **materials identified are often specific to a sector or sub-sector**, linked to the particular needs and activities of the sector. Therefore a broad range of materials and material types are seen, which is also sector dependent.

However, **several materials were identified at a high level which had a much broader influence** across several sectors, namely water, steel, copper and plastics (see Cross Sector Materials Summary on following page). These warrant consideration at a wider, cross-sectoral level due to their fundamental importance and uses.

Common raw material supply issues identified across sectors include:

- Disruptions to supply or lead times;
- Price increases and volatility;
- Competition from other markets;
- Poor diversity of suppliers, and lack of local supply chains;
- Stock management challenges; and
- Sourcing of low volume/high specification materials.

At a business level these were manifested as higher costs, longer lead times or uncertainty of supply to customers.

[1] Scottish Enterprise, Highlands and Islands Enterprise, Scottish Government, SEPA and ZWS

Sectoral Summary

Sector	Materials Highlighted	Business Issues	Main Business Responses
Aerospace, Defence & Marine	Aluminium, titanium, plastics, composites.	Price rises and volatility. Lead times. Sourcing of obsolete specifications.	Seek new suppliers. Increase inventory. Absorbing/passing on costs. Consolidating orders.
Construction	Aggregates, cement, steel, timber, topsoil, plastics and resins.	Price rises and volatility. Competition for supply. Supplier concentration. Sourcing low volume materials.	Absorbing costs. Supplier diversification. Alternative materials. Long term supply agreements.
Energy	High grade steel, rare earth elements, helium.	Price rises and volatility. Reliable availability. Access to correct grades.	Supplier diversification. Passing on costs.
Food & Drink	Animal feed, malt barley and other crop inputs.	Lower quality materials. Rising prices.	Improve processing efficiencies. Long term supply agreements.
Forest & Timber Technologies	Timber and resins.	Availability and competing markets. Supply constraints. Price fluctuations.	Diversifying suppliers. In-house production.
Life & Chemical Sciences	High purity chemicals, plastics, blood plasma and bovine serum, aluminium.	Sourcing low volume/high specification materials. Lead times. Price rises.	Supplier diversification. Localised supply. In-house production. Long term supply agreements.
Manufacturing	Steel, glass fibre, plastics, fish and soya protein.	Competition for supply. Lead times. Quality of materials.	Supplier diversification. Long term supply agreements. Localised supply. In-house production.
Technology & Engineering	Non-ferrous metals, industrial and high purity chemicals, resins, plastics.	Consolidation of suppliers. Sourcing low volume/high specification materials. Lead times.	Supplier diversification. Recovery of process scrap. Reduction in capacity.
Textiles	Natural fibres, speciality synthetic fibres, water, bovine hide.	Price rises and volatility. Competition for supply.	Changing products' composition. Passing on costs.

Cross Sector Materials Summary

Materials	Issues Highlighted	Main sectors affected
Water	Obtaining correct quality or purity. Access to required quantities.	Food & Drink, Forest and Timber Technologies, Life & Chemical Sciences, Manufacturing, Textiles.
Steel	Access to correct grades. Price volatility.	Construction, Energy, Manufacturing.
Copper	Increasing costs. Competition for supply.	Construction, Energy, Manufacturing, Technology and Engineering.
Plastics	Obtaining correct specification. Competition for supply.	Aerospace, Defence & Marine, Construction, Life & Chemical Sciences, Manufacturing, Textiles.

Although there is variation between sectors, common actions include **negotiating longer term supply agreements, diversifying supply, delaying or reducing production, seeking alternative materials, and absorbing or passing on costs.**

Although individual businesses faced these issues and dealt with them, **no high level sector- or industry-wide strategy was evident.**

The analysis also highlights how **the materials identified as being important to different sectors have the potential to impact on sector growth initiatives**. For example, failure to ensure a sufficient supply of high-grade materials, such as steel for the energy sector and water for the whisky sub-sector, could hinder growth strategies within these and other sectors. Furthermore, the increasing use of materials such as composites (in aerospace) and thermoset plastics (in manufacturing) which cannot be easily or cheaply recycled may impact on the aim of achieving a 70% recycling rate for all of Scotland's waste by 2025.

International analysis and responses were reviewed to compare with the findings of this work, and to provide information on responses taken elsewhere. This analysis covered studies undertaken at the Scottish, UK, EU and global level, from the perspectives of Government, business and technological development.

In contrast to these other studies, where basic raw materials are often identified, the survey highlights several processed or specific grades of materials. This is a result of the different stages of the supply chain investigated by different studies. In addition, the sectoral approach taken for this work led to a greater number of materials being identified. This suggests that a fully defined list of critical raw materials may be inappropriate.

This analysis highlighted six key themes that responses took:

- **Improving the knowledge base** on raw materials and related issues;
- **Development of indigenous resources** to reduce supply risk;
- **Supply chain development and diversification** to increase resilience to disruptions;
- **Strengthening external supply circumstances** to reinforce trade;
- **Increasing material efficiency** to reduce raw materials reliance; and
- **Enhancing materials recovery** to provide viable sources of secondary raw materials.

These themes, and the findings of the survey, were used to produce recommendations for the Scottish Government and its Agencies, to assist businesses dealing with these issues.

- Raw material issues were of high concern to almost all the businesses responding. However, responders were often not aware of wider issues within the sector or economy. **Raising the profile of raw materials issues** to a wider audience across industry will highlight that raw material risks are of broad concern and not isolated within specific instances or businesses. Actions could include: holding workshops with industry to highlight specific issues in different sectors; equipping Account Managers within the Enterprise Agencies with up-to-date materials criticality information to inform discussions with their managed businesses; commission a study to clarify the potential impacts of the identified materials issues on planned infrastructure provision in Scotland; and holding events in higher education and research departments to engage with the future generation of business leaders.

- This research has identified issues associated with certain materials that are important to different sectors and for which serious issues have been identified. **Interventions to bring supply chain organisations together** will help to identify and resolve the issues associated with materials supply. Such interventions could come through the creation of material-specific working groups, primarily for materials that have cross-sectoral importance such as steel, copper, water and timber.
- Whilst this report has highlighted sectors in which materials are used according to the principles described in the Government Economic Growth Strategy, it has also highlighted situations where primary materials are used in place of recycled options and where previous virgin materials are not used for their most value added purpose. Businesses that implement measures such as reduced resource inputs and materials substitution within their supply chains should be rewarded for their efforts by i**ncentivising sustainable supply chains**. The Scottish Government could help businesses here by establishing a hierarchy of uses for internal materials resources, for example prioritising the potential uses of virgin timber. Incentives, such as subsidies (subject to fiscal studies), could be offered for using renewable raw materials, improving materials efficiencies, using materials that are socially and environmentally beneficial, or for using raw materials from Scotland when these exist.
- This research has found that the majority of businesses are employing similar responses to materials issues. However, some are engaged in proactive measures such as materials substitution, resource efficiency strategy and moving to more circular business models. This research has also identified a desire of businesses within and across sectors to learn from the successful supply-chain approaches of others, and similarly for those with successful approaches to educate other businesses. Creating a **knowledge exchange platform for supply chain strategy** would enable similar-sized businesses in different sectors to learn from successful supply-chain approaches, including raw materials sourcing strategies, stock management, innovative business models and demand forecasting. For example, the aerospace sector has robust supply chain methods, for materials quality checking and demand forecasting in particular, that they would happily share with other sectors, especially suppliers.
- Through discussions with businesses from a wide range of industrial sectors, this report identified a common theme; namely, that these businesses do not (typically) gain real practical value from the excellent research that occurs throughout Scottish universities and research centres. **Continuing to develop links between research organisations and businesses,** to allow businesses (particularly SMEs) to better benefit from the technical research capacity within Scotland, will help industry problems to be understood and resolved in collaboration. Better links will also provide students and staff at research organisations with access to Scottish businesses, with the potential for secondments, full-time jobs and viable funding streams.

2 Introduction

2.1 Background

Access to certain raw materials has been of growing concern over the course of the last few years, particularly where these materials are of vital importance to an industry or to applications. This situation is highlighted by the growing number of studies assessing which materials can be considered as critical to a given sector, application, company or economic area. These studies have led to work assessing the risks, potential impacts and mitigation strategies for critical raw material issues.

Scottish Enterprise, along with the other members of the Steering Group[2], have recognised material supply issues as a potential threat to the Scottish economy, including to sectors which are targeted for growth in the future. This study has been commissioned as a consequence of this awareness. Its aim is to build a ground-up view of raw materials issues related to the Scottish economy, building on the previous study by SEPA by gathering data from industry.[3] The overall aim is to identify critical raw materials issues that the Scottish economy may face, potential impacts, and associated opportunities and mitigation strategies.

This study has involved two parts: a review of related studies on raw materials issues, and a survey of industry. The review of studies seeks to draw on these documents to identify resource security strategies, and uses them to inform the rest of the project. The core part of the study was to survey businesses and industry organisations, across nine key sectors listed below, to build an industry view of raw material issues. The sectors were pre-selected as part of the project's scope, using considerations such as their reliance on raw materials, importance to the Scottish Economy, and future significance based on the Scottish Government's Economic Strategy.

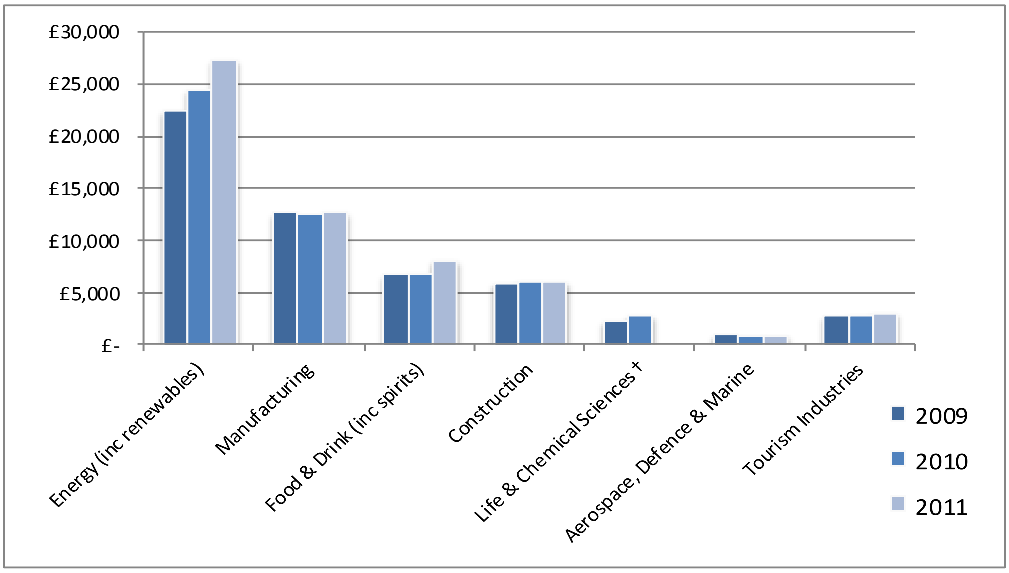
- Food and Drink
- Energy – Oil and Gas and Renewables
- Life and Chemical Sciences
- Textiles
- Aerospace, Defence and Marine
- Manufacturing Sector
- Forest and Timber Technologies
- Construction
- Technology and Engineering

Analysis of the gross value added (GVA) data from these sectors is shown in Figure 1, providing some indication of their scale, and comparison with other sectors such as tourism.

2 Highlands and Islands Enterprise, Scottish Government, SEPA and ZWS

3 Raw Materials Critical to the Scottish Economy, SNIFFER, 2011

Figure 1: GVA for selected sectors in Scotland, with tourism included for comparison



†Data not available for 2011
Source: Scottish Government Growth Sector Statistics Database. The sectors here are defined as per Scottish Government sector definitions, which may differ from Scottish Enterprise Industry definitions, and not all sectors are included in this analysis

At a higher level, the Scottish Government's Economic Strategy highlights aspects designed to achieve economic recovery, drive sustainable economic growth and develop a more resilient and adaptable economy.[4] Within this strategy six priorities are highlighted:

- Supportive Business Environment, particularly those in growth markets and sectors. The main actions in this area include establishing Enterprise Areas such as those focussing on low carbon manufacturing, providing advice and support to help SMEs grow, promoting Scottish exports, strengthening levels of innovation and commercialisation (including links between research organisations and businesses) and supporting early stage innovative technologies through the Scottish Investment Bank.
- Transition to a Low Carbon Economy, to ensure that investment and jobs are secured in this growing sector. Key aims here include a £70 million National Renewables Infrastructure Fund to support off-shore development, position Scotland as a world leader in low carbon sectors, and drive initiatives to improve energy efficiency.
- Support Learning, Skills and Well-being, particularly among young people, to create a competitive and resilient economy. Actions here include providing Opportunities for All to ensure that every 16-19 year old is either in education, training, a Modern Apprenticeship or a job, delivering 25,000 Modern Apprenticeships per annum, and investing in Higher Education in Scotland.
- Focus on Infrastructure Development and Place, to harness the strengths of different regions and towns in Scotland and promote the digital economy. Key actions in this area include investing in important municipal infrastructure projects, delivering

[4] The Government Economic Strategy, Scottish Government 2011

superfast broadband across Scotland working with the Next Digital Generation Fund, and introducing a strategy to maximise the potential of every city and region in Scotland.

- Ensure an Effective Government, which includes increasing the public sector's direct contribution to the economy, ensuring that public services remain fit for purpose, and improving the efficiency of the public sector by focussing on better regulation.
- Driving Social, Regional and Inter-generational Equity to ensure growth. Key actions here include tackling social and health problems which prevent people from realising their potential, maintaining household incomes, and supporting the development of Scotland's third sector.

Beyond these strategic aims focussed on economic growth, the Scottish Government has outlined its 'Blueprint' plan[5], the aim of which is to prevent waste, increase resource efficiency and enable a shift towards a more circular economy. To support this aim, the plan will focus on:

- Helping businesses use resources more efficiently, including preventing construction wastes, and providing businesses with better information about becoming more resource efficient.
- Stimulating businesses opportunities in the reuse and remanufacturing sectors, including establishing loan funds to support reprocessing and remanufacturing activities, increasing the supply and demand of quality reused items, and gathering evidence to better understand the breadth of opportunities.
- Promoting sustainable product design, including supporting the work of the Product Sustainability Forum, promoting the case for sustainable design in EU legislation and policies, and offering support for circular economy activities through Resource Efficient Scotland.
- Reducing the impacts of packaging, including introducing producer responsibility measures for all key products, working with Local Authorities and businesses to undertake collection trials for small WEEE, and further evaluating the Recycle and Reward pilots of vending systems.
- Improving access to information on the significance of materials to the economy and businesses, including improving the tracking of materials - including critical materials - through the economy.
- Developing a culture of resource efficiency, including engaging with and educating the public, and devising community action plans to prevent waste.

The nine sectors outlined earlier in this section are also tasked with creating sustainable growth strategies, supported by other government priorities to promote resource efficiency and circularity. These are discussed throughout the report in the sector-specific sections.

To provide insight at an economy level, this study will not only assess the potential impact of critical raw materials issues on these strategic priorities, but also identify opportunities for actions and development to support these goals. More widely, aims such as zero waste to landfill and the development of a circular economy also influence raw materials issues.

[5] Safeguarding Scotland's Resources: Blueprint for a more Resource Efficient and Circular Economy, Scottish Government 2013

2.2 Aims

The overall purpose of this study is to provide an understanding of the experiences that companies have in relation to the issue of raw materials supply compared to other supply chain issues. It will also provide insight into the key factors influencing their decision-making at present and in the future.

The specific aims of this project are to understand, in the context of raw materials:

1. Key drivers of change impacting or likely to impact the Scottish economy.
2. Implications for Scottish companies and sectors, including sector growth plans.
3. International aspects, such as how other geographical regions and companies are assessing and dealing with issues associated with critical raw materials, and what lesson can be learned specifically for Scotland.

The body of the study falls into three sections:

- **Section** 3**:** Wider context on critical raw materials, including a summary of relevant literature, government responses to the issues associated with materials criticality, and a summary of high level actions.
- **Section 4**: Government responses to raw materials issues
- **Section 5:** Industry consultation on raw materials issues, including a description of the approach adopted in this research, and an analysis of critical materials and their impact within and across sectors in Scotland.
- **Section 6:** Conclusions and recommendations, in which the main conclusions and recommendations from this research are presented.

3 Wider context on critical raw materials

3.1 Introduction

As a result of growing concerns over access to raw materials, several studies have been published recently which assess or discuss their 'criticality' or strategic importance.[6] While these concerns are not new, the issue has been brought to the fore due to the direction of technological development, an increasing reliance on a wider range of raw materials in technology, and growing markets for these products. Behind this, the demand for raw materials more generally is increasingly linked to factors such as economic growth (especially in emerging economies) and increasing population. This growth in demand is combined with concerns over the supply of materials. Supply for many materials is concentrated in a small number of countries, and to increase or diversify supply would be challenging.

The studies vary in their perspective and coverage: some seek to understand which materials are the most critical in a given context (e.g. for an economy, technology area or business); some aim to identify mitigation strategies for materials issues; other work targets both.

The means of identifying the most 'critical' raw materials vary, and the definition of a 'critical raw material' varies depending on context. For example, raw materials may be 'critical' only for a territory, company or sector, or over different timescales. However, in all cases, consideration of 'criticality' goes beyond the absolute scarcity of a material. Rather, a combination of factors is considered: such as supply concentration, political risk, impact of shortage, and evaluations of the importance of the material to a sector or economy. Furthermore, even though a quantitative scale may be used to assess criticality, materials are ranked against each other rather than measured against an absolute scale.

As a result, there is no universal definition of a critical raw material: the definition depends on perspective. However, the materials identified in this broad range of studies are likely to be of importance to Scotland due to their wider coverage, and to Scotland's global markets and supply chains. Although responses to criticality vary, there are consistent themes that can be identified and applied appropriately.

A selection of relevant studies have been identified and reviewed, focussing on emergent themes relating to scope, strategy, recommendations and conclusions (Table 1). Reviews of each of these studies are in Annexe A: Summary of reports, specifically focussing on recommendations and outputs, and learning from the Scottish economy. The summary and findings of this analysis are in Section 3.2.

Government responses from the UK, EU, and European and other countries are also summarised. This summary, together with the analysis of studies, has been used to generate a selection of high level thematic responses, with some examples of specific actions. From this, and the consultation process, we have made recommendations for the Scottish economy.

[6] In the context of this analysis, the focus is on non-energy, non-food materials; this includes metals, minerals and certain biotic and hydrocarbon derived materials.

Table 1: Studies on raw material issues reviewed

No.	Published by	Document	Scope	Year
1	SNIFFER	Raw Materials Critical to the Scottish Economy	Scotland	2011
2	Defra/BIS	UK Resource Security Action Plan	UK	2012
3	BIS	The Future Impact of Materials Scarcity on the UK Manufacturing Industry	UK	2013
4	EPOW	Study into the feasibility of protecting and recovering critical raw materials through infrastructure development in SE England	England/UK/EU	2011
5	UK Government	Inquiry into Strategically Important Metals	UK	2011
6	EC	Critical Raw Materials at EU level	EC	2010 &'14
7	EU JRC	Critical Metals in Strategic Energy Technologies	(EU) Energy Technologies	2011 &'13
8	US DoE	Critical Materials Strategy	Energy Technologies	2011
9	General Electric	Research Priorities for More Efficient Use of Critical Materials from a US Corporate Perspective	Company	2010
10	McKinsey Global Institute	Resource Revolution: Meeting the world's energy, materials, food and water needs	Global	2011
11	PWC	Minerals and metals scarcity in manufacturing: the ticking timebomb	Global	2011
12	Department for Transport	Lanthanide Resources and Alternatives	Electric Vehicles & Wind Turbines	2010

3.2 Summary of literature survey

A number of themes can be identified within these studies, linked to scope and approach, findings, and recommendations.

3.2.1 Scope and approach

The scope of materials considered, the approach and the output varies between studies due to the context in which each is produced (Table 2). This is summarised below and compared to this present study. Further discussion on scope and approach of these studies is provided in Annexe A: Summary of reports.

Across the studies the material scope focusses on non-energy, non-food raw materials, differentiating these from energy materials such as petrol and other petrochemical fuels, gas and food crops. However, there is variation in the range of materials this includes. Some studies are limited to metals, others broaden this to minerals, and others consider a wider range of materials such as wood and plastics. In this present study, a broad definition of raw material input has been used for the industry consultation; not all studies align with this approach.

The approach studies take to assessing criticality varies considerably within these studies. By contrast to the methodology used in this study, they all take a 'top-down' approach - using data from literature and other sources to assess the criticality of materials, and identify risks. This current study takes a 'bottom-up' approach by directly surveying industry organisations to garner their experience of these issues.

Table 2: Summary of scopes used in the studies analysed

No	Document	Materials				Approach	Outputs
		Metals	Minerals	Biotic	Plastics		
1	Raw Materials Critical to the Scottish Economy	X	X	X		Criticality analysis (geographic) & survey	List of CRMs, mitigation options, and recommendations
2	UK Resource Security Action Plan	X	X	X		Strategy document	Mitigation options
3	The Future Impact of Materials Scarcity on the UK Manufacturing Industry.	X	X	X	X	Sectoral analysis using existing CRM list	Mitigation options, and recommendations
4	Study into the feasibility of protecting and recovering critical raw materials	X	X			Sectoral analysis using existing CRM list	Mitigation options, and recommendations
5	Inquiry into Strategically Important Metals	X				Expert evidence	Recommendations and mitigation options
6	Critical Raw Materials at EU level	X	X			Criticality analysis (geographic)	List of CRMs, mitigation options, and recommendations
7	Critical Metals in Strategic Energy Technologies (EU)	X				Criticality analysis (sectoral)	List of CRMs, mitigation options, and recommendations
8	Critical Materials Strategy (US DOE)	X				Criticality analysis (sectoral)	List of CRMs, mitigation options, and recommendations
9	Research Priorities for More Efficient Use of Critical Materials from a US Corporate Perspective	X	nd	nd	nd	Criticality analysis (company)	List of CRMs, mitigation options, and recommendations
10	Resource Revolution: Meeting the world's energy, materials, food and water needs	X	X	X	X	Business strategy analysis	Mitigation options, and recommendations
11	Minerals and metals scarcity in manufacturing: the ticking timebomb	X	X			Industry survey to gauge impact of materials risk	Mitigation options, and recommendations
12	Lanthanide Resources and Alternatives	X				Impact assessment of REE shortages on technology	Mitigation options, and recommendations

3.2.2 *Findings*

The studies consistently found that the increasing risks and insecurity associated with raw material supply has had impacts now, and will continue to do so in the future. This is therefore an issue that concerns governments and businesses alike. The studies universally identified that the issues were wider than just geological scarcity, and that factors such as increasing demand, geopolitical risk, poor recovery rates from waste, and the importance of the materials are more relevant over the timescales considered. This is not to say that geology is not important: it underpins much of the understanding of current and potential supply and the development of resources. However, absolute geological scarcity of materials is commonly accepted not to be an issue.

Certain studies identified materials that were of specific concern (i.e. CRMs or strategically important materials), whereas others identified possible high-level impacts from supply disruptions or increased volatility. Perspectives on the impacts differed between industry and government, and between sectors. For instance, certain sectors rely heavily on certain materials which are viewed as critical: in the renewable energy generation industry, for example, rare earth elements (REEs) are used in certain wind turbine types, and there are concerns over the supply of these materials. Other sectors are either less reliant, or less aware of this vulnerability and supply chain risk.

It is difficult to compare territorial studies because, although there is some overlap, the studies also largely analyse different materials.

Using the reports analysed, a meta-analysis of nine industrial sectors was conducted, identifying metals which are input materials to these sectors (Table 3). This drew on an analysis of industry sectors within these reports and specific examples that had been highlighted, and used data on applications for certain materials. To support the further analysis, the materials identified were placed into six categories, partly linked to production (e.g. base metals, industrial minerals and biotic materials) and partly linked to applications (e.g. steel and speciality metals).

It should be noted that the same materials are used across many sectors because their use is linked to applications. For example, many materials are used in electronics, which in turn are used across all sectors. However, the purpose of this work was to highlight where analysis has identified specific issues. Even though a material is highlighted against a sector, it does not necessarily mean it is not important to other sectors. This analysis identifies where there are specific concerns at either a sectoral or a (linked) application level.

A common theme amongst the findings is the identification of several speciality metals as critical materials. These materials often make up a large proportion of critical materials (Table 3) but a very small part and cost of an overall product. They generally perform an essential function, are usually not substitutable, and often have a very low recycling rate. They are also produced in lower quantities compared to bulk materials or may be by-products of other production processes. For example: global production of indium is in the hundreds of tonnes, and for individual REEs it is in the hundreds or thousands of tonnes; production of each of these CRMs is concentrated in one or two countries.[7] By contrast, iron ore and aluminium are produced in billions and millions of tonnes respectively, across tens of different countries.[8]

As a consequence, concentration of supply and resulting criticality is often associated with this lower supply diversity seen for speciality metals. These supply conditions are also the reason that, in steel production, materials used in processing or as alloying metals are often considered more critical than the major component, iron ore.

Many studies are limited to metals or mineral based resources, which will have an impact on the materials identified as critical and the frequency in which they appear in studies. Timber, plastics, water and crop-based biotic materials are often excluded, for example, and the analyses result in some sectors with fewer materials -particularly the textiles, forestry and timber technologies, and food and drink sectors.

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[7] Critical Metals in Strategic Energy Technologies, EC JRC 2013

[8] Annex V – Critical Raw Materials for the EU, EC 2010

Table 3: Analysis of critical materials with major applications linked to the priority sectors

Category	Material	Aerospace, Defence and Marine	Construction	Energy (Oil and Gas and Renewables)	Food and Drink	Forest and Timber Technologies	Life and Chemical Sciences	Manufacturing Sector	Technology and Engineering	Textiles
Other	Water (as input)				●					
	Plastics		●					●		●
Biotic Materials	Rubber	●								●
	Timber		●		●	●				
	Cotton									●
	Palm oil				●		●			
	Fish				●					
Industrial Minerals	Phosphates				●		●			
	Graphite (other)								●	
	Fluorspar (other)						●			
	Aggregates		●							
Speciality Metals	Tungsten	●						●		
	Tantalum	●							●	
	Rhenium	●		●						
	REEs	●		●					●	
	PGMs	●		●			●	●	●	
	Magnesium	●	●		●			●		
	Lithium							●	●	
	Indium								●	
	Germanium						●		●	
	Gallium								●	
	Cobalt	●		●			●	●	●	
	Beryllium	●							●	
	Antimony							●	●	
Steel (Production & Alloys)	Vanadium Niobium Nickel (steel) Molybdenum Manganese Graphite (steel) Fluorspar (steel) Chromium	●	●	●				●		
Base Metals	Tin	●			●			●	●	
	Nickel (other)	●					●		●	
	Lead		●	●				●		
	Copper		●	●				●	●	

Source: Twelve highlighted studies with Oakdene Hollins' analysis

In the documents analysed, wider concerns have been raised over several materials which underpin many industries. These are generally bulk materials such as copper, steel and petrochemical-based materials (e.g. plastics). In this study, these are highlighted in specific sectors, but it is also acknowledged that they are considered a broader risk. The materials that are identified as critical are often the alloying agents for these materials, for example niobium in steel or magnesium in aluminium.

This distinction is also evident in the types of materials identified in each sector. For example, the construction sector generally relies on large quantities of a few bulk materials such as aggregates and steel. By comparison, the technology sector uses a larger range of low volume speciality metals which have highly specific properties and functions. In some sectors there is a mix: for example, the aerospace, defence and marine sector relies on speciality metals for high performance superalloys, but also requires bulk materials such as aluminium for components.

Material grades/quality may also be of importance in some cases, and these are taken into account for certain materials (e.g. different grades of graphite used in the steel industry for refractories, and in the technology sector in batteries). However, due to availability of information this is not true of all; for example, different steel grades or different purities of metals such as tantalum in different applications.

Table 4 highlights where specific concerns have been raised, and where it might be expected to see some responses or concerns amongst Scottish businesses based on sectors and growth strategies. A discussion of the materials appearing in each sector is given in Section 5 to provide a wider context, with specific responses highlighted where appropriate.

Table 4: Examples of materials where the greatest concerns have been raised linked to sectors identified in this study

Sector	Highlighted applications and materials
Aerospace, defence & marine	**Superalloys:** Cobalt, PGMs, rhenium, tantalum, tungsten **Structural materials:** Magnesium (in aluminium alloys), steel
Construction	**Construction materials:** Aggregates **Structural materials:** Steel, lead, plastics, timber
Energy (oil and gas & renewables)	**Pipe lines, wind turbine structures**: Steel **Refining/reforming catalysts**: Cobalt, PGMs, REEs rhenium, **Wind turbine magnets:** REEs
Food and drink	**Fertilisers:** Phosphates **Packaging:** Magnesium (in aluminium alloys), tin **Other inputs:** Water, palm oil
Forest & timber technologies	**Timber**
Life and chemical sciences	**Catalysts/pigments:** Antimony, nickel, cobalt, germanium, PGMs **Feedstock:** Fluorspar, palm oil **Flame retardants:** Antimony
Manufacturing sector	**Structural materials;** Steel, magnesium (in aluminium alloys) **Tooling:** Cobalt and tungsten (in cemented carbides) **Automotive components**: antinomy, lead, PGMs
Technology & engineering	**Electronics:** Beryllium, copper, PGMs, tin, tantalum **Lighting:** Gallium, germanium, REEs **Flat panel displays/transparent conducting layers:** Indium **Batteries:** Cobalt, lithium, graphite **Magnets:** REEs
Textiles	**Feedstocks:** Cotton, (other material inputs), **Other Inputs:** Water
Industry wide	Steel, copper, petrochemical based products (e.g. plastics)

Source: Oakdene Hollins' analysis

3.2.3 Recommendations

Recommendations for mitigation actions were made in all the studies. These are discussed related to the individual studies in Annexe A: Summary of reports, and vary hugely in their breadth, focus, and type. Table 5 provides a high-level summary of identified actions. Here, actions have been separated into four categories: improved data and information; primary material supply; resource efficiency/resource productivity measures; and legislative, regulation and other. For each high level action, the desired impact has been identified, and the major and minor drivers are highlighted, based on the information in the reports. These are split between policy, business strategy and technology development. This is to help identify from where the impetus for action may arise.

Table 5: Summary of recommendations and types of identified actions (●=Primary involvement , x = minor involvement)

	Action	Impact	Policy	Business Strategy	Technology Development
Improved Data & Information	Raising awareness of risks/issues	Allows stakeholders to plan & respond	●	●	
	Data on supply	Improved confidence for purchasers and understanding of risks	●	X	
	Materials flow analysis	Better understanding of the lifecycle of materials and their movement in products	●	X	
	Data on waste composition	Generate interest from waste processors	●	X	
	Collaboration/sharing of information	Wider awareness of potential issues & solutions	●	●	
	Environmental impact data	Understanding of environmental issues related to supply, use & disposal	●	X	
Primary Material Supply	Developing material resources	Directly increases/diversifies primary supply	X	X	●
	Developing material processing	More efficient material processing	●	X	X
	Diversification of supply	Sourcing from multiple locations & companies to reduce risk	●	X	
	Cooperation across supply chains	Minimisation/sharing of risk & impact	X	●	
	Supply contracts & agreements	Greater certainty in supply & pricing	X	●	
	Stockpiling	A buffer for short term shortages	●	●	
	Geo-diplomacy	Supply agreements and removal of trade barriers	●	X	
	Transparency and stewardship of resources	Certainty in the provenance of materials, reducing supply risk	●	●	
Resource Efficiency/Resource Productivity Measures	Enabling efficient resource use	Lowering overall material demand	X	X	
	Development of waste prevention measures	Reduce loss of materials	●	●	●
	Improve product design for recycling/re-use	Enable recycling & re-use activities to improve recovery possibilities	X	●	X
	Substitution (material)	Reducing usage of CRMs	X	X	●
	Substitution (technology/system)	Reducing usage of CRMs	X	X	●
	Improved waste collection	Prevent materials being lost to landfill or through other routes	●	●	X
	Improved waste sorting	Ensure materials/components are properly separated to enable recovery	●	●	X
	New recycling technologies for speciality materials	Enabling recycling of currently non-recycled materials	●	X	●
	Remanufacturing & re-use of CRM containing products	Enable these activities to reduce materials demand	●	●	●
Legislative, Regulation & Other	More sophisticated waste recovery targets	Provide better incentive to recover specialist materials/CRMs	●		
	Industry initiatives (e.g. Individual Producer Responsibility)	Provide a framework for businesses to demonstrate their actions	●	●	
	Trade agreements	Longer term agreements to ensure supply	●		
	International cooperation	Collaboration amongst nations/companies that face similar problems to drive solutions	●	●	
	Investment	Underpins many of the development actions	●	●	

4 Government responses

The growing awareness of raw materials issues highlighted in Section 3, particularly related to mineral resources, has led to a number of responses by governments at a national and multinational level. These are generally aimed at reducing any impact of resource shortages on the wider economy, environment and society. As most of the responses are in their early stages, it is difficult to gauge impact. However, some positive outcomes have been seen; for example, new recycling technologies for REEs have been developed, alternative sources of materials are coming online, and there is a growing awareness of resource issues that businesses and society will be faced with in the future.

The two most likely government responses to influence Scottish businesses at present are from the UK and EU Governments, discussed below. Strategies of other countries are also highlighted below, but in less detail.

4.1 United Kingdom

The Resource Security Action Plan was published in 2012 (Study 2 above), as a joint strategy by UK Government Departments, led by BIS, on natural resources. It details how the UK Government recognises raw materials issues and sets out a framework for business, and a plan of action to build on partnerships between government and businesses on natural resource concerns. The key actions launched by the strategy, outlined below, often focus on WEEE which uses a large number of critical materials:

- Develop a critical resources 'dashboard' to provide companies with information on resource risks. (This was launched in 2013.)[9]
- Improve capture of data on WEEE being treated by waste management companies and other players.
- Analyse flows of materials in electrical and electronic equipment (EEE) to provide an insight into the flow of critical raw materials through parts of the UK economy. (This study was published in 2013.)[10]
- Form an industry-led consortium to bring together interested parties to address opportunities and concerns.
- Seek opportunities to streamline REACH to reduce costs to businesses to reduce uncertainties in supply for some materials.
- Provide funding to establish the feasibility of new approaches to closed loop processing. This aims to enable businesses to extract value from domestic and commercial waste streams (e.g. through re-use and recovery).
- Investigate the application of Individual Producer Responsibility more generally to WEEE to recover resources and combat illegal trade in WEEE.
- Promote WEEE re-use activities through the re-cast of the WEEE Directive.
- Set up demonstration trials to highlight potential for improving recovery of critical materials in WEEE.

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[9] https://connect.innovateuk.org/web/the-resource-dashboard
[10] Mapping consumption and waste of raw materials in electrical products in the UK, WRAP 2013

- Press for Implementing Measures under the Ecodesign for Energy Related Products Directive to address more efficient use of resources, as well as provide a level playing field for producers through fewer but more stringent standards.
- Ensure that the UK plays an active role in discussions at an EU level, specifically the EU Transparency, and/or Accountability Directives.

Other organisations/programmes involved in this agenda include:

- Joint research by the Material Security Special Interest Group[11], coordinated by the Environmental Sustainability, Chemistry Innovation and Materials KTNs. This highlights the risk and innovation opportunities available to different sectors, and provides a central resource for interested companies.[12]
- The UK Energy Research Council is conducting research in this area, which has focused to date on the materials' availability for energy technologies including PV thin film solar and vehicle batteries and motors.
- The British Geological Survey (BGS) has produced a risk list to identify relative risks for materials, and are actively involved in this agenda. In addition the BGS provides information on UK-wide and Scottish mineral resources.[13]
- The Institute of Materials, Minerals, and Mining (IOM3) is a UK engineering institution, involved in almost all aspects of the materials cycle. In Scotland the IOM3 operates the Mining Institute of Scotland, which is the professional body across the minerals production industries, including oil and gas, and mining.[14]

Within the academic arena, NERC is running the Security of Supply of Mineral Resources programme, which is currently funding 16 catalyst projects.[15] The EPSRC launched a £10 million funding programme (Materials Substitution for Safety, Security and Sustainability), which has funded four projects:[16]

- Sustainable Manufacturing of Transparent Conducting Oxide (TCO) Inks and Thin Films (Lead: University College London).
- Photovoltaic Technology based on Earth Abundant Materials – PVTEAM (Lead: University of Bristol).
- MAnufacture of Safe and Sustainable Volatile Element functional materials - MASSIVE Materials (Lead: University of Surrey).
- Sustainable polymers (Lead: University of York).

Other examples of universities working in this area include: University of Aberdeen (Geology and Petroleum Geology)[17], University of Edinburgh (GeoScience)[18], Strathclyde Business

11 https://connect.innovateuk.org/web/material-security
12 http://www.bgs.ac.uk/mineralsuk/statistics/riskList.html
13 http://www.bgs.ac.uk/research/ukgeology/Scotland.html
14 http://www.mining-scotland.org/index.htm
15 http://gotw.nerc.ac.uk/list_them.asp?them=Mineral+Resources&
16 http://www.epsrc.ac.uk/funding/calls/2013/Pages/materialssubstitution.aspx
17 http://www.abdn.ac.uk/geology/research/
18 http://www.ed.ac.uk/schools-departments/geosciences/research/institutes-index

School (History and Strategic Raw Materials Initiative)[19], University of Dundee (Geomicrobiology Group and Centre for Energy, Petroleum and Mineral Law and Policy)[20], University of St Andrews (Centre of Earth Resources)[21],Camborne School of Mines (Exeter)[22], University of Edinburgh and University of Leeds (Undermining Infrastructure – Avoiding the Scarcity Trap project)[23], and University of Birmingham (Rare earth element recycling and magnetic materials)[24].

Funding for Research and Innovation projects has been made available by the Technology Strategy Board (TSB), which includes projects that focus on the recovery or reduction in use of critical or precious raw materials, for example:

- Substitution of Ag in Electronic conductive inks (SAGE).
- RECycling Of high Value materials from fuel cell ElectRode assemblies (RECOVER).
- MOtors for Transport Omitting Rare Earths (MOTORE).
- Sustainable supply of high purity graphite.
- Light Touch (substitution of ITO in capacitive touch screens for mobile applications).

These are linked to supply chain innovation calls or similar, though they consider raw materials issues within them, for example a recent call focussed on design challenges for a circular economy.

4.2 European Union

Raw materials strategy is primarily centred around the EU Raw Materials Initiative (RMI), managed by DG Enterprise and Industry. Launched in 2008, the RMI acts as hub to the EU's responses to raw materials issues.[25] The initiative is based on three pillars, with actions focussed toward these aims:

1. Ensuring a level playing field in access to resources in third countries.
2. Fostering sustainable supply of raw materials from European sources.
3. Boosting resource efficiency and promoting recycling.

The work programme of the RMI to date has included raw materials diplomacy, trade and development, research and innovation, sustainable EU supply, resource efficiency and recycling, as well as assessment of critical raw materials (as discussed in Annexe A). The most recent actions of RMI and more widely across the European Commission have been brought together under the European Innovation Partnership on Raw Materials (EIP).[26]

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19 http://www.strath.ac.uk/business/hsrmi/
20 http://www.lifesci.dundee.ac.uk/research/gmg
21 http://www.cersa.org.uk/
22 http://emps.exeter.ac.uk/csm/
23 http://sure-infrastructure.leeds.ac.uk/ui/
24 http://www.birmingham.ac.uk/research/activity/metallurgy-materials/magnets/index.aspx
25 http://ec.europa.eu/enterprise/policies/raw-materials/index_en.htm
26 https://ec.europa.eu/eip/raw-materials/en

Table6: Priority areas and actions identified for the EU EIP on Raw Materials

Technology Pillar	Raw materials research and innovation coordination	Improving R&D&I coordination in the EU
	Technologies for primary and secondary raw materials production	Exploration
		Innovative extraction of raw materials
		Processing and refining of raw materials
		Recycling of raw materials from products, buildings and infrastructure
	Substitution of raw materials	Materials for green energy technologies
		Materials for electronic devices
		Materials under extreme conditions
		Applications using materials in large quantities
Non-Technology Pillar	Improving Europe's raw materials regulatory framework	Minerals Policy Framework
		Access to Mineral Potential in EU
		Public Awareness, Acceptance and Trust
	Improving Europe's waste management regulatory framework conditions and excellence	Product design for optimised use of (critical) raw materials and increased quality recycling
		Optimised waste flows for increased recycling
		Prevention of illegal shipments of waste
		Optimised material recovery
	Knowledge, skills and raw materials flows	EU Raw Materials Knowledge Base
		Knowledge and Innovation Community
		Optimised raw materials flows along value chains
International Five priority areas are highlighted by	International Cooperation Pillar	Technology
		Commodity Trade – diversification of supply sources
		Health, Safety and Environment
		Skills, Education and Knowledge
		Investment activities

The EIP has set overarching goals for innovation relating to raw materials, driven by the Europe 2020 Innovation Union and Europe 2020 Resource Efficient Europe programmes. Drivers for greater innovation in the raw material supply chain within the EU have been identified as:

[27] http://ec.europa.eu/enterprise/policies/raw-materials/innovation-partnership/index_en.htm

- A need to increase innovative activity to levels equivalent to, or levels beyond those of, the EU's international competitors.
- The need for greater security of supply within the EU caused by increasing import dependence and the potential for restriction of supply or lack of fair access that puts Europe's industries at a competitive disadvantage.
- The need for greater resource efficiency that, it is hoped, will improve material security, reduce environmental impact and improve competitive positioning.

The EIP on raw materials is on-going, with the way forward defined by the Strategic Implementation Plan (SIP). The ultimate aim of the EIP in the wider context is to help raise industry's contribution to EU GDP to around 20% by 2020, along with other initiatives. However, a number of concrete outputs are specifically targeted by the EIP by 2020, including:

- Up to 10 innovative pilot actions on exploration, mining, processing, and recycling for innovative production of raw materials.
- Substitutes for at least three applications of critical and scarce raw materials.
- Framework conditions for primary raw materials that would provide a stable and competitive supply from EU sources and facilitate its public acceptance.
- Framework conditions for enhanced efficiency in material use and in waste prevention, re-use and recycling, and raw materials efficient product design.
- European raw materials knowledge base with information, flows and dynamic modelling system for primary and secondary raw materials.
- Network of Research, Education and Training Centres on sustainable raw materials management, as a Knowledge and Innovation Community.
- Pro-active international cooperation strategy of the EU at bilateral and multilateral level, promoting synergies with countries such as the US, Japan, Australia, Canada, Latin America and African Union across the different areas covered by the EIP.

Whilst no funding is directly available through this route at present, the EIP supports other areas of EU work, acting as a focus for many raw materials based activities. For example, setting research and innovation agenda in linked funding schemes such as Horizon 2020, or providing a mechanism to back project bids that fit with the targets outlined in the SIP.

Various other European Commission-led initiatives are underway, which have linkages with the activities of the RMI:

- DG Research and Innovation have funded several FP7 projects in the area of critical raw materials, with funding provided for various mineral processing and production technologies, an EU intelligence network on raw materials, and other related activities. For instance, a UK-led FP7 project, CRM_InnoNet, specifically focusses on developing networking, policy, and innovation in the field of critical raw material substitution.[28] Other projects in this area include ProMine[29], Minerals4EU[30], and Polinares[31].

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[28] http://www.criticalrawmaterials.eu/
[29] http://promine.gtk.fi/
[30] http://www.minerals4eu.eu/
[31] http://www.polinares.eu/

- The EU Joint Research Centre has undertaken two studies related to raw material demand associated with the Strategic Energy Technology Plan (discussed in Annex A), and this is now leading to an online knowledge hub on these materials and technologies. The JRC's Institute for Environment and Sustainability has published a study discussing a potential methodology for including criticality in lifecycle assessments, allowing measurement along with environmental impacts.[32]
- Within DG Environment, resource efficiency has been identified as a key policy by the EU as part of the Europe 2020 strategy to smart, sustainable and inclusive growth. The focus of this work relates to environmental protection. There are some projects relating critical raw materials underway, mainly for to recycling. Other key areas include alternative materials, battery technologies, clean technology, electric vehicles, electronic material and renewable energy, due to the critical raw materials contained in these products.
- A series of dialogues between different nations have been held by several DGs, discussing trade, research and innovation, and other common themes relating to critical raw materials; for example, the on-going series of EU-Japan-US tri-lateral dialogues which addresses many issues across raw materials.[33] Policy dialogues also are ongoing with Argentina, Chile, China, Colombia, EuroMed countries, Greenland, Mexico, Russia, and Uruguay relating to trade.[34]

At an institutional level, 33 national and regional geological surveys have formed the EuroGeoSurveys organisation to provide coordination and cooperation across Europe on issues of raw material resources.[35]

Many EU countries have developed their own national strategies. Some examples are provided below:

4.2.1 France

Critical raw materials have received considerable attention within France, and the French Government has recently announced a €400 million investment in the state-owned mining company to explore resources of REEs and gold across the globe.[36]

The French Ministry of Ecology, Sustainable Development and Energy updated its strategy for minerals in 2010, identifying four policy areas as a result of concerns over raw materials:[37]

- Improving access to French mineral deposits by reforming French Mining Law and making it easier to exploit the significant mineral potential of the French Overseas Territories (e.g. French Guyana).
- Promoting increased recycling of ferrous and non-ferrous metals.

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32 http://lct.jrc.ec.europa.eu/assessment/assessment/assessment/ResourceSecurity-SecuritySupply

33 http://ec.europa.eu/research/industrial_technologies/event-13_en.html

34 http://ec.europa.eu/enterprise/policies/raw-materials/international-aspects/index_en.htm

35 http://www.eurogeosurveys.org/

36 France to set up state-owned worldwide mining venture, Financial Times 21 February 21 2014

37 Politique des Ressources Minérales Ressources Minérales, French Ministry of Ecology, Sustainable Development and Energy, 2012

- Ensuring security of supply of raw materials for French industry through the monitoring of mineral markets and by working closely with industry.
- Improving international cooperation to secure a supply of raw materials for French industry, and ensuring the development of sustainable exploitation of mineral resources in exporting counties.

The French Strategic Metals Plan identifies areas where France is vulnerable to a shortage of CRMs, and outlines Government actions that could or are being taken to secure supply of materials.[38] These include:

- Promoting search for new supplies of critical metals.
- Promoting efficient extraction and production of metals.
- Looking further at recycling policy for critical metals to improve recovery.
- Appointing a senior civil servant with overall responsibility for strategic metals.
- Establishing a Committee for Strategic Metals (COMES), which includes officials, industry and academics, responsible for implementing the Plan as well as investing in the substitution of critical raw materials, encouraging exploitation of resources, and engaging with EU and international responses.[39]

The Geology and Minerals Research Institute (BRGM) in France is also active in this area; for example, in the exploration of REEs, in which the BRGM has been involved in a collaborative project in Kazakhstan to develop new supply.

4.2.2 Finland

Unlike many of the other countries highlighted, Finland is a resource-rich country, with many deposits of minerals - including many CRMs - and it is already a global leader in mining in many areas of knowledge and technology. The Finnish response has therefore focused on ensuring that its domestic mineral production remains competitive, as well as securing a supply of raw materials for industry.[40] Its 'Vision 2050' plan outlines that further developments in the mineral sector should be environmentally sustainable and provide regional benefit.

4.2.3 Germany

The German Government adopted a Raw Materials Strategy in 2010[41], which was prepared by an inter-ministerial Committee on Raw Materials. This focussed on supporting German industries through securing raw materials that are essential for their business. However, actions do not extend to taking an active role in securing these raw materials. Instead, support takes the form of instruments on raw materials policy, funding for research, as well as Germany's international raw materials policy being pro-German industry. Examples of actions include:

38 Information from Critical Metals in Low-Carbon Energy Technologies, EU JRC 2013

39 http://www.brgm.eu/content/strategic-metals-france-gets-organised

40 Vision 2050 – Finland's Mineral Strategy 2010

41 Safeguarding a sustainable supply of non-energy mineral resources for Germany, Federal Ministry of Economics and Technology 2010

- **Reducing trade barriers and distortions of competition** to guarantee fair access to raw materials for German companies.
- **Diversifying raw material sources**, for example by providing guarantees for loans and investments against political and commercial risks for German companies engaging in the exploration of new raw material sources in foreign countries, and supporting the respective preparatory geological studies.
- **Increasing materials efficiency** through support for scientific and R&D activities. This targets the extraction of raw materials in an environmentally sound manner and the optimal use of existing raw materials' potential. This is led by the Federal Institute for Geosciences and Natural Resources (BGR) and the Federal Ministry of Education and Research (BMBF), and resulted in the formation of the Helmholtz Institute for Resource Technology in 2011.
- **Enhancing raw material recycling,** which addresses changes to legislation on closed-loop recycling and waste management at national, EU and global levels; for example, exploring new sources of secondary materials such as end-of-life buildings or infrastructure.
- **Maintaining advanced processing capabilities.** Many material values chains are global; however, it is necessary to maintain advanced processing capabilities for important raw materials within Germany if German industry is to remain competitive and maintain secure supply.
- **Increasing materials efficiency**, which is initially being addressed through workshops - including several Federal Ministries and the Federation of German Industries - exploring new ways to improve efficiency. This led the Ministry for the Environment to initiate the German Resource Efficiency Programme (ProgRess) in 2012.
- **Cooperating with developing countries** with known resources; for example, Mongolia, Vietnam, Sierra Leone and the Central African Union. This also targets the establishment of responsible and transparent use of raw materials, which is mutually beneficial to the State and German companies seeking to invest.

Other actions include the formation of the German Alliance for Raw Materials, an industry group comprised of industrial multinationals such as BASF, Bayer, Bosch and ThyssenKrupp, backed by the government.[42] The objective of the group is "*to improve and sustainably secure its associates' and partners' supply of selected raw materials in order to strengthen the industrial value creation*". The motivation for this joint action is that it minimises risk to individual companies, allows for stronger negotiation positions, and groups expertise.

The Federal Ministry for Education and Research has launched programmes which focus on the supply and efficient use of raw materials.[43] In the Framework Programme *Research for sustainable development* (FONA), one out of five central fields of action is "sustainable economizing and resources", which contains various relevant actions (including substantial financial support) such as:

- CLIENT - Supporting cooperation with emerging countries in resource efficiency and other contexts.

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42 http://rohstoffallianz.com/en/resource-alliance/

43 Information from Critical Metals in Low-Carbon Energy Technologies, EU JRC 2013

- r2 – Innovative technologies for resource efficiency in resource-intense production processes.
- r3 – Innovative technologies for resource efficiency for strategic metals and minerals.

In the Framework Programme *Innovative materials for industry and society* (WING), one relevant focus of promotion is MatRessource – Materials for a resource-efficient industry and society.

4.3 Non-EU countries

Responses to the raw materials risks have been adopted by countries across the globe. Some examples are provided below:[44]

4.3.1 Japan

Issues over raw material supply are of high importance to Japan, and a list of around 30 metals which are strategically important to Japanese industry has been identified through analysis. This includes speciality metals such as REEs and PGMs, steel alloying metals, and base metals such as copper and iron. The overall aim of the national strategy is to secure a stable supply of raw materials for Japanese industries, and it sits on four pillars:

- Securing mineral interest abroad.
- Developing deep sea mining.
- Maintaining a strategic stockpile of materials.
- Developing recycling and substitution technologies.

The responsibility for securing supplies of materials sits with JOGMEC, which funds exploration, excavation, refining and safety research, and operates a stockpile which holds the equivalent of 42 days' industrial demand for certain materials.[45] Research programmes have been funded through METI[46] and MEXT[47], investigating minimisation of materials, substitution, and recycling, particularly for REEs (see Section 5.5.5 for discussion on these).

4.3.2 South Korea

South Korea is also responding to issues around raw materials, as much of its economy is based on hi-tech industries, reliant on metals. Its response has focused on ensuring a reliable supply of materials critical to mainstay industries, through:

- recycling end-use products
- designing for recyclability
- substituting materials
- production efficiency.

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[44] Adapted from Critical Materials Strategy, US Department of Energy 2010, with additional information

[45] http://www.jogmec.go.jp/english/stockpiling/stockpiling_015.html

[46] Ministry of Economy, Trade and Industry

[47] Ministry of Education, Culture, Sports, and Science and Technology

This has been driven at least partially by investment; for instance, providing funding of $300 million over 10 years for its research into 40 technologies covering refining, smelting, processing, recycling and substitution.

4.3.3 United States

At present the USA does not have a single policy or strategy for critical raw materials; however, several bodies are fully engaged with these issues.

The **Department of Energy** has investigated the impact of raw materials' supply issues related to the implementation of renewable technologies. Three response areas are highlighted:[48]

- Diversifying global supply chains to provide alternative sources for materials, including US-based supply.
- Developing substitute technologies to provide flexibility in technology implementation.
- Improving recycling, reuse and more efficient use of these materials.

Several areas are highlighted as on-going areas of progress:

- Research and development into new technologies and materials (e.g. US$40 million for substitutes for REEs in magnetic motors). This is centred around the Critical Material Institute, a multi-institute project led by the Ames Laboratory.[49]
- Interagency coordination has begun, with roadmaps and cross-governmental agendas being developed.
- International engagement has resulted in several workshops with the EU, Japan, Australia and Canada to identify R&D collaboration topics and improve the transparency of materials markets.

The **Department of Defense** has long operated a stockpile (the National Defense Stockpile), which manages around 75 raw materials viewed as strategic and critical for defence applications.[50] They range from speciality metals, metals such as aluminium and titanium, through to ores and industrial minerals. The stockpile is regularly reviewed and reconfigured to suit the requirements of the armed forces.

The US Geological Survey has also conducted research in this area, focussing on supply of REEs, lithium, indium, tellurium, gallium, niobium, tantalum, rhenium, and PGMs[51], including aspects such as domestic and global resources, emerging resources, mine tailings, and extraction.

In 2010 the White House Office of Science and Technology Policy formed an inter-agency working group on critical materials and their supply chains. This group investigates issues including market risk, and critical materials in emerging high-growth industries.

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48 Critical Materials Strategy, US DOE 2011

49 https://cmi.ameslab.gov/

50 http://www.strategicmaterials.dla.mil/Pages/default.aspx

51 http://minerals.usgs.gov/east/critical/activities.html

4.4 Summary of high level actions

Within each report and national response, a combination of actions were generally identified which were most relevant to the context of the work (e.g. related to a specific technology or a geographical region or specific material). The types of action were consistent across international, national and regional strategies, but the approach and scale of response varied depending on specific circumstances.

Overall six key themes are identified, and discussed below. The examples provide possible general interventions in Scotland, and form the basis for specific recommendations later.

4.4.1 Knowledge base

Increase awareness, information and cooperation (between governments and business): studying materials flows, understanding industry needs, support for SMEs. For Scottish based interventions, this may involve:

- Spreading awareness through established organisational/public bodies, events, and initiatives, through dissemination and knowledge sharing.
- Conducting materials flow analysis for key materials/products, linked to other responses and other initiatives (e.g. industrial biotechnology plan, green growth, economic strategy and circular economy).

4.4.2 Indigenous resources

Understand and exploit indigenous resources linked to specific materials of concern and available resources, for example:

- Characterisation, quantifying and prioritisation of Scotland’s natural resource potential across all material types, identifying where these fit with materials concerns and Scottish development plans. This should include primary as well as secondary resources. A first step could be to identify and collate available information on reserves and resources, focussing on materials of concern.
- Streamlining the processes for exploitation, whilst retaining strict conditions, to allow faster responses to demand and develop local supply. This does not necessarily require lowering requirements such as environmental standards, but making the process more efficient, to allowing faster and more flexible responses.
- Generating a better evidence base for balancing impact of exploitation of important resources (e.g. local vs national vs global impacts.
- Maintaining and improving technological expertise, and develop leading edge technologies to remain competitive.

4.4.3 Supply chain development

Develop more robust supply chains to support businesses, localising a greater share of raw material value chain and diversifying supply. In some cases this may involve stockpiling of certain materials. Examples of actions include:

- Supporting actions which broaden and strengthen supply chains, such as through investment in infrastructure and technology and bringing supply chain actors together.

- Intervening to enable aspects of the circular economy such as recycling, re-use and remanufacturing. This will provide an internal supply of materials and components from end-of-life products and will reduce raw material demand. This should focus on reducing the demand for materials with no indigenous supply.
- Identifying where these extended supply chains could lead to external trade.
- Developing local, shorter supply chains for materials where opportunity exists (linked to the identification of indigenous resources).

4.4.4 External supply

As trade in raw materials will always be required, strengthen and improve external supply through cooperation mechanisms such as assisting with business agreements, funding for international business dialogue, and other incentives. For example:

- Supporting Scottish businesses in identifying potential international supply partners to ensure or diversify supply, through mechanisms such business advice or industry trade missions.
- Supporting businesses investing in projects abroad.
- Developing industrial, research and innovation, and administrative links with countries facing similar raw material issues.
- Encouraging the use of stewardship or transparency schemes both at home and abroad, to provide greater certainty of the provenance of materials.

4.4.5 Material efficiency

Support initiatives to increase material efficiency and identify materials and technology substitutes. These incorporate research and development, as well as enhancing skills, knowledge and know how. Actions may include:

- Providing funding to R&D centres, and innovation initiatives to address key issues in materials efficiency. This should include relevant organisations from all aspects of a products' lifespan from design through to disposal.
- Enabling involvement in existing substitution programmes (at global, EU and UK level) linked to strategic technologies such as wind turbines.

4.4.6 Materials recovery

Improve the viability of materials recovery through R&D into recycling technologies and more targeted legislation. The focus elsewhere for many of these has been on WEEE, which contains small quantities of many materials that are viewed as critical. Possible actions are:

- Developing improved information on the composition of waste, particularly on materials, and researching the potential for recovery and re-use within Scotland to reduce supply risk.
- Investing in research and technology for the recovery of raw materials (e.g. through sorting, recycling, or re-use and remanufacturing). This should also contribute to reducing overall waste and improving environmental performance.
- Creating more sophisticated waste recovery targets and waste management practices, moving from purely weight-based measures to incentivise the recovery of particular materials.

- Enabling industry initiatives to motivate the recovery of materials, through actions such as extended user responsibility or 'advance disposal fee' schemes. This could also tie into material efficiency actions.

These approaches may be focussed around the materials of concern or may be more general. They may also be linked to specific sectors such as the renewable energy or automotive sectors. Therefore these broad strategies are likely to be relevant to Scotland, but to differing extents depending on the technology, market or priority area, and requiring appropriate implementation tailored to suit the circumstances.

5 Industry consultation on raw materials

5.1 Approach

5.1.1 Overview

The primary information gathered during this project has been sourced from businesses and trade associations from across the nine sectors featured:

- Food and Drink
- Energy – Oil and Gas and Renewables
- Life and Chemical Sciences
- Textiles
- Aerospace, Defence and Marine
- Manufacturing Sector
- Forest and Timber Technologies
- Construction
- Technology and Engineering

The information produced by this 'ground-up' strategy is representative of the stakeholders that agree to participate. Therefore, it is important to the robustness and validity of the findings to ensure a broad range of stakeholders– in terms of types and sizes of businesses - in each sector. For example, if all contributing stakeholders from a given sector were of a similar size and manufactured a similar product, the observations for that sector may be biased towards a narrow portion of its constituent businesses. However, it should be remembered through this discussion that the businesses surveyed represent a relatively small cross-section of Scottish businesses.

In order to engage with a diverse set of stakeholders, the approach consisted of several distinct tasks which are discussed in the following sub-sections.

5.1.2 Consultation pro-forma

To ensure the desired information was gathered at a consistent and acceptable level, a pro-forma was used consisting of a standard set of questions and agreed by the steering group[52] .

The pro-forma consisted of a number of specific, structured questions requiring short answers to open-ended semi-structured questions that allowed a more descriptive answer. This allowed quantitative and qualitative data to be gathered. The pro-forma consisted of the following main sections:

- Brief introduction to the project and its purpose.
- **Basic information about the organisation/company** (e.g. size, location, sector, specific product).
- **Their understanding of wider critical raw materials issues** (e.g. awareness of materials criticality issues, comparison with other supply chain risks, which sectors are most affected).

[52] Scottish Government, Scottish Enterprise, the Scottish Environment Protection Agency, Zero Waste Scotland and Highlands and Islands Enterprise

- **Critical raw materials from their perspective** (e.g. which materials are they aware of, would they add any to the list, have any impacted their business and how, what has their response been).
- **Longer term trends** (e.g. do they view their issues as short term, what other similar issues might arise in the future, are other materials likely to be critical in the future).
- **Opportunities and threats** (e.g. where are opportunities and threats, what could the Scottish government to support industry, where is support most needed).
- Other comments.

The pro-forma was used as the basis for conversations with trade associations and businesses. The pro-forma is provided in Annexe B: Supporting Data.

5.1.3 Industry stakeholders

The first stage of the stakeholder engagement process was to identify the trade associations and businesses that might participate in this research. A list of suitable trade associations and businesses was compiled for each of the nine sectors, drawn from contacts held by the steering group and consultants.

Trade associations were primarily contacted as a means of publicising this research to the membership base, thereby helping to attract participants. These participation requests were distributed by trade associations through their newsletters, as one-off mailshots, and at conferences or meetings. Where appropriate the trade associations were themselves consulted regarding the materials issues considered in this report. We found that, whilst trade associations were generally willing to distribute news of the research to their memberships, they were less willing to offer direct sector-specific insight. They felt it more appropriate for us to talk directly with their members due to the variability in the types of supply chains that their members operate.

Businesses that had not already been contacted by trade associations were approached individually, with initial contact by email and follow-ups made by telephone.

5.1.4 Consultation methods

Email surveys

Several rounds of email surveying were conducted, each separated by a period of several weeks; this break period gave individuals the opportunity to complete the survey or to pass it on to a member of staff better placed to respond to the questions.

Telephone interviews

Conducting telephone interviews enabled capture of more qualitative information from individuals than was possible through the email surveying approach. Interviews typically lasted for between 15-20 minutes, and were the preferred method of data collection. A total of 15 telephone interviews were conducted.

Face-to-face interviews

Face-to-face visits were held with businesses at their sites across Scotland. The aim of these visits was to explore in detail the raw material issues important to their business operations.

A total of 16 face-to-face interviews were conducted, with a minimum of one visit per sector. These have not been identified here due to requests for confidentiality.

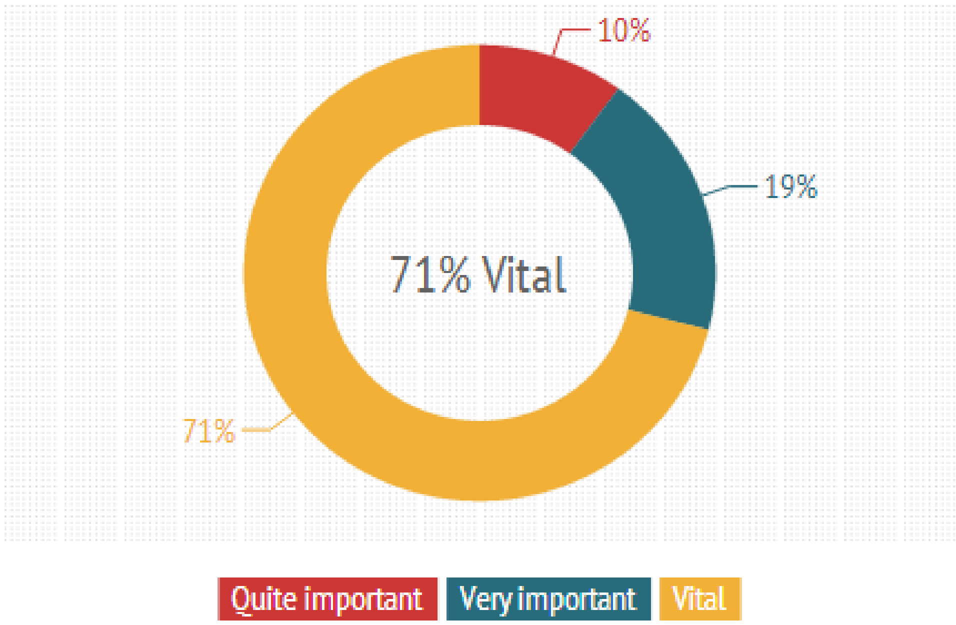
5.2 Cross sectoral analysis

This section presents the analysis across all sectors, bringing together the work from each of the nine industries surveyed. However, analysis was conducted on a sectoral level, which is discussed in Sections 5.3 to 5.11. Overall conclusions and recommendations are presented in Section 6.

5.2.1 *Reliance on raw materials*

From the results of the survey and discussions presented above it is clear that raw materials are viewed as essential inputs to the sectors surveyed. Of the sectors and businesses that have been included in this report, 90% believe that raw materials are either very important or vital to their operations (Figure 2).

Figure 2: The proportion of businesses, of those consulted, across all nine sectors considered in this report that believe raw materials are quite important, very important or vital to their business.

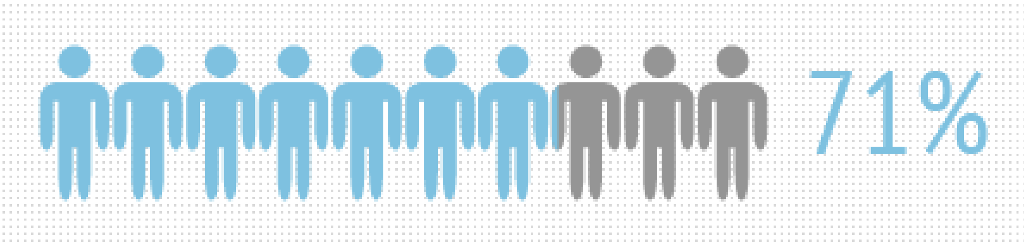


This highlights the importance of issues relating to raw materials as inputs to business, and particularly those targeted by this study, suggesting that it is essential for these sectors and hence to Scottish growth, to ensure access to the raw materials they require.

5.2.2 *Consistent themes*

Due to the diversity between and within sectors, a large number of different views were found from the consultation process. These are discussed in the following sections. A number of consistent themes can be identified from the analysis, relating to materials, issues faced and responses. What is clear is that concerns over raw materials are not isolated to one particular sector or business type. However, companies often viewed these issues in isolation, unaware that the issues were not restricted to their business or sector.

Across the businesses surveyed, 71% stated that they have been affected by issues relating to material supply in the last two years.



Yes, my business has been affected by material supply issues in the last 2 years

However, when asked about the materials that their business relies on, only 42% of participants believed there has been a change in the threat to supply over this time, with 51% stating that they are aware of a change in the size of risk to supply of these materials. This implies that businesses are largely affected by materials supply issues, such as price changes and supply security, but that the level of this threat to their businesses has been unchanged, at least recently. This may be because businesses are becoming more used to the issues associated with material supply, that they have implemented internal controls to ensure that their exposure to these issues does not increase, or that the global recession has temporarily reduced resource pressures.

Materials

A wide range of materials were identified within the sectors, and are discussed in the relevant sections. However, several materials were identified across multiple sectors. These may not have been the highest profile materials nor those experiencing the most disruption, but they are highlighted here because they underpin much of the industrial activity occurring within Scotland.

Water – Water was highlighted by almost all sectors as an important input. This was often for different reasons. Some manufacturers use large quantities, and so either cost or reliable access to large quantities was an issue. Whisky production requires water from certain sources, which were sometimes threatened by other activities or demands for water. The textiles industry requires water for processes such as dyeing, requiring that waste water is correctly treated before it is returned to the water system. Therefore, while it was accepted that water availability was not limited, it was indicated that it was not always located in a place where it is in demand, or that it was not of the required purity or quality. In global terms, water supply is of concern. However, this is linked to absolute availability of water due to droughts, and the impact on supplies of water for drinking, industrial processes and agriculture. Learning from these external cases could allow better management or specific environmental controls be put in place within Scotland. In addition, the potential risk on supply chains could be investigated by assessed embedded water for imported materials and products (c.f. embedded carbon emissions or energy),[53] or through cross reference against a water risk index. This may be particularly useful if materials are sourced from water stressed

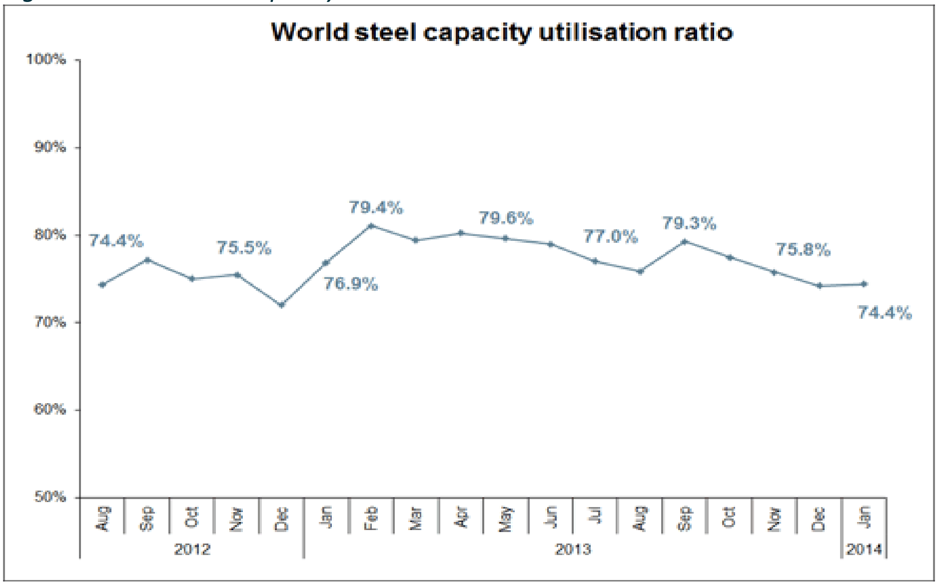
[53] Hunt ASP, Wilby RL, Dale N, Sura K, Watkiss P (2014) Embodied water imports to the UK under climate change. Clim Res 59:89-101

areas as many mined raw materials are; such circumstances have already led to restrictions on water supply to extractive industries.[54]

Some action has been taken by Scottish Water, focussed on the protection of drinking water sources.[55]However, a similar consideration could be made for other uses. There may also be cross-sectoral learning about water management, both internally and from other countries, which could be applied. For instance, within the drinks sector schemes are in place to increase water efficiency,[56] and many international companies have worked to reduce their water usage.[57]

***Steel* –**Steel was highlighted by several of the large scale manufacturing sectors, such as construction, energy and general manufacturing. The issues faced by these sectors varied, depending on their requirements, and this is highlighted in the Spotlight section in the energy sector analysis (Section 0).

Figure 3: World steel capacity utilisation ratio



Source: World Steel Association, January 2014 crude steel production

Global crude steel production in 2013 was estimated at 1,578 million tonnes.[58] However, at present there is excess capacity in the global steel market (*Figure 3*) resulting from long term increases in capacity combined with a lower-than-expected growth in demand. These circumstances have caused prices to drop significantly through 2009, although they appear to have stabilised over the last few years, though at a lower price than seen previously (Figure 4).

54 http://www.reuters.com/article/2013/10/04/us-safrica-platinum-water-idUSBRE9930R420131004

55 http://www.scottishwater.co.uk/about-us/corporate-responsibility/sustainable-land-management

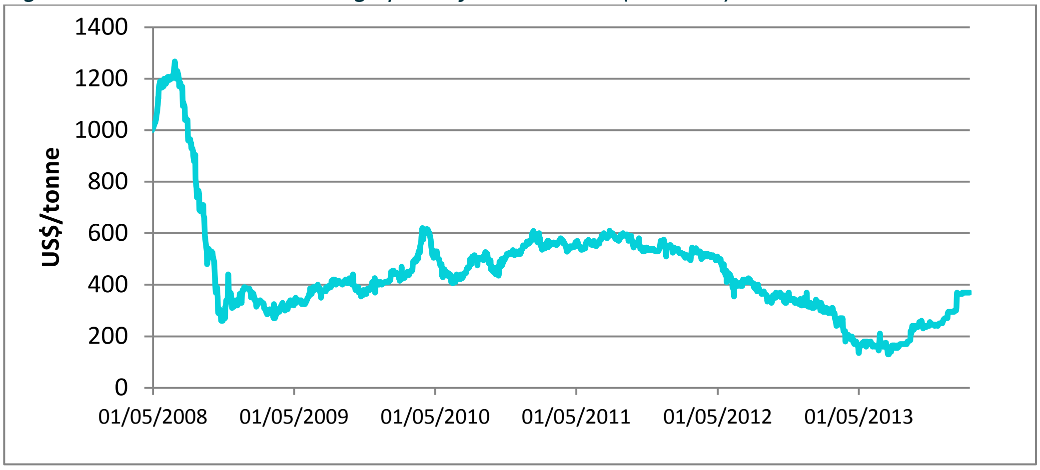
56 For example see The Federation House Agreement (WRAP), http://www.fhc2020.co.uk/fhc/cms/; Brewing Green 2013, BBPA;

57 For examples see: Water Futures and Beyond 2012, SAB Miller; http://sustainabilityreport.heineken.com/improve/green-brewer/water.html?ac=5, Heineken; 2013 Water Report: The Coca-Cola Company, Coca-Cola Company

58 https://www.worldsteel.org/statistics/statistics-archive/2013-steel-production.html

However, issues for businesses within Scotland appear more related to the availability of the correct grade of steels for a particular use. For example, grades are available for structural uses, pipes and tubes, railway tracks, engineering, amongst others. These have different technical properties and therefore compositions. For example steel containing metals such as chromium, niobium, molybdenum or vanadium in specific percentages may be required. Issues with supply for some of these grades was particularly evident for smaller applications (compared to the overall market), and it was stated that steel mills generally have large capacities so favour the production of high volume grades (even a small scale plant may have a capacity of 1.5 million tonnes per year).

Figure 4: London Metal Exchange prices for steel billet (2008-13)



Source: Metal Bulletin

Therefore reports from industry indicated that the excess capacity and lowering prices have not necessarily led to an increase in the availability of all grades of steel, for instance those that are required for construction of wind turbines and oil pipelines.

In other studies, materials related to steel have been highlighted (though not steel, iron or iron ore). Such materials may be linked to steel production (e.g. fluorspar as fluxing agent, or graphite as a heat resistant refractory material), or are alloying metals used to make high grades or stainless steel (particularly niobium and chromium). Therefore concerns linked to the issue of steel supply are more those of criticality of other materials, rather than production or availability of grades.

An on-going study is investigating the potential for development of steel production in Scotland, linked to internal steel demand and renewable energy supplies. The results of this study should be taken into consideration prior to taking action in this area.

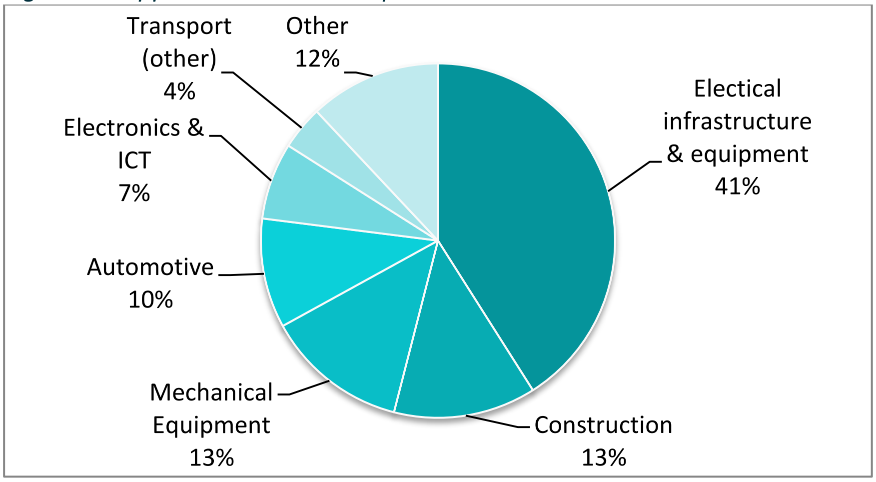
The wider industry conditions have impacted on the EU steel industry, which prompted the European Commission to launch the Steel Action Plan in 2013 to support the existing industry.[59] This includes stimulating demand through development of sustainable

[59] Commission presents an action plan for the steel sector, http://europa.eu/rapid/press-release_IP-13-527_en.htm

construction industry to support existing steel capacity, which may provide supply opportunities for Scottish industrial sectors.

Copper –Copper is a metal that underpins much of the electronics and electrical equipment that is used across almost all sectors. It is also an important construction material. Around 16 Million tonnes of copper are mined globally, with major suppliers located in Chile, Peru and China, however as with other high volume metals its supply is diverse.[60] Primary uses of copper include electrical infrastructure and equipment, construction, and mechanical equipment (Figure 5).

Figure 5: Copper end-uses in Europe



Source: International Copper Association

Recent issues with copper prices are highlighted in the Spotlight section in the manufacturing sector analysis (Section 5.9). However, companies across many sectors identified the rising price of copper, due to international competition, as a threat to their business. This may provide an opportunity for developing internal supplies of copper within Scotland, through improved collection, separation and processing. To provide further value this could be combined with refining and manufacturing into new copper products such as cabling or piping; however, a full business case would require to be developed. The high value of copper has seen an increase in copper scrap collection. However, further advances could be made in collection and separation from post-consumer WEEE, or from commercial buildings and communications networks upgrades, to improve recovery.

More widely copper is not considered a critical material in studies, mainly due to its supply from many countries. However, it is often considered of strategic importance due to its irreplaceability, and the significance of its uses.

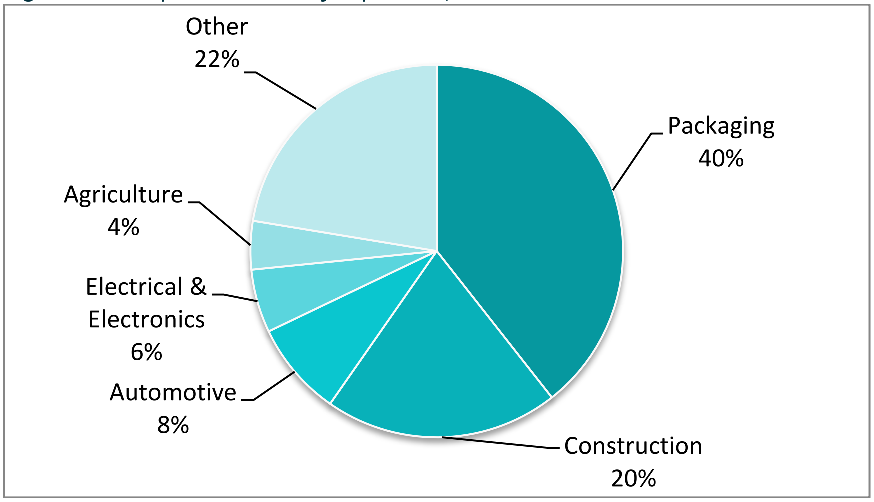
Plastics – Plastics of several types were identified in various sectors; these ranged from commodity scale to small-scale niche materials with highly specific requirements. Plastics are also essential for many composites which are also used across different sectors. Companies identified issues in obtaining certain plastic types, specialist types in particular were experiencing longer lead times or higher costs than previously.

[60] USGS (2012) Mineral Yearbook 2010, Copper

The term plastics includes a wide range of materials, such as polyethylene terephthalate (PET), polystyrene, polyester, nylon, and Teflon, with most derived from petrochemicals. The properties, cost and ability to tailor these materials to specific applications mean they used across all sectors. Globally production of plastics, excluding fibres is estimated at 288 million tonnes in 2013, and has more than doubled in the last 20 years.[61]

As bulk materials they find applications across all sectors in packaging, textiles, furniture, construction, vehicles, electrical equipment amongst other uses (Figure 6).[62] In these large scale applications the production of materials is high, with different grades and forms produced to suit the needs of the application. In more specialist applications, such as healthcare, defence, chemical and life sciences, or in some composites specific properties, or higher purities may be required, relying on smaller scale production processes and specialist techniques.

Figure 6: European demand for plastics, 2012



Source: Plastics Europe

In a 2013 report, the British Plastics Federation highlighted the security of supply of raw materials for the UK plastics industry.[63] This highlighted a long-term trend in the relocation of manufacturing from UK and Western Europe to the Middle and Far East. These shifting supply chains are identified as a risk to economic growth, both from a manufacturing and supply perspective. While this focusses on bulk materials, these issues are echoed by the industry survey where more specialist grades of many plastics were highlighted. The report also highlights threats such as lack of investment within the UK and Western Europe leading to ageing and unreliable plants. This was identified as causing difficulties in processors fulfilling contracts. The impact of shortages of other materials on the industry is also highlighted, such as titanium dioxide which is used to whiten plastics.

In other studies, plastics are not widely discussed as they are generally out of scope due to petrochemical sourcing. Therefore direct comparison with other materials is difficult.

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[61] Plastics – the Facts 2013, Plastics Europe

[62] The UK Plastics Industry, British Plastics Federation 2012

[63] A Progress Report, The UK Plastics Industry: A Strategic Manufacturing Sector, British Plastics Federation June 2013

However, this study has found these important industrial input materials experience supply issues, so can be considered within the same context as the other materials discussed in this section.

Issues: drivers of change impacting on the Scottish economy

Issues varied across sectors, and at a low level they are often linked to the specific circumstances of a business or material. Many of these issues are not mutually exclusive:

- **Supply disruptions** – Many businesses noted supply disruptions for certain materials as a result of factors such as increased competition, lower capacities, and the growth in 'just-in-time' supply strategies. This had led to longer lead times, more expensive products, or in some cases the cancelling of orders by the affected businesses.
- **Consolidation of supplies, reducing diversity of supply** – It was commonly noted that the diversity of suppliers available to companies was reducing, often due to consolidation. For some this had made accessing raw materials more difficult as capacity was reduced. For many smaller buyers it has made negotiations difficult due to larger companies' lack of interest in smaller markets.
- **Lack of internal supply chains** – Many stakeholders identified the lack of local or indigenous supply chains as a risk to their business. Globalisation has resulted in longer supply chains, spanning the globe. It was felt, particularly by small businesses, that - as a result - materials suppliers were often less responsive to their needs. It was suggested that shorter, more locally-based supply chains may remedy this, through quicker responses and better relationships. Businesses indicated that they would be prepared to pay more for locally-sourced materials, since they would have greater visibility and control over their supply chain and they would be able to make savings through reduced logistics costs.
- **Price increases for raw materials –** This was identified as an issue across most sectors. Whilst the underlying reasons varied, increases were often linked to increasing international competition.
- **Poor awareness of supply chain issues and difficulties in stock management -** Many companies had little awareness of supply chain issues up-stream of their immediate supplier, contributing to problems associated with supply due to lack of communications or understanding. This was sometimes coupled with difficulties with stock management, as businesses preferred to have low stocks of items to reduce costs.
- **The requirement for low volume, high specification or high purity materials** - Many of the materials highlighted had specific applications, leading to specific requirements and properties. A number of stakeholders stated that this resulted in difficulties obtaining the correct purity or grade (e.g. steel grades or high purity chemicals). Other materials have low production volumes compared to the bulk alternatives. These factors had contributed to issues with sourcing consistent supplies of these materials.

When asked whether these issues will change much in the future, 86% of businesses believed that they would not. This implies that the vast majority of businesses believe that the associated issues will neither increase nor decrease in significance.

This may mean that respondents believe they have a good understanding of the issues relating to their use of raw materials, whether or not they are able to implement measures to alleviate either their exposure to these issues or the impact they have on their operations, or just that they do not believe that the current issues will change much in the foreseeable future. A common explanation for these issues not changing in significance, or indeed for new issues not appearing on the horizon, was the length of time it takes to change processes that are external to their own operations. Changes to national or sector policy, for example, can impact greatly on the way these businesses are run, but can also take years to devise and implement.

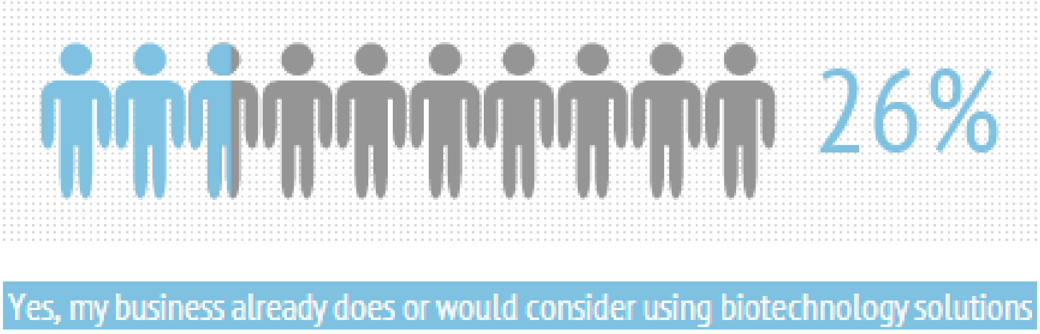
Responses

The impacts of these issues were felt across all sectors. The most common impact to businesses was the increasing price of their sourced materials, often coupled with higher variability in supply. These main drivers had other effects on business operations, included the potential to delay production and cancel orders, which can contribute to lower levels of turnover.

Responses have involved actions such as initiating longer term agreements with suppliers to minimise the impact of future prices changes and provide a more consistent supply. This has side benefits such as better understanding of the supply chain and stronger business relationships. In parallel with this, companies have sought to diversify suppliers, though this is not possible in all cases. Others have taken production of particular raw materials in-house or bought in expertise, though this is only viable in certain cases.

Where higher prices have been experienced, some have absorbed higher costs into their business, which has impacts on other activities such as growth. Some were able to pass costs onto their own customers, or reduce capacity.

In a few cases alternative materials have been sought; however, this appears to be the exception in all sectors. For example, only 26% of businesses currently do, or would be prepared to where relevant, use biotechnology as a solution to their materials issues. Some of these are limited by materials, others were unaware of possibilities, though there was no consistent pattern of responses across sectors.



The main concerns raised by businesses around the potential use of biomaterials relate to a lack of awareness regarding biomaterial options, the cost of researching, developing and producing suitable biomaterial alternatives and the reliability of those materials. Promotion of biomaterial alternatives within sectors, by trade bodies for example, may change this view, simply by making businesses more aware of their options.

Some businesses did note that they had tried to make materials efficiency gains, either at the product design stage or by incorporating a proportion of unused materials back into the production process (e.g. for polymers). Others described a willingness to use recycled feedstock ahead of virgin materials (e.g. timber for bioenergy), but stated that availability, quality and price can be limiting factors. The response of retaining ownership over a product, to enable the business to re-use materials or working parts at the product end-of-life, was only touched upon by businesses involved in the production of mechanical equipment, such as aeroplanes.

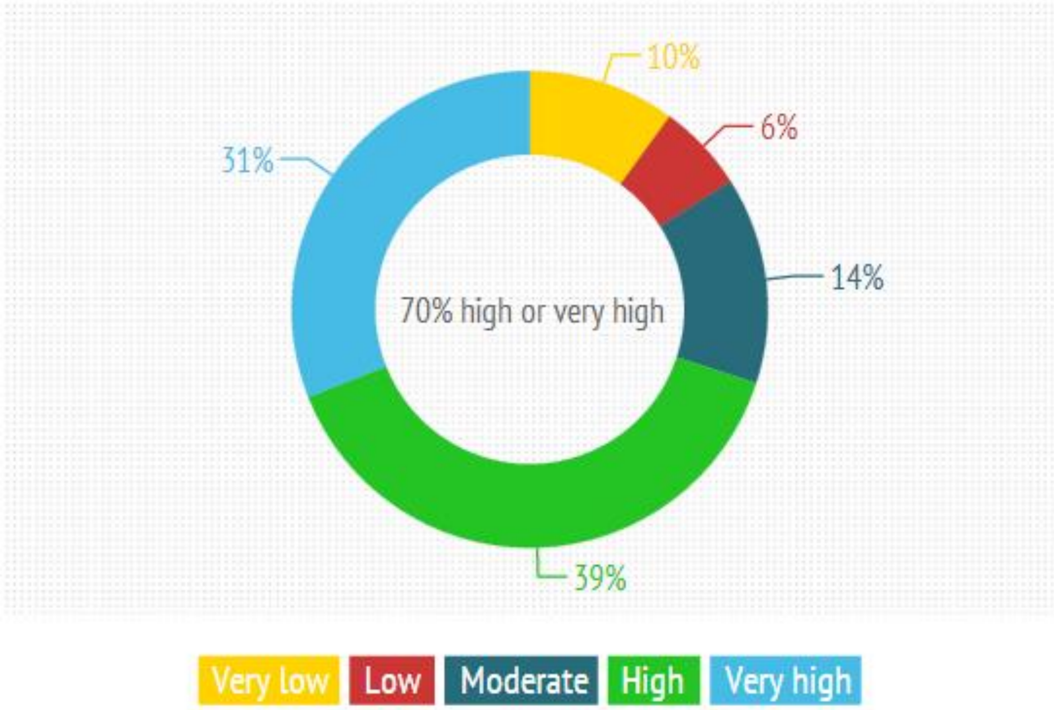
5.2.3 Other supply chain risks

Of the sectors and businesses that have been included in this report, 70% consider raw material risk to be either high or very high in comparison to other risks in their supply chains (Figure 7). Therefore, despite the diversity of sector and businesses, raw materials are of consistently high concern across industry.

Other supply chain risks commonly highlighted include:

- Costs associated with utilities (energy, water, gas), transport and certain taxes (e.g. import).
- Variability of downstream demand.
- Operational risks (e.g. accidents, or equipment malfunction).
- Availability of correct skills in workforce.
- Excessive and unstable legislation, particularly for waste management, and health and safety.
- Climatic conditions (linked to impacts such as flooding, blocked transport routes, interruption of utilities).

Figure 7: The proportion of businesses, of those consulted, across all nine sectors considered in this report that consider raw material risk to be of very low, low, moderate, high or very high importance compared to other risks in their supply chain



5.2.4 Comparison with other studies

Overall, the high level findings support the conclusions of other studies, which are that raw materials issues are impacting on businesses, and that they are experiencing difficulties in sourcing and variations in price. However, there are differences in the materials identified linked to the approach to the studies.

Most other studies used literature-based methods to assess materials criticality, and tended to focus on raw materials at the start of the value chain (e.g. unprocessed minerals, or individual metals that underpin much of the world's economic activity). By contrast, depending on the sector, most of the materials (and issues) identified by businesses consulted for this study were linked to downstream forms of raw materials that have been processed or purified in some way. This is unsurprising as most of the businesses consulted were not primary users of raw materials, instead relying on an upstream supply chain to supply them. This also suggests that most upstream supply chains extend outside of Scotland, which is not always considered within other analyses.

In addition, the wide range of materials identified within this study extends beyond the scope of most studies (e.g. water, inputs from crops and animals are identified) leading to a greater diversity of materials considered. In addition to this, responses often highlighted particular grades, purities or standards of materials, a consideration not generally addressed in other studies. When produced in small quantities these appear to experience more acute issues than materials do in bulk.

The downstream raw material inputs identified by businesses experience slightly different influences than the raw materials identified by other studies do. However, many of the issues (such as production capacity, lead times, competition for supply and increased prices) map well onto to those identified for the upstream raw materials. The responses identified by industry also seem to align well with the thinking of other businesses and governments in other territories.

5.3 Aerospace, defence and marine (AD&M)

5.3.1 Overview

Around 750 businesses employ almost 40,000 people in the AD&M sector in Scotland. This high-technology sector produced over £5.5 billion in sales in 2012, and contributes an annual GVA of around £1.8 billion to the Scottish economy. Scotland is host to a wide range of international businesses in this sector, many of which are served by Scottish ventures. The shipbuilding and ship repair businesses in Scotland account for around 40% of all UK activity in this segment, and include specialities in manufacture and design. The marine segment itself employs over 20,000 people in Scotland.[64]

The Industry Advisory Group (IAG) for this sector, consisting of leading individuals from across industry, academia and government, created a growth strategy that was launched in 2009.[65] This strategy highlighted the following actions that are important for Scotland to achieve growth in the AD&M sector:

- secure skills that the industry will need in the future
- attract more AD&M companies to Scotland
- increase research and development activity
- increase the involvement of Scottish companies in the industry supply chain.

A total of **5** trade bodies and **21** distinct businesses were contacted in the AD&M sector during the course of this research, although additional businesses were asked to participate by some of the trade associations. Responses to the questions listed in the pro-forma (either through email, telephone or face-to-face interviews) were obtained from **5** individuals in this sector, working for 1 small sized company (<50 employees), 2 medium (<250 employees) and 2 large sized companies (≥250 employees). Of the responses, 4 were from the aerospace sector (both commercial and defence) and 1 from the marine sector: these encompassed repair and maintenance businesses, component manufacturers and product assemblers.

5.3.2 Reliance on raw materials

From the results of the survey the sector appears reliant on several types of raw material, with metals, plastics and composites specifically highlighted. These may either be linked to the raw materials themselves, or components, such as forgings, castings and mouldings. Some specific materials were highlighted as of particular importance. For example, the metals aluminium and titanium are commonly used in the manufacturing of components and

64 Scottish Keyfacts, Scottish Enterprise 2013. Available at http://www.scottish-enterprise.com/knowledge-hub/articles/publication/scottish-key-facts

65 Scottish aerospace, defence and marine industry strategy 2009, Scottish Enterprise Industry Advisory Group 2008

products within this sector. Further along the supply chain, metal castings and other components were also identified as important inputs into businesses.

A large proportion of participants in this sector identified raw materials as vital or very important to their business. The remaining small proportion stated that materials were only quite important –probably because of their business type (repair of aircraft) and where they sat in the supply chain, with issues with materials influencing their suppliers rather than them directly.

5.3.3 Raw material issues

Of those that participated, around two-thirds stated that their business has been affected by issues relating to material supply in the last two years. The businesses that claim to be unaffected by these issues require their customers to handle all aspects of material sourcing and pricing. In addition, a small number of businesses in this sector believed that the associated threat to materials supply has changed recently, and that the risk to supply has changed. The materials issues faced by this sector therefore appear to be consistent, at least over the recent past.

The materials identified in this survey are fairly common across many sectors, though their use here is arguably more crucial due to performance requirements for these applications. **Aluminium** and **titanium** were identified as metals of particular importance for the aerospace industry, where the combination of their properties - particularly of weight and strength - makes them ideal for these applications. Both these metals are mainstays of the industry. Aluminium was identified as a particular risk due to the high reliance on this metal in the aerospace industry (aluminium alloys often constitute the largest percentage of planes' weight, though the use of composites is growing). Changes in price have influenced the market in recent times, and customers have also had to consolidate orders to meet required production capacity. It was also noted that lead times associated with titanium had increased recently, due to competition for supply.

Plastics and technical composites (see Spotlight, overleaf) were also identified as issues by some companies. In the cases identified, this was linked to access to materials and components that are required for repair but are no longer available on the market. Some impact from price increases had been identified; however, this was deemed less important than availability, possibly due to the nature of the aviation sector.

When asked whether the current issues around materials in the AD&M sector will change much over the near future, no respondents believed that it would. This is a reflection of the belief that supply chain management, including aspects associated with materials, performs well across this sector. For example, businesses in this sector often remove themselves, to an extent, from the materials sourcing process by making their Tier-1 customers also act as their suppliers. This means that the business is able to work closely with the supplier to ensure that materials are supplied on time and at the desired quality and cost, which in turn means that the product can be delivered to the customer as planned. This kind of system can remove a large amount of supply risk from a business' operations, but is generally only implementable with scale.

In general the response from several organisations has been to seek out alternative suppliers, or to hold more stock themselves to provide a buffer in case of supply restrictions. Where price rises have been seen in supply, these have either been absorbed by the company or passed directly onto customers depending on the type of business and agreements in place. None of the businesses indicated a willingness to use biotechnology as a solution to the outlined materials issues, principally because of the extremely high structural requirements of the materials that are used in this sector.

More widely, re-use and remanufacturing are known to commonly occur throughout the industry due to the high value, high quality and longevity of parts and components used.[66] These activities are very much part of the industry, and can reduced the reliance on primary raw materials as well as reduce costs and enable more service based business models.

Spotlight on… fibre-reinforced polymer composites

Composites or composite materials are materials made by combining two or more materials together into a unified structure while remaining as distinct components. The purpose is to enhance the overall properties of a material (e.g. increasing strength, lowering weight or improving heat resistance). The component materials have different properties that, when brought together, yield a material that has new properties and characteristics which can be tailored for an application. This allows design and performance obstacles to be overcome.

Composite materials are commonly found in many applications, and vary widely from e.g. construction materials such as cement, concrete and plywood, to e.g. high performance metal or ceramic composites. There are currently around 1,500 businesses involved in the UK composite sector, with annual production revenue of around £1.1 billion. Carbon-fibre composites account for around £0.6 billion and glass-fibre composites around £0.4 billion.

Within the AD&M industries, as identified in this study, the most commonly used composites are of fibre-reinforced polymer (FRPs), and these industries are reliant on these materials to improve efficiency and reduce costs. FRPs are made of a polymer (plastic) matrix that is reinforced with fibres of materials such as glass (glass reinforced plastic), carbon (carbon fibre). These composite materials are light, strong, and can be moulded into the correct shape, and may be cheaper than metal components that they replace. This is particularly attractive for industries where weight savings and forming components from single moulded parts is of benefit, such as the aerospace industry where their use has grown over the last four decades. Commonly, up to 30% of the weight of a passengers plane's airframe is made from composites. Newer designs have increased this further, with most new Airbus and Boeing aircraft designs constructed from high performance composites. In the maritime industry modern composites are used for a wide range of applications, including aramid FRP for hulls, carbon fibre masts, and FRP-based interior mouldings and sails.

FRPs are based on a range of feedstock materials; various polymer matrices are used, as well as a variety of fibres. The particular composition will be based on the needs of the user. Information from industry indicated that there had been problems associated with obtaining some raw composite materials such as resins as they are typically sourced outside Scotland. Global demand for these has recently increased, leading to delays in sourcing. In addition, the technical expertise to produce and shape more advanced composites is often localised in

66 Remanufacturing in the UK, Centre for Remanufacturing and Reuse 2010

a few companies or territories: this creates further barriers for business.

The main environmental impacts of composites are seen in the production phase, where high energy and solvent use is commonplace. The production phase impacts of carbon-fibre reinforced composites (CFRC), for example, are far higher than construction-grade steel.[1] However, the properties of the composites mean that they perform far better than their metal or plastic counterparts during the use phase. This out-performance leads to faster construction times, prolonged lifetimes, less maintenance and increased fuel savings when the materials are used in vehicles.

Recycling these materials at end of life is a challenge, as they generally cannot be recycled in the composite form, or be separated into the individual components. The hybrid properties of the composite often increase the difficulty, as individual difficulties in processing the component materials may be combined. For CFRCs several recycling and recovery technologies have been developed, including: mechanical grinding, used primarily for CFRC waste to produce filling materials; pyrolysis, to burn off resins; and cement kiln, with materials heated and 2/3 transferred for use in cement and 1/3 used in energy production. These processes are expensive and, at present, not widely used, but further development of these technologies could help the move to a more circular economy.

Due to the difficulties in recycling it is desirable to ensure that a material's useful life is extended as far as possible. This is already happening in the ADM sector through repair and remanufacturing activities.

Further R&D into cleaner production as well as improved end of solutions will reduce the whole-life environmental impact of composite materials, which is important considering their increasing use across the sectors discussed in this report.

[1] Ernst & Young, 2010, "UK composites supply chain scoping study – key findings"

5.3.4 Other supply chain issues

When compared to other risks in the supply chain, a difference of opinion over relative importance was found: half believed raw material risks to be very high compared to other risks in the supply chain, and half believed them to be low in comparison. Where the risk was considered low, agreements were in place for customers to act as Tier-1 suppliers. Where it was high, the company produced components themselves so were highly exposed to raw material issues.

Several other supply chain risks were identified in the interviews, generally related to the operation of the business. These mainly identified issues further along the supply chain which were often a consequence of raw materials issues: for example, in the supply of metal forgings and castings, or other components required for aerospace or marine application, where suppliers had begun to hold less stock to reduce working capital, had resulted in longer lead times. This was particularly evident for some businesses with suppliers outside the EU, for example in steel components for the marine industry.

Some businesses noted the impact of parts or materials becoming obsolete, making sourcing difficult and time-consuming. One company noted the appearance of counterfeit components on the market, which were viewed as having lower quality.

Increasing costs had also been noted, linked to freight and the price of components (partly raw material influenced). In some cases this has had a knock-on effect on business, and at least one firm indicated that developing new business was hampered as a result of issues with suppliers.

5.3.5 Wider context

Other studies on critical raw materials for this sector have tended to focus on the aerospace industry; there is some (public) discussion on defence, and little consideration of marine industries.

In the aerospace sub-sector, certain metals within specialist alloys and structural materials (such as aluminium alloys) have been identified as critical, with governments and industry highlighting issues.[67] The industry is reliant on a several key materials; Tier 1 companies are often well aware of raw materials issues, and act accordingly in business models and strategies.

Sections of the aerospace industry are known to rely on **specialist alloys**, such as super-alloys for high temperature applications. These often contain specialist, low volume metals, such as **cobalt, PGMs, rhenium, tantalum** and **tungsten**, with the alloys linked to high performance, irreplaceable functions such as blades in gas turbines. These were not directly identified in responses to the survey; most likely due to types of companies responding which do not include engine manufacturers/suppliers.

Concerns over these particular metals are generally linked to their very low volume of supply and high cost. For instance, rhenium has a global production of just over 50 tonnes per year. This production is from a small number of countries (mainly Chile, USA and Poland). It is also a by-product of copper and molybdenum, and the low overall value of rhenium compared to the carrier metal often means there is little incentive to expand capacity. Similar, though less acute, situations occur for the other metals, leading to similar concerns over supply. For example, cobalt is mainly sourced from the Democratic Republic of the Congo, which is viewed as unstable. Such situations have led transparency schemes for the extractive industries to be launched.[68]

Rhenium is often cited as of particular concern, as over 80% of its production is linked to super-alloys for various applications (including in turbines aerospace and energy generation).[69] Companies such as Rolls Royce use strategies such as maintaining a working inventory of material through service-based contracts in which they retain ownership over turbines and consequently the materials. Activities such as maintenance, remanufacturing, and recycling are used to improve the efficiency of materials use, minimising the impact of supply disruptions. Research into new super-alloys with different compositions has also been widely conducted; however, for these applications the focus is generally on improved performance, as increasing the operating temperature of a turbine increases its efficiency.

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[67] For examples see Study into the feasibility of protecting and recovering critical raw materials through infrastructure development in SE England, EPOW 2011; Materials Challenges for the Aerospace Sector Presentation, Andy Clifton (Rolls Royce) 2013; and Research Priorities for More Efficient Use of Critical Materials from a US Corporate Perspective, GEC 2010.

[68] For example the Extractive Industries Transparency Initiative - http://eiti.org/

[69] Study of the By-Products of Copper, Lead, Zinc and Nickel, International Nickel Study Group et al 2012

Structural materials have also been raised as a concern by the aerospace industry, both elsewhere and in responses to this study. These are the major materials (by weight) used in this sector. Other studies most commonly consider the alloying metals used for aluminium (in particular) and various alloying metals associated with steel which, though only a small fraction of the alloy, provide a significant improvement in properties. This is important in this sector as high performance (such as strength and light-weighting) is required. These alloying metals are generally produced in much lower quantities than the primary metal, leading to more concentrated supplies due to smaller markets. Responses from the survey followed a similar theme. Steel and aluminium were highlighted, as were other materials such as composites and titanium. However, it was the final input material (i.e. steel) that was identified rather than the component metals, and issues with supply may be linked to access to specific alloying metals as well as other bottlenecks in production. Steel is discussed further, in respect to all industries, in Section 5.2.2.

Critical raw materials in the context of the defence industry are considered, though this is in regard to resilience and security, rather than impact in economic terms. There is also a certain amount of sensitivity over releasing information, which limits knowledge in this area. The US Department of Defense operates a National Defense Stockpile, which acquires stores and sells around 75 raw materials viewed as strategic and critical for defence applications, including most of those highlighted in Table 3.[70] This stockpile is regularly reviewed and reconfigured to suit requirements.

The issue was brought to the fore in the EU, where the issue of critical raw materials was recently highlighted in a communication.[71] This highlights the need for screening raw materials that are critical for the defence sector within the context of the EU's overall raw materials strategy and for investigating policy actions. The UK MoD's DSTL group also recently investigated the recovery of certain raw materials from land based platforms, though the results are not publically available.

5.3.6 Impact of materials issues on sector growth initiatives

The IAG has stated, as one of its key strategies, a desire to increase the involvement of Scottish companies in the industry supply chain (see Section 5.3.1). This may be the most difficult of their aims to realise, given the reliance of this sector on low volume specialist materials, which are typically supplied by a small group of manufacturers who supply to the global marketplace. The IAG should not be adversely affected by the other materials issues highlighted for this sector, in its ambitions to achieve its other stated aims.

Many of the materials that are sourced in this sector are used to manufacture speciality components. When these components fail and need to be replaced, the sector struggles to recycle the failed components because of their composition. Composites are difficult and very expensive to recycle (see Spotlight section). Although components do not account for a large proportion of Scotland's total waste by weight, the current low recycling potential of

70 http://www.strategicmaterials.dla.mil/Pages/default.aspx

71 EC COM(2013) 542 final, 2013

the speciality materials used in this sector will not help to achieve a national recycling target of 70% of all waste by 2025.[72]

Generally, the AD&M sector is active in remanufacturing and reuse, utilising components from equipment that has reached the end of its operational life. An increase in the recycling potential associated with the specialty materials in this sector will add to the circularity that is evident in this sector.

5.3.7 Suggested actions from industry

The responses from industry provided a number of suggestions for alleviating raw materials issues, with support from the Scottish Government:

- **Enable diversification and condensing the supply chain.** Businesses were often limited to a small number of suppliers, which were often part of a much longer supply chain. Enabling more sourcing options could reduce lead times, as could developing supplies within Scotland, the rest of the UK and other nearby countries. The IAG has an ambition to increase the number of Scottish-based suppliers within this sector, which this action would complement; though the types of materials used may make this ambition difficult to realise.[73]
- **Provide investment to support business operations.** Several responders felt the Government and private finance could provide more funding to alleviate supply chain issues, such as through loans, investment and other funding mechanisms. This could be used to improve stock management/holdings, or develop localised supply chains. This action is strongly aligned with one of the IAG's key aims, namely to increase investment in R&D in this sector (see Section 5.3.1).
- **Improve collaboration between academic and business R&D.** Improving the interaction between R&D institutes, SMEs and large businesses to develop technical solutions would allow business (particularly SMEs) access to R&D expertise, for example through the creation of R&D centres of excellence on specific topics such as material performance under different stresses and scenarios. This action fits with the Government's aim of supporting business environments by improving the links between universities and private sector companies.[74] Interface, which provides a central point of access to the expertise available in Scotland's Higher Education and Research Institutions, should be involved here.
- **Improve recycling of industrial waste.** It was felt that waste material was often not recovered or used in certain parts of the sector, possibly due to the high grade materials required. Therefore there may be an opportunity to improve collection and recycling of some materials, such as carbon fibre, into other sectors. This would benefit both parties, and would contribute to the Government's ambitions of achieving a 70% recycling rate by 2025.[75]

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72 Scotland's Zero Waste Plan, Zero Waste Scotland 2010

73 Scottish aerospace, defence and marine industry strategy 2009, Scottish Enterprise Industry Advisory Group 2008

74 The Government Economic Growth Strategy, Scottish Government 2011

75 Scotland's Zero Waste Plan, Zero Waste Scotland 2010

5.4 Construction

5.4.1 Overview

The construction sector is one Scotland's most important sectors. Around 31,000 businesses employ over 170,000 people in total (10% of all Scottish jobs), and contribute £8.7 billion in GVA to the Scottish economy annually. The housing construction segment is performing well, with a 22.5% increase in house sales in the second quarter of 2013 compared to the first quarter, and the infrastructure segment is also growing thanks to major public sector projects such as the Forth Replacement Crossing.[76]

Construction Scotland has identified key aims for this sector[77], including achieving the following by 2016:

- increase GVA by 10% to £9.62 billion
- increase exports by 10%
- achieve a 5% increase in reported innovation activity
- recycle at least 42% of industry waste
- maintain completion levels of Modern Apprenticeships
- increase leadership and management development activity in the industry, focusing on the future leaders of the industry.

In addition to these targets, the European Union has adopted a Directive which aims for 70% of non-hazardous construction and demolition waste to be recycled by 2020.[78]

22 trade bodies and **14** distinct businesses in the construction sector were contacted during the course of this research, although additional businesses were asked to participate by some of the trade associations. Responses to the questions listed in the pro-forma (either through email, telephone or face-to-face interviews) were obtained from **6** individuals in this sector, working for 3 small sized companies (<50 employees) and 3 medium sized companies (<250 employees). The businesses involved largely serve the housing market, though some also provide solutions to industrial and municipal construction projects.

5.4.2 Reliance on raw materials

The construction industry covers a diverse range of different businesses, and those surveyed range from those that supply materials or building components into the industry, to businesses performing the construction, to those fitting out buildings and landscaping.

The responses received suggest that raw materials issues are high on the agenda for businesses in the construction sector, and raw materials are often direct inputs into business operations. The materials identified as important for this sector by this survey encompass a large variety of different types, sources and issues. A recent report on construction product supply chains in Scotland provides a detailed view of this sector.[79] From this survey, it was

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[76] Scottish Keyfacts, Scottish Enterprise 2013. Available at http://www.scottish-enterprise.com/knowledge-hub/articles/publication/scottish-key-facts

[77] Building for the future, the Scottish construction industry's strategy 2013-2016, Construction Scotland 2013

[78] The Waste Framework Directive (Directive 2008/98/EC)

[79] Construction Product Supply Chain Overview, Zero Waste Scotland 2013

clear that raw materials issues had affected this sector, as 50% of the responses stated that raw materials were vital to their business, and 33% that they were very important. These were mainly business relying on construction materials as direct inputs into their businesses. The one company that identified raw materials as being of lower importance nevertheless viewed other risks such as costs and quality of materials as important.

5.4.3 Raw material issues

Of the businesses asked, two-thirds believed that they have been affected by material supply issues in the last two years. However, only half stated that there is a change to both the threat to materials supply and the size of risk to supply.

The materials identified in the responses can roughly be divided into three categories: metal /mineral based, bio-based and hydrocarbon based materials, each facing different issues.

Mineral and metal-based materials identified as important to the construction industry include: **aggregates** (including sand, and topsoil), **cement**, **steel**, **stone**, and **plasterboard**. Of these the greatest issues were identified with aggregates (see Spotlight below), steel and cement, which shared similar issues. Problems identified were often associated with fluctuating prices for these materials, combined with sector competition from businesses in other EU countries. There was some evidence that companies had found it difficult to negotiate a reduction in prices or to sign longer term supply agreements due to the nature of the business. The supply situation was made more complex by the lack of diversity in the supply of these materials: in some cases (such as cement) this had led to disruptions in supply. However, it was acknowledged that these industries were difficult to change, and that effects were felt by all companies further down the supply chain.

Bio-based materials identified include **timber**, **topsoil and compost**, **bark** and **plywood**. Of these the greatest concern was over timber supplies. For this material demand and supply can be difficult to match due to the length of time it can take certain timber types to grow and rapid changes in demand. This could lead to shortages. In addition, certain timber types had to be imported (particularly high strength timber), so competition from the international market also influenced business in this situation. There was also some indication that competition from the biomass market had influenced the timber market.

Hydrocarbon-based materials identified include **plastics** and **resins**. These ranged from bulk plastics such as uPVC used to form building fittings, to resins with specific properties. The former was not highlighted as a large issue by the industry; however, the latter highlights a general problem with certain low volume products, where supply relies on a single or small number of producers.

Spotlight on… aggregates

'Aggregates', or 'construction aggregates', describes particulates or fragments of hard materials used for construction purposes. Aggregates cover a wide range of materials including primary raw materials (such as sand, gravel, rock fragments), reclaimed materials (such as ground slag from ore smelting) and recycled materials (such as concrete). In 2010 it was estimated that there were 21 million tonnes of saleable crushed rock arising in Scotland with an estimated value of £153 million, though this figure does not include all materials in the classification described above. A broader estimate of 35 million tonnes is also available; this includes minerals and around 6 million tonnes of recycled and secondary materials.

Common uses for aggregates include road construction, concrete, railway ballast, drainage applications, and foundations for buildings. Due to their importance, the diversity of materials used, and different applications requiring different properties, a range of British Standards are used to ensure the correct aggregate type is used for the correct purpose.

In the survey, supply issues with specific aggregate sub-types were identified; for example, sand for use in concrete and top soil manufacture, and stone and gravel for structural uses. However, wider concerns were raised for all types of aggregate, and aggregates were identified in the SNIFFER study as a critical raw material. Concerns mainly arise over future supplies, as and when new quarries will be required. However, many are opposed to developing new sites, largely on environmental and social grounds. This is coupled with what industry feedback stated is a complex and lengthy permitting process, which it was felt could be streamlined without loss of controls.

Recycled materials (see image) offer an alternative which presents potential environmental

and economic benefits, and WRAP has developed a Quality Protocol for recycling these materials from waste. There are therefore opportunities for utilising aggregates from secondary sources (e.g. from demolition sites on nearby construction projects), tying in with the industry's commitment to halve waste to landfill. However, this is not always straightforward as the bulky nature of this material has cost implications for transport, and construction firms often prefer to source locally. According to a recent report on the construction industry, most Scottish concrete manufacturers source aggregates from nearby quarries.[1] Recycled materials may be used if they can be locally sourced, which limits the availability of alternatives such as slag and fly ash which are supplied from further afield, limiting the potential impact in Scotland of these sources.

According to the Mineral Products Association, recycled materials account for 26% of the total aggregate supply in the UK.[2] The recycled materials must be processed before being used as aggregate materials, including cutting to size and cleaning. This production phase environmental impact is far less than the corresponding impact for primary materials, largely because the energy and mineral intensive processes have already been completed in the production of the primary material.

Recycled aggregates can be used in the production of concrete and asphalt, and as pipe bedding, capping and structural fill materials.[3] At present, recycled aggregates are most commonly used for low specification purposes. An increased uptake of these materials for high specification construction purposes will reduce the reliance on primary alternatives as well as lowering the environmental impact attributed to the Scottish construction sector's use of primary aggregate materials.

A more in-depth analysis of the Scottish aggregates industry can be found in the recent ZWS report: Construction Product Supply Chain Overview.

[1] Construction Product Supply Chain Overview, ZWS 2013
[2] MPA aggregates information sheet, Mineral Products Association 2011
[3] Recycled aggregates: guidance for contractors, WRAP 2008

Of the businesses that communicated the outlined materials issues, only 20% believe that these issues will change over the short term. Concerns were raised over supplies of aggregates in the future due to the requirement for local sourcing. At a high level, diminishing access to natural (including renewable) materials in the future was raised, as it was felt this would lead to greater competition for materials.

The responders acknowledged that mitigating these risks and impacts was difficult. For instance, increased costs of raw materials could not always be passed onto customers, therefore these costs had to be absorbed or other costs had to be reduced. Some viewed this as part of the way the industry worked. Some had sought to diversify supply, for example looking for supplies outside the EU for certain materials. Although biomaterials are rarely used in the construction sector, 75% of the businesses who could feasibly use them in their construction projects indicated that they would be willing to do so. The main limiting factor at present is the lack of a reliable and robust bio-plastic alternative to rigid thermoset polymers that are used throughout this sector.

5.4.4 Other supply chain issues

Of the responses gathered, most (67%) viewed raw material risk to be amongst the highest business risks. Several other risks were identified as being as or more important than raw materials, though these were generally business-specific, and only downstream demand variability is considered to be a more consistent risk than raw material risk, particularly after several years of poor industry growth.

Costs were highlighted as a major concern; however, this varied between responses. Some felt increasing logistics costs were an important factor, particularly those businesses reliant on the transport of bulk materials. Increasing energy costs were also highlighted, which affected the prices of many items. Taxes were also identified as this affected competition with companies based outside Scotland.

Other large risks highlighted included availability of a labour force with appropriate skills (linked to activities relying on specific skills); this impacted on the businesses' ability to take on and complete work according to customers' requirements.

5.4.5 Wider context

The materials identified by this survey and the literature analysis map reasonably well onto each other. They generally consist of the structural materials such as steel alloys and timber, and aggregates. A wider selection of materials was identified in this study, partly because the scope of this work is wider than others and the approach taken to gathering information captures more niche markets.

Steel alloying metals have been commonly identified in other criticality studies, generally due to concentrated production compared to other materials. This is discussed in more detail in Section 5.2.2. However, the reasons for highlighting steel as an issue in the survey differ to a certain extent, with price fluctuations identified as the main concern.

Timber and aggregates are not widely identified as critical beyond the SNIFFER and Defra studies, though in many other studies they are not considered within the scope of the work. At the EU level these materials are considered within scope for analysis for the most recent critical raw material analysis[80], though they are not considered critical. This does not exclude them from resulting actions, and both are considered within the scope of the Raw Materials EIP. This initiative is on-going, but the SIP document provides an outline of required actions. This includes actions focussing on primary production, such as:[81]

- Technologies for primary and secondary raw materials production, including exploration, innovative extraction, processing and refining, recycling of raw materials from products, buildings and infrastructure.
- Improving Europe's raw materials framework conditions; minerals policy framework, access to mineral potential in the EU, and public acceptance and trust.

This may be used to influence both timber and aggregate production within the EU, and it is noted that both are produced in Scotland. These actions are on-going therefore the outputs have not been measured; however, a monitoring scheme is in place to quantify overall impacts of the EIP.

5.4.6 Impact of materials issues on sector growth initiatives

Construction and demolition waste represents around 44% of total waste produced in Scotland. In order to reduce the overall level of waste produced by this sector, more resource efficient measures must be implemented. These measures may include increasing the proportion of recycled content in construction materials or making the industry more resource efficient to help reduce waste output, in line with the Scottish Government's ambitions of a more resource efficient Scotland and preventing construction wastes.[82]

Discussions with individuals from the construction sector during the course of this research suggest that there may be a barrier to these ambitions being achieved; namely, that recycled materials are not always preferred, at present, to primary materials by large parts of the construction sector. Some industry participants suggested that this may be because of doubts around performance (e.g. the structural integrity of aggregates that are high in recycled content versus primary aggregate material), with others suggesting that materials with a higher recycled content are not as aesthetically pleasing (e.g. manufactured topsoil versus primary topsoil). The Enterprise Agencies will have to work at changing the attitudes of this industry, including the clients for whom construction companies work. A good place to start may be to encourage companies to work towards more sustainable design.[82]

Other respondents noted the difficulty in recycling some plastics and polymer resins that are used widely in this sector, which may hinder efforts to achieve a 42% industry recycling rate by 2016[83] and a 70% recycling rate by 2020.[84] Scottish Enterprise is tackling this issue, with

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[80] Pulpwood and sawn softwood are included in the on-going EC revision. This is the first study to directly compare these biotic materials with abiotic metals and minerals.

[81] Action areas 2 and 4 - https://ec.europa.eu/eip/raw-materials/en/content/about-sip

[82] Safeguarding Scotland's resources: blueprint for a more resource efficient and circular economy, Actions 1 and 4 - Scottish Government 2013

[83] Building for the future, the Scottish construction industry's strategy 2013-2016, Construction Scotland 2013

support from Zero Waste Scotland, having launched the Scottish Recycling Fund to encourage investment in recycling and reprocessing of plastics. This fund has been launched to help achieve the aim of supporting Scottish reprocessing and remanufacturing industries.[85]

There are wider concerns here regarding the impact that raw materials issues will have on Scotland's Critical National Infrastructure plans, including developments in energy, transport, communications, finance, water, food, health, emergency services and government. It is likely that these issues will impact these plans, but further research will be required to identify the risks and quantify the associated significance levels.

5.4.7 Suggested actions from industry

Suggestions for policy-level change are also varied, reflecting the diversity of the sector. Actions proposed include:

- **Provide investment in businesses seeking to mitigate risks**. Provide finance to encourage diversification of supply of certain raw materials, and investment in capital schemes to provide more robust indigenous supply. This aligns with the Scottish Government's drive for a more circular economy, specifically the ambition to address supply risks. Furthermore, it could contribute to the aim of using the Scottish Investment Bank to support early stage technology based businesses, described in the Economic Growth Plan.[86]
- **Improve the recycling of materials to high quality products.** Recycling of materials into high quality products that have value and can be used within the sector; the use of numerous types of material in the production of aggregates, for example. Although around 25% of aggregates are already comprised of recycled materials, this proportion should be increased to help the sector achieve its aim of recycling at least 42% of its waste.[87] Furthermore, this action will contribute to Action 4 of Scotland's blueprint for a more resource efficient and circular economy, aimed at preventing construction wastes.[88]
- **Improve logistics.** Many of the bulk materials such as aggregates and concrete are transported long distances by road. This could be made simpler and cheaper through better utilisation of rail. This aligns with one of the Scottish government's key growth aims for the country, namely developing infrastructure to keep pace with growing sectors.[86]

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[84] The Waste Framework Directive (Directive 2008/98/EC)

[85] http://www.zerowastescotland.org.uk/content/scottish-recycling-fund

[86] The Government Economic Growth Strategy, Scottish Government 2011

[87] Building for the future, the Scottish construction industry's strategy 2013-2016, Construction Scotland 2013

[88] Safeguarding Scotland's resources: blueprint for a more resource efficient and circular economy, Scottish Government 2013

5.5 Energy

5.5.1 Overview

The energy sector includes oil and gas, thermal generation, renewables, environmental activity and the emerging low carbon industries. Around 80% of the businesses in this sector, around 2,000, are in the oil and gas segment and include multinationals, Scottish global companies and a wide SME base. The energy sector contributed £27.4 billion to Scottish GVA in 2011, with the oil and gas segment accounting for roughly 55% of this. The sector employs over 250,000 people in Scotland, with around 200,000 of those based in oil and gas, 10,000 in thermal generation, 11,000 in renewables and 34,000 in other low-carbon technologies. In 2012 Scotland generated 39% of domestic electricity demand from renewables, which is now the second largest source of domestic supply, slightly behind nuclear.[89]

The strategic focus for the oil and gas sector, as formulated by the Oil and Gas Industry Leadership Group, is on maximising oil and gas recovery.[90]The aims of this industry are to:

- accelerate industry-led innovation and building the Scottish supply chain to £30 billion by 2020
- recruit a further 100 oil and gas companies to the managed portfolio by 2016
- contribute heavily to the Scottish government's plan of increasing exports by 50% by 2017.

The Renewables Industry Advisory Group, working with the Scottish Government, has defined a strategy for the renewable energy sector in Scotland out to 2020.[91] The key aims are to:

- support innovation by investing in areas that can deliver necessary industry cost savings and technology advancements
- support a globally competitive Scottish supply chain through supporting indigenous companies to grow and expand into new renewables areas
- invest in infrastructure to support the expansion of the sector, specifically to deliver 100% of energy demand through renewable supply by 2020 (current level is 40%)
- provide project finance for established companies, where relevant, to ensure that the right levels of finance exist in the various sub-sectors.

13 trade bodies and **91** distinct businesses were contacted in the energy sector during the course of this research, although additional businesses were asked to participate by some of the trade associations. Responses to the questions listed in the pro-forma (either through email, telephone or face-to-face interviews) were obtained from **7** individuals in this sector, working for 4 medium sized companies (<250 employees) and 3 large sized companies (≥250 employees). The businesses involved span the oil and gas and renewables sectors and include some consultancies.

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[89] Scottish Keyfacts, Scottish Enterprise 2013. Available at http://www.scottish-enterprise.com/knowledge-hub/articles/publication/scottish-key-facts

[90] Oil and gas strategy 2012-2020, maximising our future, Oil and gas industry leadership group 2012

[91] 2020 Routemap for Renewable Energy in Scotland, Scottish Government 2011

5.5.2 Reliance on raw materials

The energy production sector in Scotland can be divided into two sub-sectors: renewable and non-renewable energy. The industry as a whole relies on a wide range of materials, including: nitrogen, oxygen and helium gas mixes for deep sea diving operations; REEs for use in wind turbines and oil refining; timber as a biofuel feedstock; copper for electronic cabling systems; and high-grade metals, primarily for turbine tower and oil rig construction and specialty equipment.

Of the energy industry members who participated in this research, 71% believe that raw materials are either very important or vital to their business operations, whilst the remaining 29% consider them to be quite important.

5.5.3 Raw material issues

71% of responding businesses in this sector believe that they have been affected by materials supply issues in the last two years. 71% state that the threat to supply and risk to supply has changed in the recent past, indicating that these are getting worse rather than better. This suggests that Scottish energy companies are either becoming more exposed to these issues as operations expand, that the issues themselves are changing over time or that a consistent set of issues are having more of an impact.

Many of the raw materials used as supply chain inputs or feedstocks in one energy sub-sector are not relevant to the other. For example, **helium** may be considered critical by the non-renewable but not by the renewable energy industry. Helium is used widely in electronics and as a cooling agent in magnetic resonance imaging scanners. But it is also used in deep sea diving operations by the oil and gas industry which, at present, could not proceed without the use of helium. The primary concern in this industry at present is price rises and volatility. According to an industry source, the price of helium doubled between 2011 and 2014. Businesses in this sector are aware of their reliance on helium and are investing in research and development to identify alternative gas-mixes to support deep sea diving. A description of the wider context on helium is provided in Section 5.5.5.

There are also many raw material cross-overs between the two sub-sectors. The **REEs** are a set of 17 chemical elements with similar properties, namely the 15 lanthanides in the periodic table plus scandium and yttrium. REEs are found in many common technologies, from smartphones to electric vehicles. REEs are also used by the energy generation sector. The renewable wind industry makes use of neodymium, dysprosium, and praseodymium as permanently excited magnets in direct-drive turbines, whilst the oil industry uses lanthanum as a fluid-cracking catalyst when separating fractions of oil during the refining process.

The primary concern around the use of REEs, due to issues with sourcing combined with an awareness that most global REE resources are either located in or controlled by China. Whilst this is of course a concern for the energy industry in Scotland, it is no more of a concern than it is to energy industries in other nations. As the wind and petroleum industries continue to expand in Scotland the demand for REEs will continue to rise. It is therefore important that the energy companies look to maximize the recycling potential of the components and fluids in which REEs are embedded. Long-term, these companies should have REE substitution as their main risk mitigation action, through material or technology alterations. A wider context on REEs is given in Section 5.5.5.

Another material that is used regularly across the energy sector, and is deemed to be the most critical to this sector, is **high-grade steel** which is discussed in the Spotlight which follows.

Generally, businesses in this sector were not able to give an opinion as to whether the outlined issues will change much going forward.

Regarding responses to these issues, the most important include the diversification of suppliers to ensure security of supply and passing material price volatility onto customers. None of the participating businesses believe the materials that are important to them can be substituted for biotech alternatives. Further, design for recovery at end of life could be a key aspect in securing secondary materials in the future, but was not mentioned by the businesses.

Spotlight on… high-grade steel

Sub-sea structures, off-shore rigs and wind turbine towers are all primarily constructed of high-grade steel which have specific properties. For example, upgrading the steel used to construct a wind tower from grade S355 to S500 will cost around 25% more per tonne of material, but will save weight, require less material and reduce transport and construction costs.[1] These high grade steels contain small quantities of alloying agents, such as chromium, niobium or molybdenum, which have a large impact on the steel's properties.

Although steel is commonly used in the construction sector in Scotland, it is generally of a lower quality than is required in energy developments. The dominance of the construction industry with regard to steel consumption has caused issues around this material for the energy sector. Businesses are prepared to pay the price for high-grade steel, which varies according to market conditions, but according to survey responses they find real difficulty in sourcing the right grade. Added to this, the industry relies heavily on imports of this material, since Scotland is not currently equipped to provide its energy sector with high-grade steel milled in Scotland. The reliance on foreign materials causes further issues such as lengthy lead times. Despite these issues, there is evidence that globally the price for speciality steels (as well as other steels) has dropped over the last few years, linked to lower than expected overall demand for steel.[2] However, this does not appear to have led to improved availability of specific grades at present.

The main environmental risks associated with the production of steel are: water use, used in large quantities for cooling, rinsing and cleaning; decreasing biodiversity, through displacement of habitats and ecosystems in order to site the operation; air quality, through release of sulphur oxide, nitrogen oxide and carbon dioxide; and human health, through generation of fine particulate matter which is released to the surrounding air.

High-grade steels have a larger cradle-to-gate environmental impact than low-grade steel, due to their larger alloy content and more complex processing routes. For example, high-grade steel that conforms to grade EN 1.4162 has been shown to have a global warming potential of 3.8 tonnes CO_2e per tonne of steel produced, whilst construction-grade steel that conforms to EN 1.4301 has roughly 25% lower impact, at around 3.0 tonnes CO_2e per tonne.[3] This is largely due to the higher grade steel having larger proportions of virgin chromium and nickel as raw materials, as well as a lower steel scrap content.

Over the lifetime of the high- and construction-grade steels, less high-grade steel is required to fulfil a function and it is also likely to last longer in the operational part of its lifecycle than its low-grade counterpart. Hence over its cradle-to-grave life, using high-grade steel is likely to be less damaging to the environment than using lower-grade alternatives.

[1] Steel solutions in the green economy: wind turbines, World Steel Association 2012
[2] Speciality Alloys Market Briefing, Metal Pages 2013
[3] Assessing the environmental advantages of high strength steel, Hallberg and Sperle 2011

5.5.4 Other supply chain issues

Of the participating energy industry members, 50% consider raw material risk to be very low in comparison to other risks in their supply chains, whilst the other 50% consider them to be either high or very high. This disparity can be explained by the types of energy businesses that participated in this research. Those that are involved in the planning side of power developments consider the related policy hurdles to be far more significant risks. These types of businesses are not directly involved with raw materials, which they are of little concern to their direct operations. However, they are concerned with the potential consolidation of customers for whom raw materials are an issue, through takeovers or buy-outs, leading to a narrower range of potential customers in the future.

Conversely, energy businesses that are involved in on-shore and off-shore construction, or in supplying equipment or resources to the energy sector, represent the view that raw materials are amongst their most important supply chain risks. The other main concern for these businesses is the health and safety of their staff, many of whom undertake hazardous activities, though they also suggest that they have appropriate training and monitoring activities in place to mitigate this risk.

5.5.5 Wider context

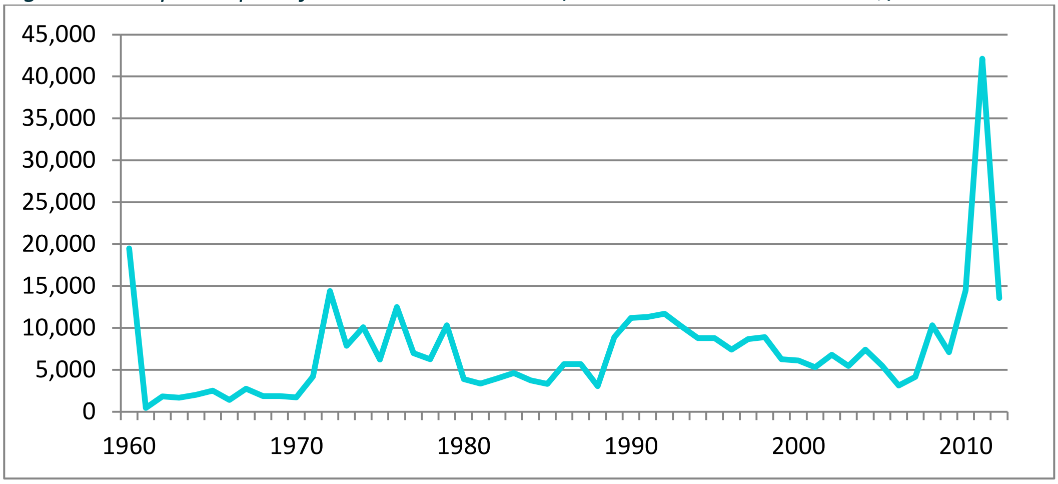
The energy sector has received considerable attention over raw materials, and particularly in relation to the uptake of renewable energy technologies such as wind turbines. General reports (such as the SNIFFER and EU studies) highlight a range of materials linked to this sector, often linked to steel, magnets (rare earth elements) and copper, and highlight there individual uses across the sector.[92] Technology-specific reports such as those from the EU JRC and US DoE focus on renewable energy technologies, highlighting certain REEs as most critical for implementing the technologies of relevance here based on forward projections of technology uptake. These map well onto the responses gathered from industry.

REEs used in magnets were highlighted by industry as a cause for concern, which is echoed across almost all other studies, with neodymium and dysprosium most often highlighted.[93] These concerns have arisen due to the combination of the supply situation, which has been

[92] Achzet B., Reller A., Zepf V., University of Augsburg,Rennie C., BP, Ashfield M. and Simmons J.,ON Communication (2011): Materials critical to the energy industry. An introduction.
[93] Critical Metals in Low-Carbon Energy Technologies, EU JRC 2013 & 2011

dominated by China for the last two decades, and a growing and unbalanced demand for the individual REEs. Over the last few years the Chinese export quota for all REEs has been reducing and predicted demand increasing, leading to large price increases and uncertainty in the market (Figure 8). These measures have led to an on-going WTO case. More recently prices have fallen as predicted shortages have not fully materialised, and alternative supply has been introduced from the USA and Australia. However, there are still concerns over the long term supply of certain elements, particularly the 'heavy rare earths' (HREEs)[94] which are far less abundant than many of the 'light rare earths', and are required for applications such as magnets in wind turbines and electric vehicles, and low energy lighting.

Figure 8: Compound price for rare earth elements, indexed to 1998 values US$/t



Source: USGS (2012)

Some of the issues around supply are associated with ore composition mismatching demand. Although geologically the REEs are not rare, they are found together and not in a proportion that corresponds to demand. As complex processing is required to separate them from each other, the supply for one REE is influenced by production of and demand for the others. For instance, the most abundant REEs are cerium and lanthanum, which account for close to two thirds of total production. These REEs find important uses in batteries, catalysts and glass polishing. However, for wind turbines (and other magnet applications) the most important REEs are neodymium and dysprosium. These are used in neodymium iron boron magnets (NdFeB), which is the strongest known magnetic material, and used in the generators in direct drive wind turbines.

Whilst neodymium is relatively abundant, accounting for 17% of production, it forms around 30% by weight of the magnet, and a wind turbine may contain several hundred kilograms of magnetic material. Concerns have been raised due to projected growth of uses in wind turbines and electric vehicles, requiring more neodymium to be produced.[95] However, similar growth is not predicted for some of the other REE, such as lanthanum and cerium,

[94] The REEs elements can be divided into the light and heavy groups. Definitions vary; here, light REEs are considered Lanthanum, Cerium, Praseodymium, Neodymium, Samarium and Scandium. Heavy REEs are considered Europium, Gadolinium, Terbium, Dysprosium, Erbium, Yttrium, Holmium, Erbium, Thulium, Ytterbium, and Lutetium

[95] Critical Metals in Low-Carbon Energy Technologies, EU JRC 2013 & 2011

meaning the total production of REEs will need to increase with no obvious market for these other REEs.

Greater concerns have arisen over the HREE dysprosium which is required in small quantities to maintain the properties of the magnet at elevated temperatures. Concerns are particularly elevated as, even with diversification of REE supply, very little production of dysprosium is predicted to occur outside China in the short term, due to mineral compositions. However, not all wind turbines require these magnets, and they are primarily used for direct drive models (which are viewed as most suitable for offshore applications). Other wind turbine generator options are available, and are in the majority at present.[96] However, these often require the use of gearboxes which can increase maintenance costs and reduce efficiency. Therefore lifetime cost/benefit analysis is required to fully understand the benefits of both, particularly for offshore installations. It is estimated that around 15% of overall wind turbine generation capacity in the EU will rely on REEs by 2020, rising to 20% by 2030.[97]

REEs as a group generally enter most critical material lists, with neodymium, dysprosium, and sometimes praseodymium receiving the most consideration related to their use in high strength magnets. Therefore specific responses have been seen at a national, international and company level. These address issues with supply, dematerialisation, substitution, collection and sorting, and recycling. Some examples are:

- Within China, the Baotou Research Institute[98] addresses many of the challenges associated with REE separation, processing, applications and recycling.
- The Japanese Government (through METI[99] and MEXT[100]) and Japanese companies such as Toyota[101]are particularly sensitive to REE issues. Over recent years these organisations have funded large research programs into the recycling of REE, the minimisation of materials in magnets (particularly dysprosium), and alternative materials, often at a fundamental level through research centres such as NIMS[102]. Companies such as Hitachi have developed and implemented magnet recycling technologies focussing on hard disc drives. At a national level an aligned programme has sought to develop non-Chinese supplies of REEs through the JOGMEC Department, and develop supply agreements with China.[103]. The Japanese stockpile REEs as part of their industrial stockpile corresponding to 42 days' consumption.[104]
- The US DoE has identified REEs are critical to renewable energy technologies, and have funded the Critical Materials Institute[105] to address issues with supply diversification (technology and primary supply), substitutes, and re-use and recycling. This institute

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96 Information from on-going ZWS study on wind turbine magnet recovery
97 Critical Metals in Low-Carbon Energy Technologies, EU JRC 2013 & 2011
98 http://www.brire.com/english/english.htm
99 Ministry of Economy, Trade and Industry
100 Ministry of Education, Culture, Sports, and Science and Technology
101 http://www.plugincars.com/major-japanese-firms-including-toyota-develop-revolutionary-rare-earth-recycling-technology-123700.h
102 National Institute for Materials Science, see http://energy.gov/sites/prod/files/Session_A7_Hono_NIMS.pdf for English overview
103 Japan Oil, Gas and Metals National Corporation
104 http://www.jogmec.go.jp/english/stockpiling/stockpiling_015.html
105 https://cmi.ameslab.gov/

will bring together several organisations in key research areas, with REEs being one area of focus.

- Within the EU, REEs are identified as critical, and with particular concerns raised over these materials. As with other materials responses are being handled through the EU EIP on Raw Materials and FP7/H2020 funding calls, and through international dialogues. The European Rare Earths Competency Network has been set up to address challenges associated with REE within the EU. Specific concerns were identified through two EU JRC studies on critical raw materials for energy applications, with recommended mitigation strategies including; diversify primary supply, design and innovation, resource efficiency, trade and international cooperation, and procurement and stockpiling. Companies in Europe such as Rhodia have had some success in developing facilities for recycling REE magnets[106], and the HydroWEEE FP7 consortium have had some success in recovering these metals from waste (this is discussed further in Section 5.10.4).
- In the UK, WRAP has undertaken a study to understand flows of REEs and other CRMs in EEE and wind turbines.[107] The University of Birmingham has expertise in recycling of REEs, and has developed a pilot scale process for recycling hard disk drive magnets. There is also a handful of small scale projects underway, investigating indigenous production of these metals, including characterising Scottish deposits.[108]
- A 2013 study by Zero Waste Scotland on landfill mining discussed the recovery of REEs (among other materials), however suggested there was uncertainty over the REE content, and a lack of processing capability at present.[109]
- A German study has estimated that the rare earth content of sales of selected electronics products amounted to 22 tonnes for 2010. Most of this is rare earth magnets within notebooks.

Overall, issues with REEs are being extensively explored from many angles, from fundamental research into materials, technologies and recycling, through to development of new resources and trade dialogue.

As with other sectors, **structural materials** such as steel are essential for these industries, and are required for pipelines and wind turbine structures. For example, it has been highlighted that for renewable energy to match the power output generated by fossil and nuclear sources, the renewables sector will need to use 15 times more concrete, 90 times more aluminium and 50 times more iron than it does at present, which increases the risk of failing to secure materials supply within this sub-sector.[110] Other studies highlight potential issues securing certain alloying elements, which are essential for high grade steels (for example, niobium, chromium, molybdenum). Industry responses have highlighted issues related to securing access to these grades of steel (see Spotlight above); however, it appears this is a wider steel industry issue than simply linked to raw materials. Steel is a cross-sectoral issue and is discussed in more detail in Section 5.2.2.

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106 Rhodia rare earth systems initiatives. Presentation June 2012, French Embassy in London

107 Mapping consumption and waste of raw materials in electrical products in the UK, WRAP 2013

108 http://nora.nerc.ac.uk/502722/

109 Feasibility and Viability of Landfill Mining and Reclamation in Scotland, ZWS 2013

110 http://www.climatecentral.org/news/renewable-energy-needs-huge-mineral-supply-16682

Metals used in petrochemical refining and reforming catalysts also consistently appear on many lists. Metals including cobalt, **PGMs**, **REEs** (specifically lanthanum) and **rhenium** are generally highlighted, and are used in the various stages of transforming crude oil to petrol, diesel and other petrochemical products. However, these are often small markets for these particular metals, generally accounting for a few percent of demand. Recovery from these uses is understood to be effective as the catalysts are used *in situ*, and can be collected and recycled once their efficacy drops, and stocks are well managed due to the cost of these materials, importance of catalysts and confined use.[111] Other catalysts have been sought to reduce the costs of these catalysts, however performance drops outweigh other benefits.

Helium was highlighted by the industry survey, but it is not commonly identified in criticality studies due to their scope. However, there has been significant uncertainty and commentary on this issue over the past decade due to price spikes and shortages.[112] Therefore it can perhaps be considered critical in this broad context. It is generally understood there is no absolute shortage of this gas; however, incentives are poor for capturing it from certain natural gas resources which are the main economic resources (much like certain by-product metals). Concerns have arisen as, in the past, the market has been fed from supply from a US stockpile: this limited the interest from other potential producers as prices has been kept low. However, recent uncertainties in on-going supply from this stockpile have been reflected in the market. A recent US Bill has sought to stabilise the market, introducing auctions for this helium. This is intended to incentivise other production sources in the future as prices increase. As helium is produced from natural gas wells, there may be opportunities for local sourcing, depending on gas composition.

5.5.6 Impact of materials issues on sector growth initiatives

REEs were identified as a material for major concern in this report, albeit on a low quantity level, and other reports have discussed their importance to the developing renewables sector in Scotland (see Section 5.5.5). Their importance in the construction of wind turbines in particular is well known. That which is less well understood at present is the potential to substitute their use with other materials, or the trade-offs required when alternative generator technology or other generation types are used. The large planned expansion in renewables within Scotland, and particularly for wind turbines, is likely to require large quantities of materials. Work at the EU and US level has sought to quantify for materials needs for their renewable technology plans, and a similar analysis may benefit Scottish plans.[113]

Materials scarcity issues also present an opportunity for the Scottish Government to move forward with several of their aims to help Scotland's economy become more resource efficient and circular.[114] These ambitions include:

- Stimulating innovation and business opportunities in the reuse and remanufacturing sectors, which could be realised in this sector by engaging with businesses on this subject and providing loans for research into reprocessing of materials of concern.

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111 Study into the feasibility of protecting and recovering critical raw materials through infrastructure development in SE England, EPOW 2011

112 Endangered Helium: bursting the myth, The Chemical Engineer Dec 2013

113 See studies 8 & 9 reviewed above

114 Safeguarding Scotland's resources: blueprint for a more resource efficient and circular economy, Scottish Government 2013

- Promoting sustainable product design, which in the renewables sub-sector may involve support for business to identify suitable alternative materials.
- Helping businesses use resources more efficiently, including gathering evidence across the Enterprise Agencies to inform the sector and the implementation of SEPA's Resource Utilisation Assessments.

With regard to the oil and gas sub-sector, the issues around the supply of high-grade steel could impact heavily on all of the Oil and Gas Industry Leadership Group's aims (see Section 5.5.1). For example, difficulty in sourcing adequate materials will put pressure on businesses in this sector to continue production at existing levels, and will limit the viability of attracting other relevant companies to Scotland. It is absolutely vital that a reliable feedstock of high-grade steel can be guaranteed for Scottish oil and gas businesses, and supplying a proportion of this stock through internal supply networks seems a sensible and viable option.

5.5.7 *Suggested actions from industry*

The participants in this research proposed a number of ways in which the energy industry could be supported by the Scottish Government. These actions include:

- **Develop and implement a Quality Standard for raw materials**, which ensures that the materials being supplied to the energy sector are of a high grade. Suppliers would then be expected to conform to this Standard when supplying specific materials for stated purposes. Industry believes that existing standards do little to help with this sector-specific issue. Scottish Enterprise are currently undertaking an evidence gathering exercise across multiple sectors, including oil and gas and renewables, as part of on-going research into moving to a more circular economy, and may wish to consider including this aspect in discussions with industry stakeholders.
- **Support research examining end-of-life waste as inputs to other sectors**. Industry suggests that a good place to start would be having important sectors identify their main waste streams and what they currently do with them. These waste materials or products may be of use in another businesses supply chain. For example, the high-grade steel that is used in this sector could either be reprocessed for use in the same sector or for use by another sector. This action aligns with several key aims of the Scottish Government, including providing a supportive business environment and stimulating innovation in business through reuse and reprocessing activities.
- **Research alternatives to using rare earths in wind power generation**. REEs are primarily used as permanent magnets in direct drive generators. Funding research into the alternatives will help to bring long-term stability to the off-shore wind sector in Scotland in particular. This action aligns with the Scottish Government's aims of strengthening innovation in businesses[115] and funding reprocessing activities[116].

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[115] The Government Economic Growth Strategy, Scottish Government 2011

[116] Safeguarding Scotland's resources: blueprint for a more resource efficient and circular economy, Action 8 - Scottish Government 2013

5.6 Food and drink

5.6.1 Overview

The food and drink sector employs around 116,000 people in Scotland, has an annual turnover of around £13 billion and contributes around £5.5 billion in GVA to the economy. The food and drink manufacturing segment employs around 44,000 people, which accounts for around 20% of all Scotland's manufacturing employees. The spirits segment is particularly large, with Scottish spirits (including Scotch whisky) accounting for 80% of total UK spirits turnover.[117]

Scotland Food and Drink has established six priorities in their efforts to grow the sector to an output of £16.5 billion by 2017[118], which include:

- helping primary producers to grow and become more responsive to changing domestic and export markets
- ensuring productivity by enabling efficient, innovative and growing businesses to compete with UK and global competitors
- increasing the exports of Scottish food and drink businesses
- embracing measures of sustainability whilst remaining profitable
- enhancing innovation to ensure that businesses are able to supply the products that customers want
- setting Scottish products apart from the products of other countries to ensure that Scotland has a long-term global reputation as a 'land of food and drink'.

30 trade bodies and **70** distinct businesses were contacted in the food and drink sector during the course of this research, although additional businesses were asked to participate by some of the trade associations. Responses to the questions listed in the pro-forma (either through email, telephone or face-to-face interviews) were obtained from **7** individuals in this sector, working for 2 micro sized companies (<10 employees), 3 small (<50 employees) and 2 medium sized companies (<250 employees). Participating businesses included those from the whisky and ale industries as well as food producers and wholesalers.

5.6.2 Reliance on raw materials

This sector incorporates a range of operations across the food and drink supply chain, including production, wholesale and retail businesses. The raw materials that these businesses are reliant upon are dictated by their position in this supply chain. For example, agricultural producers use seed, fertilisers and animal feed to grow crops and rear animals. Wholesalers rely on the outputs from such producers as the main inputs to their activities. In turn, retailers rely on the outputs from wholesalers, and in some instances the outputs from producers, as inputs to their business activities.

The materials identified through this research include animal feeds used by livestock producers, pesticides and fertilisers used by arable producers, malted barley used by the

[117] Scottish Keyfacts, Scottish Enterprise 2013. Available at http://www.scottish-enterprise.com/knowledge-hub/articles/publication/scottish-key-facts

[118] Scotland: a land of food and drink. Developing our vibrant and dynamic industry – the next chapter, Scotland Food and Drink 2013

Scotch whisky and ale industries, sugar, butter and milk used by the confectionary segment, and wheat used by bread and cereals businesses.

Raw materials are of great significance to this sector, and 100% of the businesses asked considered raw materials to be vital to their operations. This is perhaps unsurprising as this sector is almost entirely product-driven, with these products often containing relatively few material inputs.

5.6.3 Raw material issues

The businesses that participated in this survey are involved in the earlier stages of the food and drink supply chain. This appears to be where raw materials are most important in this sector. Of these businesses, 100% state that they have been affected by material supply issues in the last two years. 71% are aware of a change in the threat level to this supply over this period, and 86% have noticed a change in the level of risk to this supply. These businesses indicate that the situation is worsening, from their point of view. The main issues faced by these companies, and the materials that are affected, are below.

They key concern for producers of livestock seems to be around materials that are commonly used as **animal feed**. These include wheat grain used to feed poultry, and hay, straw and forage for sheep and cattle. For wheat grain, respondents note the lack of quality supply and rising market prices, which is consistent globally. In addition to the obvious impact on costs, these producers suggest that lower quality feed results in lower quality meat which has a significant impact on attainable sales price and resulting margins. For hay, straw and forage feed, availability of even low grade materials seems to be the main issue. All of these arable livestock feeds are subject to seasonal variation in yield and quality: producers in this sector suggest that there is little they can do in the long-term to manage this risk effectively. In the short to medium term, producers are starting to negotiate longer contracts with suppliers and learning to manage their feeds more effectively.

Other inputs such as malted barley were highlighted by several industry stakeholders. Malt barley is important to the whisky and brewing industries (see Spotlight section).

Water was also identified as a material of concern, but only amongst those businesses that require high-purity water. The Scotch whisky industry in particular relies on high quality water for use in all of its production phases, from malting to mashing and for reducing alcoholic strength. Many whisky distilleries are situated above or near to natural springs or boreholes and have direct abstraction permits but, for those that are not obtaining high purity, water can be a major part of their raw material bill.

None of the businesses that participated in this research believe that the outlined issues will change over the near future. They foresee the threat and risk to materials supply continuing along current levels. In addition, the types of businesses responding are less likely to identify these materials.

A common response for dealing with the outlined materials issues include paying the market price and attempting to recoup these costs through improving materials efficiencies, or passing increased prices onto customers, though this is rarely possible in this sector. Food producers at the head of the supply chain are beginning to sign their customers into long-term contracts, whilst businesses further down the supply chain, such as retailers, are diversifying their upstream suppliers. This sector as a whole relies primarily on natural materials, with the majority indicating that biotechnology solutions are not relevant.

Spotlight on… malt barley

Dried germinated barley grain, known as malt, is used to make beer, whisky, malt vinegar and some baked goods such as malt loaf and biscuits. In 2009 around 332,000 hectares of barley were farmed in Scotland, with a total yield of 1.9 million tonnes.[1] Roughly 35% of this annual yield goes into malting, primarily for use in the food and drink sector. The biggest market for Scottish barley producers is the Scotch whisky industry, which contributed £4.2 billion to Scotland's economy in 2012 and employed 36,000 people in its supply chain.[2]

According to the Scotch Whisky Association, Scottish distillers used over 0.8 million tonnes of malt barley in 2011, i.e. more than 50% of the 1.5 million tonnes of spring barley produced in Scotland that year. Scotch whisky manufacturers prefer to source their barley (as well as their wheat if making grain whisky) from within Scotland. From the perspective of large-scale Scotch whisky producers, Scottish malt barley is a stable commodity which is only subject to small variations in quality. And even though the market price of malt barley has increased in recent years, such companies are able to pass these costs on to customers, who are prepared to pay for this luxury product.

Small-scale whisky and beer producers that rely on malt barley have a different view of this raw material. Here, SMEs have to compete against much larger whisky and beer producers to secure the right quantities to satisfy orders. Whilst SME whisky producers can pass some of the increasing raw material costs onto customers, the remaining costs are taken out of their margins. SMEs in the beer segment are not able to pass increasing raw material costs on to customers, and have little option but to pay the market rate and try to cut operating costs in other areas of their business.

The images below show the form in which malt barely arrives on-site at a typical SME beer brewery (left) and the fermentation tanks used in a microbrewery (right).

The potential environmental impacts of barley production are to: land-use, including natural habitat and ecosystems displacement leading to impacts on regional biodiversity; soils, through erosion of soil and decreases in fertility from over-cropping; water, which includes the use of freshwater resources in the growing cycle and impacts to those water courses from surface run-off and drainage; and air, principally due to the release of greenhouse gases by planting and harvesting machinery. Furthermore, allocating land to crops for industry (and export) has an impact on Scotland's ability to provide food for indigenous consumption. These risks can be mitigated, to an extent, by ensuring that land, water and air management plans are followed through the crop cycle.

[1] What we produce, NFU Scotland 2014. http://www.nfus.org.uk/farming-facts/what-we-produce
[2] Scotch whisky and Scotland's economy, Scotch Whisky Association 2014

5.6.4 Other supply chain issues

The food and drink sector depends heavily on raw materials, and 66% of respondents consider raw material risk to be either high or very high in comparison to other risks in their supply chains.

Variability in orders from downstream customers was the only consistent supply chain risk, other than those associated with raw materials, identified by this research. Respondents indicated that retail customers in particular have a record of adjusting order quantities at relatively short notice. Orders that are adjusted upward can put pressure on food and drink producers to achieve the required quantities, whilst adjustments downward, if large enough, can severely impede the ability of these producers to operate.

5.6.5 Wider context

Most criticality studies analysed omit food crops from their analyses, and therefore do not map on to these responses from industry.

Phosphates have been highlighted by some studies due to: their importance in fertilisers and agrichemicals (and consequently food production); concentrated supply from Morocco, the US and China; lack of alternatives; and difficulty in recycling. Despite these concerns, none of the producer-level members of this sector indicated that this material or its derivatives are of concern to them. Supplies of the bulk material, phosphate rock, are in decline and associated prices are suffering sharp periodic increases; for example, a 700% increase was observed between 2007 and 2008.[119] Therefore, manufacturers of such agricultural chemicals would state phosphorous as a critical material in their operations. The fact that agricultural producers do not cite phosphorous as a concern is evidence of how raw material criticality varies according to the position a business occupies in its sector's supply chain.

Concerns within the EU led to the formation of the EU Phosphorus Platform in 2013.[120] This initiative aims to develop a sustainable supply of phosphorous to the EU, as there is little indigenous production. This Platform goes beyond material criticality (e.g. alternative supplies, minimisation and recycling), and addresses environmental aspects such as leaching and eutrophication, and linkages with food security. Phosphates were included in the recent EU analysis of critical raw materials, having previously been omitted.[121] In the UK a phosphorus recovery plant was brought online by Thames Water recovering phosphorus from waste water that has a high phosphorus content due to nearby industrial processes or the application of sewage sludge on farmland.[122]

Palm oil was identified by the SNIFFER study, though not by other studies. It was not directly identified in the survey, however; other similar agricultural inputs were identified, most likely as these are considered the most important inputs to businesses. Concerns were raised in the SNIFFER study due to import dependence, and the controversy over supply that this material faces. This in turn was linked to factors such as deforestation, competition with

[119] Raw materials critical to the Scottish economy, SNIFFER 2011

[120] http://www.phosphorusplatform.eu/

[121] 2014 analysis is unavailable at time of writing

[122] http://www.thameswater.co.uk/media/press-releases/17393.htm

other crops such as rubber and social impacts, as well as a relatively concentrated supply in Indonesia and Malaysia. These concerns were raised broadly across the globe, and in response the industry formed the Round Table on Sustainable Palm Oil.[123] This group has developed standards for sustainable palm oil production. This provides some assurance of the sustainability of supply, through certified sustainable palm oil label.[124]

Packaging materials such as magnesium (in aluminium alloys) and tin are often highlighted in other studies, due to the lack of supply diversity: China is the major supplier of both. These materials were not raised during the consultation, most likely as they were outside the direct consideration of responders. Concerns over these materials are not directly linked to this application, but the wider uses across sectors; for example magnesium in aluminium alloys, and tin in the electronics sector in solders, and in the chemicals sector in plastics production. Though there is awareness of supply issues, specific actions have not focussed on these materials from a critical raw materials standpoint. Recycling processes for both these materials are relatively efficient compared to other critical materials, particularly for industrial uses. However, related to the food and drink industry, studies have highlighted that increasing collection and consequent recycling of consumer product packaging could be improved. For instance, in the UK increasing the recovery of used beverage cans in line with other countries would reduce dependency on magnesium, as well as produce other resource efficiency benefits.[125] Actions are underway within Scotland to address this at present, as recycling rates are lower than across the UK. Substitutes for both are available, in the form of different packaging materials such as glass or plastic[126] or refillable containers.

5.6.6 Impact of materials issues on sector growth initiatives

From a sector-specific perspective, some of the materials identified as being important in this report (and other reports) may impact on Scotland Food and Drink's aims out to 2017.[127] For example, competition between product manufacturers in the same and different sub-sectors for materials, such as barley and high-quality water, may hinder their aim of helping these businesses expand. This may, in turn, limit the capacity of these businesses to increase their exports, another stated aim of this sector. However, it does present opportunities for the primary producers that supply these materials to product manufacturers to increase the size of their businesses, if certain factors (such as land space, allocation and planning) allow.

A related issue is a lack of desire to change attitudes across generations of farming families and communities, as highlighted in conversations with agricultural producers. Some producers consider the old ways to be the best and are disinclined to implement measures aimed at improving resource efficiency and minimising waste outputs. This kind of attitude may severely impact on Scotland Food and Drink's ambition for the Scotland-wide farming community to embrace sustainable practices whilst remaining profitable or to ensure productivity of this part of the supply chain by enabling innovation across the sector. A lack

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123 http://www.rspo.org/

124 http://www.rspo.org/en/how_to_be_rspo_certified

125 Study into the feasibility of protecting and recovering critical raw materials through infrastructure development in SE England, EPOW 2011

126 Annex V – Critical Raw Materials for the EU, EC 2010

127 Scotland: a land of food and drink. Developing our vibrant and dynamic industry – the next chapter, Scotland Food and Drink 2013

of generational change may also impact on wider attempts to move the sector as a whole to a more circular approach.

Low existing and potential recycling rates of certain natural materials such as phosphates, and chemical substances such as those found in pesticides, could hinder Scotland in achieving targets around minimising waste and increasing recycling of materials, which forms part of the strategy for moving to a more resource efficient and circular economy.[128] As with most of the material threats identified in this report, this also presents an opportunity for the Scottish Government to improve understanding around the substitution of these materials (e.g. phosphates).

Beyond materials, the Waste (Scotland) Regulations 2012 requirement for separate food waste collections from households and businesses in non-rural areas will significantly increase the quantity of material returned to the food cycle, largely via anaerobic digestion to the soil. This initiative could play a key role in driving the circularity of this sector in coming years.

5.6.7 Suggested actions from industry

The participants in this research proposed a number of ways in which the food and drink sector could be supported by the Scottish Government. These actions include:

- **Fund sector initiatives to increase material efficiency.** SMEs in the food and drink sector, especially producers, believe that they may be missing out on the level of material efficiencies that larger companies in the same segments are able to gain. Whilst SMEs are very unlikely to achieve the efficiencies that major businesses can, they should be encouraged to apply for existing funding and to collaborate with existing research centres and universities with expertise in this area. Support from Scottish Enterprise will help this. One of the Scottish Government's key aims is to help businesses use their resources more efficiently.[129]
- **Commission a social study of attitudes in the agricultural community**. Producers that implement scientific and resource efficient measures to gain the most from crop and livestock yields are believed by this sector to be the exception rather than the rule. This segment of the sector believes that this may be because of long-held attitudes of the majority of agricultural producers, and that social factors (such as a lack of willingness to change these long-held beliefs) may be the root cause. This action may fall under the remit of the Enterprise Agencies, specifically the aim of gathering evidence from different sectors to enable transition to a more circular economy.[129]
- **Initiate collaboration between Scotland's sectors regarding waste**. This sector produces many types of waste, which may be used in the operations of businesses in other sectors. Barley grain that is used through the whisky and ale production process could be used as inputs to the agricultural sub-sector as fertiliser or to the salmon industry in the manufacture of fish feed. SMEs in particular do not have the resources or time to research potential downstream users of their waste products, and the Scottish Government could provide a platform to link these businesses together. Such a

[128] The Government Economic Growth Strategy, Scottish Government 2011

[129] Safeguarding Scotland's resources: blueprint for a more resource efficient and circular economy, Actions 1 to 6 - Scottish Government 2013

platform would provide businesses with better information around resource efficiency and would strengthen levels of materials innovation within this sector, both of which are key components of a more circular economy.

5.7 Forest and timber technologies

5.7.1 Overview

The forest and timber technologies sector incorporates planting, managing and harvesting of forests plus downstream activities such as sawmilling, pulp and paper production, and panel and board manufacturing. It consists of around 1,700 businesses, which employ around 50,000 people and contributes around £1 billion in GVA to the Scottish economy annually.[130]

Scottish Forest & Timber Technologies Advisory Group and Scottish Enterprise have identified four aims as part of a plan[131] intended to help the sector grow over the coming years:

- grow and communicate the forest and timber sector's contribution to Scotland, by increasing GVA by £1.1 billion by 2025
- grow the area of new productive forest planning by 10,000 hectares per annum
- grow the market share and value added of Scotland's forest products, by increasing supply chain efficiencies and product innovation
- grow the skills and capacity of the people in the sector, by putting an emphasis on personal and career development.

19 trade bodies and **23** distinct businesses were contacted in this sector during the course of this research, although additional businesses were asked to participate by some of the trade associations. Responses to the questions listed in the pro-forma (either through email, telephone or face-to-face interviews) were obtained from **6** individuals in this sector, working for 2 small sized companies (<50 employees) and 3 medium sized companies (<250 employees) and 1 large sized company (>250 employees). The participating businesses are positioned throughout the supply chain, from foresters and harvesters to millers and paper manufacturers to users of pulp and paper.

5.7.2 Reliance on raw materials

All of the businesses that participated in this research believe that raw materials are of vital importance to their business operations. Materials that are commonplace in this sector include virgin timber for products and for biomass feedstock, processed timber (e.g. plywood), water, and chemical starches and pigments.

[130] Scottish Keyfacts, Scottish Enterprise, 2013. Available at http://www.scottish-enterprise.com/knowledge-hub/articles/publication/scottish-key-facts

[131] Roots for future growth: A strategy for Scotland's forest and timber industries 2011-2014, Scottish Forest and Timber Technologies 2011

5.7.3 Raw material issues

The majority of businesses in this sector, 83% of those surveyed, believe that their business has been affected by materials supply issues in the last two years. However, less than half of these businesses are aware of a change in the level of risk to supply over this same period. This implies that whilst businesses are being affected by materials issues, their level of exposure to these issues, or the impact that these issues have on their business, has not changed in the recent past. It seems apparent that this sector has learned to cope with these issues, which are discussed below.

The raw materials issues faced by businesses in the forest and timber technologies sector depend largely on their position along the product supply chain. At the start of this chain are those responsible for the planting and management of forests and the supply of equipment and materials to that segment. These same businesses may also harvest those forests or contract the harvesting and logging activities out to specialist contractors. Felled timber must then be processed in a mill before it can be used in a downstream sector, usually manufacturing, construction or energy.

Businesses that operate in the upstream part of this sector, such as forest harvesters, cite **timber** as their most critical raw material. We believe that this is the most critical material for the whole sector, and it is discussed in the Spotlight section overleaf.

Businesses that are positioned at the products manufacturing part of the sector supply chain have other concerns besides their timber inputs. In addition to the virgin or recycled timber required to make their products, particle and chipboard manufacturers will also use **synthetic chemical resins** to bind the wood fibres together. Melamine, used to manufacture melamine faced chipboard, is a high cost raw material which most Scottish chipboard manufacturers will import. Melamine is subject to global supply constraints and price fluctuations, much like other input materials.

Manufacturers of paper pulp use vast volumes of **water** in their pulping operations. Water is a big concern for paper manufacturers that make their own pulp. However only one of the paper mills in Scotland produces its own pulp; the others choose to buy in treated wood pulp.[132] Water is of high importance to manufacturers of other wood-based products too, but arguably no more important than to manufacturers of products in other sectors that use other materials in similar processes and quantities.

The responses to these issues by companies in this sector range from diversifying products and/or material suppliers to moving the supply of materials in-house, thus reducing exposure to supplier reliability issues. Biotechnology solutions are possible in some instances, particularly where adhesives, solvents or pigments are used, but none of the businesses here indicated that they are currently using biomaterials.

Businesses in this sector largely believe that the current situation with regard to raw materials issues will not change much going forward, so these responses are crucial to the short-term success of operations.

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[132] An economic analysis of water use in the Scotland river basin district, SEPA 2005

Spotlight on… timber

Timber is a critical material to this and other sectors. Foresters, harvesters, millers and manufacturers rely heavily on this raw material to be the main input to their operations. The reliance on one material through the entire supply chain makes timber unique in this report: no other material considered here has the same level of significance across the supply chain. Furthermore, timber is used extensively outside of the forest and timber technologies sector; for example in the construction sector and as biofuel feedstock in the energy sector.

Focussing on businesses in this sector only, those at the start of the supply chain, such as forest harvesters and loggers, suggest that short-term risks are focussed primarily around market volatility. At present, the price of virgin timber is affected by increased demand from the bioenergy segment. Whilst this has the potential to inflate the value of timber, it creates significant financial burden for harvesters or millers that do not sell their timber as biofuel.

Timber logs coming out of a mill having had the bark stripped (left) and in storage (right).

Businesses further down the forest and timber technologies supply chain in Scotland include paper manufacturers. Whether these businesses create their own pulp or purchase treated pulp, they are all also affected by inflated market prices driven by the bioenergy segment. At present there is little that they can do to mitigate these price pressures. Businesses right across the supply chain believe that significant investment is required in the development of many more forests that are dedicated to the production of wood for biofuel.

The environmental impact of timber varies greatly according to the type of product in which it is used and whether or not virgin or recycled materials feature. For example, the cradle-to-paper mill global warming impact of producing 1 tonne of paper pulp from virgin wood sources is 2.87 tonnes CO_2e, compared to 0.60tonnes CO_2efor pulp from waste paper.[1]Pulp produced from waste paper is almost five times less environmentally harmful than its virgin fibre counterpart, despite the mechanical and chemical processes required to remove the ink from the waste paper. It is largely because of this de-inking process that waste paper can only be recycled around four or five times before the fibres degrade to a low quality that is not suitable for paper production.[2]

An aim of the paper manufacturing sector in Scotland that uses recycled content may be to improve the technology associated with the deinking process, to increase the number of lifecycles of their paper products. This would reduce the associated environmental impact and would lower the materials costs to the paper mills involved. However, the recycled content portion of the sector is small when compared to the portion that uses virgin materials, and so process improvements should focus on the latter.

[1] Lifecycle assessment of virgin and deinked pulp, Environ 2012

[2] Paper recycling information sheet, Waste Watch 2006

5.7.4 Other supply chain issues

Businesses in the forest and timber technologies sector generally consider raw material risks to be the most significant ones they face in their supply chain, with 83% stating that raw materials issues are either high or very high in comparison to other supply chain issues faced by the business.

A separate supply chain risk highlighted by some businesses in this sector includes the existence and spread of diseases through forests. A proportion of the forest feedstock is lost every year to pests and diseases. Whilst many of these diseases are manageable, invasive threats such as ash dieback can cause widespread forestry loss. Others cite the difficulty and cost associated with transporting heavy-duty goods, such as logged or milled timber, between remote parts of Scotland and shipping ports.

5.7.5 Wider context

The scope of most criticality studies excludes timber and other similar materials from analysis, and this sector is not particularly well characterised in this context. However, timber was highlighted by the SNIFFER study, due to its importance across several sectors (construction, biofuels and furniture), and in the BIS Foresight paper on manufacturing. Timber is also identified as a key theme by the Scottish Forest Strategy.[133]

Sawn softwood and pulpwood have also been included for analysis in the most recent EU study on critical raw material; this aligns with Scotland's main timber and paper industries.[134] However, due to diversity of supply, they are unlikely to be considered critical despite their importance to the economy. In addition, a significant amount of production occurs within the EU. However, there may be imbalances for different types and qualities of wood, though this has not been explored within this context. For example, hard and softwoods require different climates and growing conditions.

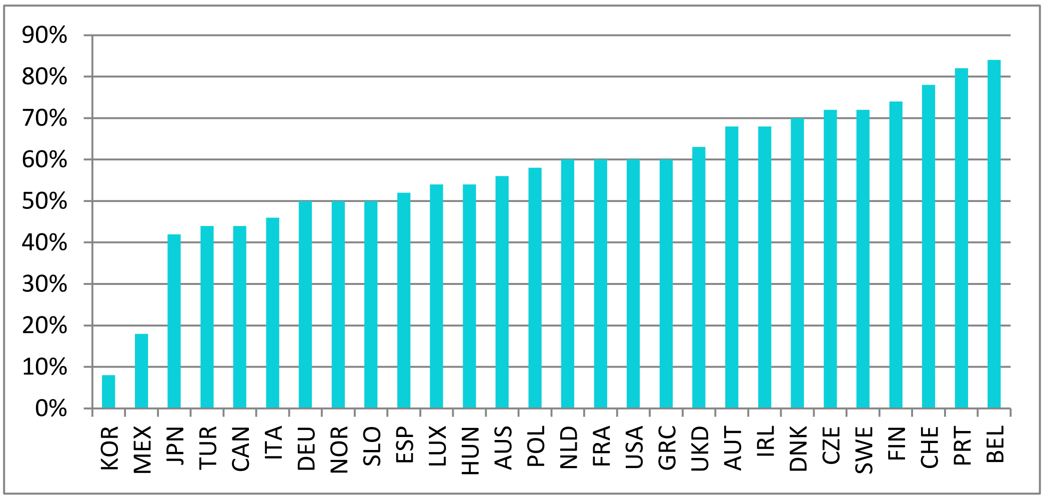
More broadly, concerns have been raised over factors such as intensity of resource use, and land use and application competition. The OECD is developing an indicator to measure the actual harvest of timber compared annual productive capacity (Figure 9). This addresses over-exploitation and degradation of resources, which are the main challenges to ensuring sustainable management of forest resources. The UK as a whole has a comparatively high score of over 60%. A similar methodology could be applied to help understand the intensity for Scottish timber resources.

In response to concerns over the sustainability of forestry two sustainable forestry schemes have been developed; Programme for the Endorsement of Forest Certification Schemes (PEFC) and the Forest Stewardship Council (FSC). In 2011, industry information indicated that only 15% of wood-producing forests (by area) in the world are certified as FSC or PEFC compliant (it should be noted that 15% of forest area does not necessarily represent 15% of wood). Increasing the quantity of certified wood could be a target for Scottish timber producers to ensure sustainability of supply for this material. Similarly sourcing of timber materials could focus on certified sources.

[133] The Scottish Forestry Strategy, Scottish Executive 2006

[134] Scotland's Forest Industries, Scottish Enterprise

Figure 9: Example of OECD indicator for intensity of forest use by country.



5.7.6 *Impact of materials issues on sector growth initiatives*

The material of by far the most importance to this sector, timber, has the potential to pose difficulties to the sector achieving its growth targets. As mentioned by this report, some companies involved in the early stages of the supply chain feel that sufficient land allocation is not being given to the growth of new timber. A key aim of the SFTT is to grow the area of new productive forest planting by the private sector by 10,000 hectares per annum.[135] According to industry, competition for the timber harvested from these new forests from the expanding bioenergy segment may require the need to increase this allocation or designate certain forests for bioenergy use only. However, better statistics on this would provide a clearer viewpoint. Industry also believes that the issue of securing a reliable supply of domestic timber for different purposes (e.g. for paper, for construction, for bioenergy) is the most important issue faced by this sector.

This report has not identified any other materials that will impact unduly on the ambitions of the sector or wider economy to achieve the forward-looking policy options mentioned throughout this report. For example, waste is not noted as an issue in this sector and the resources that do exist are used efficiently, if not always for the correct purpose according to some industry participants (e.g. virgin timber for biofuel instead of construction).

5.7.7 *Suggested actions from industry*

The participants in this research proposed a number of ways in which the forest and timber technologies sector could be supported by the Scottish Government. These actions include:

- **Establish forests for dedicated purposes**. Businesses right across the sector agree that forests dedicated to producing wood for bioenergy is a sensible strategy. It would reduce the amount of virgin timber that goes into the bioenergy segment, and would help to stabilise both the timber and biofuel markets. The Scottish Forest & Timber

[135] Roots for future growth: A strategy for Scotland's forest and timber industries 2011-2014, Scottish Forest and Timber Technologies 2011

Technologies Advisory Group and Scottish Enterprise aim to increase the total growth of productive new forest by 10,000 hectares per annum. A proportion of this should be designated as having a specific purpose.

- **Improve internal logistics**. For businesses that have to transport bulk timber or timber products within and outside of Scotland, logistics fees comprise a substantial part of their financial outlay. Whilst these businesses do not expect financial aid, some would prefer to transport these materials via rail rather than road, but suggest that this is not possible at present. Others who have to ship bulk materials to and from ports in southern England seek improvements in port facilities in Scotland. This action fits with the ambition of the Scottish Government to boost investment in Scotland's infrastructure by working with Scottish Futures Trust, including maximising investment from the Rail Regulatory Asset Base.[136]

5.8 Life and chemical sciences

5.8.1 Overview

Scotland's life science sector includes over 650 organisations and businesses which employ over 32,000 people. There is a significant international presence, with leading international businesses choosing Scotland as a base for part of their global operations. The primary focus is on human healthcare, which accounts for 70% of all life science activity in Scotland. The chemical science sector is even bigger, employing around 70,000 people in Scotland, with exports of £3.7 billion and a turnover of around £9 billion. This sector as a whole, which includes world-leading academic research centres, is crucial to Scotland's economy.[137]

In terms of policy setting, the sector is split into two distinct parts: life sciences and chemical sciences. Life Sciences Scotland has identified a target of doubling sector turnover to £6.2 billion by 2020[138], and the following actions that will help achieve this:

- create an attractive, dynamic environment to retain businesses in Scotland
- create a more robust business base out of the broadly based population of largely small players
- strengthen the ability to attract key skills and management talent.

Chemical Sciences Scotland has also identified a set of actions[139] that they believe will help ensure that a vibrant and competitive chemicals industry exists in Scotland in 20 years' time, which include:

- to achieve a balanced portfolio of chemical businesses in Scotland
- to sustain a critical mass of chemicals businesses in Scotland
- to explore and exploit opportunities between industry sectors
- to create competitive advantage through the ease of doing business in Scotland
- to attract and retain talent

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[136] The Government Economic Growth Strategy, Scottish Government 2011

[137] Scottish Keyfacts, Scottish Enterprise 2013. Available at http://www.scottish-enterprise.com/knowledge-hub/articles/publication/scottish-key-facts

[138] Scottish Life Sciences Strategy: 2020 vision, Life Sciences Scotland 2011

[139] The Formula for Success: A strategic plan for the Chemical Sciences in Scotland, Chemical Sciences Scotland 2013

- to improve the perception of the industry.

11 trade bodies and **38** distinct businesses were contacted in the life and chemical sciences sector during the course of this research, although additional businesses were asked to participate by some of the trade associations. Responses to the questions listed in the pro-forma (either through email, telephone or face-to-face interviews) were obtained from **6** individuals in this sector, working for 1 small sized company (<50 employees) and 5 medium sized companies (<250 employees). These included three from the life sciences and three from the chemical sciences (all chemical manufacturers).

5.8.2 Reliance on raw materials

The life and chemical sciences sub-sectors are each quite diverse sectors within Scotland, representing a wide range of businesses. Therefore the materials identified for each can be considered exemplars as they may be quite specific to a given company or process.

The life and chemicals sciences sector as a whole relies heavily on raw materials, with 100% of the participants in this research believing that raw materials are either very important or vital to their business operations.

Materials identified as important to the life science sub-sector include **blood plasma** and **bovine serum** used for medical developments. Also identified was a selection of **high purity chemicals** required for production, and materials such as **plastics** used in manufacturing. However, as stated above, individual organisations are likely to have very different needs.

Materials identified as important to the chemical science sub-sector include a variety of **bulk chemicals** such as methanol, acetone, lactone diol, hydrochloric acid, sodium hydroxide, and feedstocks such as **propylene**, **aluminium** and **waste biomass**. Discussions with industry representatives indicated that the diverse nature of the chemical industry in Scotland means that many of the input raw materials will be associated with only a few companies, though some common substances may be required.

Therefore, for both sub-sectors, it was not possible to pick out materials which represented the full sector, and the illustrative examples given are influenced by the types of company that responded. However, this also leads to some unique problems in the sector.

5.8.3 Raw material issues

All the life and chemical science businesses that participated in this research stated that they have been affected by issues relating to material supply in the last two years, but most have not noticed a change to the level of threat or risk to supply of those materials in that time.

The largest issues were often associated with obtaining low volume materials. Several companies reported that obtaining materials of the correct quality and high purity was an issue. This was partly linked to the specialist needs of the sector (e.g. materials must meet certain standards for medical use), and the small volumes of products required. Even where a bulk material is used, the usual sources may not be suitable due to the requirements of the industry. This means that the supply chains for some of these materials are not as flexible as they are for bulk substances. These issues were manifested in several ways, notably: rising costs, delays in manufacture, and longer lead times for production.

Spotlight on… human blood and plasma

Donated human blood is used for a number of purposes, including in life-saving transfusions and as testing material in medical equipment manufacture. Blood consists of plasma (the liquid part of the blood), red cells (RBCs, which oxygenate the blood), white cells (which help to fight infection) and platelets (which aid clotting); any of these can be donated, depending on the wishes of the donor and the collection requirements of the blood type being donated.

From the perspective of companies that manufacture medical equipment for use in blood grouping, donation, disease testing and transfusion, human blood is an absolute necessity. Blood plasma, red and white cells and platelets are all raw materials for manufacturers with operations in Scotland. The main supplier of these materials to manufacturers has typically been the Scottish National Blood Transfusion Service (SNBTS), through which all blood donations are made in Scotland. The images below are of packets of RBCs (not for clinical use) supplied by SNBTS, and cells being put to use in testing procedures.

A certain proportion of blood sourced from foreign countries has always been required in order to test the manufactured equipment with different blood types from different geographies. This reflects the need to manufacture diagnostic equipment that works for a global population, and which can be developed for and sold into specific regions. However, fluctuating levels of supply from the SNBTS, along with questions over whether the materials should be used for testing of products that are then sold on to international OEMs or for NHS-bound products only, has seen manufacturers switch to overseas suppliers.

Blood (or its constituent parts) sourced from overseas poses a different set of challenges to that sourced from within the UK, such as the cost of identifying suitable overseas suppliers, validating credentials, and assessing the quality of the blood. A manufacturer that we spoke to during this research suggested that foreign blood is ca.80% more expensive (including logistics costs) to source than British blood. Another key concern is the shelf-life of RBCs (~40 days) and platelets (~7 days), and the fact that a blood-based material needs to be kept refrigerated from the day of bleed until it is used. Supply chain interruptions to the delivery of blood from Asia, for example, can render entire shipments of this raw material unusable.

The longer term strategy for managing this raw material has been for businesses to diversify suppliers and improve the accuracy of stock forecasting. However, companies believe that failure to secure a reliable and cost-effective supply of blood, particularly the short-life aspects, may result in an inability to manufacture the associated products. Relevant Scottish companies would like to see development of initiatives to support the provision of blood-materials from transfusion services within Scotland and the rest of the UK. These companies also believe that customs duty on imported blood-materials should be reduced until private companies can source most of these materials from within the UK.

Where standard bulk materials could be used the issues appeared to be less acute, though some price rises had been seen.

Companies had used several approaches to mitigate these issues and possible risks. Several had sought alternative suppliers, often trying to find sources within Scotland or the UK. Some were in the process of developing internal production to provide greater control over supply. This was not possible in most circumstances, however, and other approaches included improving stock management (e.g. holding more stock and more regular ordering) had been taken. Many stated they had good relationships with suppliers and were able to develop working arrangements and supply agreements for the benefit of both parties. Others had simply had to pass on the costs to their customers. This range of approaches reflects the nature of the industry, and it is unlikely that there is a 'one size fits all' solution.

This industry's reliance on synthetic chemicals with very specific properties means that, in general, biotech solutions are not appropriate. Businesses communicated this view in our discussions with them.

5.8.4 Other supply chain issues

Most businesses (80%) identified that raw material risks were amongst the most important, compared to other supply chain risks. Several other supply chain issues were highlighted by the organisations interviewed.

Most companies surveyed believed there were possible issues relating to the size of their specific market. This often means that there were limited options for changing up- and down-stream supply chain actors. Some saw this as an opportunity, others as a threat.

Several identified that the costs of meeting regulations linked to their activities (e.g. waste disposal and manufacturing) posed a risk to their businesses. It was stated that this was particularly an issue for smaller companies. This was also true of changes in regulation which could rapidly and unexpectedly change upstream and downstream markets.

Logistics was identified as another issue for businesses, with transports costs and complexities in transporting certain materials identified as particular problems. Equally, this will be tied to regulations to ensure the safe transport of materials.

Other operational issues identified included lack of options for expansion. This was partly linked to the cost and availability of facilities to expand business, and the availability of labour with the correct specialist biochemical skills and expertise (though this was not a view shared more widely across the sector).

One industry representative stated that upstream raw materials risks may be present, but companies may not be directly aware of them. For instance, chlorine supply in the UK relies on a single site, with import from other countries not viable. The changing way in which energy is produced may also influence the availability of feedstocks. An example given was the shift to shale gas from oil, which may influence the availability of certain hydrocarbon feedstocks in the future (e.g. C4 compounds such as butadiene) due to the way in which these are produced.

5.8.5 Wider context

The life and chemical sciences can be seen as underpinning activities in many of the other sectors. Therefore the diversity of businesses, technologies and processes means that responses from industry are often quite specific by material and by process. Therefore the responses do not align well with high level analyses of CRMs that focus on bulk materials. In addition, not all materials are in scope for other studies; for instance, plastics and high purity petrochemical derived substances. It is also notable that inputs into the biotech and life sciences are often omitted by default due to the scope of these studies which do not include biotic or petrochemical inputs; therefore they are particularly poorly represented.

However, analysis of materials highlighted in other studies identifies several groups of materials which have links to this sector, which can be viewed as exemplars.

Catalysts and pigments are commonly used across this sector. Catalysts are used in small quantities to improve the efficiency of chemical reactions, and are essential for many industrial processes to be viable. Catalysts often rely on critical raw materials for their activity; for instance **cobalt** and **nickel** in bulk and fine chemical manufacture, almost all of the six **PGMs** are used in chemical production, for instance in plastics manufacture, and **germanium** in plastics production. Pigments are used for colouring paints, plastics, printer inks, cosmetics and other materials, and use a wide variety of different metals, for instance **antimony** and **cobalt**. However, in general these are typically used in low quantities compared to other applications; therefore issues are more evident in other sectors.

Recovery is common in certain situations. In industrial processes catalysts will be collected where economic, and regenerated. However, for some catalytic processes and for pigments the material is incorporated into the final product in very low concentrations, and this dispersion makes recovery impossible. Responses generally seek to substitute catalysts or pigments with cheaper alternatives. However, this is not a direct result of criticality: it is driven by on-going research to increase performance and reduce costs. Therefore, whilst substitution of a metal is considered, it is generally of secondary importance to performance, as a small drop in efficiency is likely to have a large impact on the overall process.

Antimony is often included in criticality studies due to its importance as a flame retardant synergist in plastics in the form of antimony trioxide. This application is linked to the chemical using industries. In this use it acts to improve the performance of certain flame retardants, including brominated substances, reducing the amount of these other materials required to achieve the desired standard. These plastics are required in many applications, including aircraft and electronics (see also spotlight in manufacturing sector discussion). In this use antimony is dispersed and difficult to recover economically. It is believed that most ends up in household waste, and therefore is essentially lost when a plastic is recycled or disposed of.[140] Concerns have arisen over supply, as China supplies over 85% of the global market, and this is heavily reliant on one mine.[141] In addition, prices have fluctuated recently due to natural disasters in China and a clampdown on illegal exports.

[140] Antimony and Antimony Compounds, Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH Verlag GmbH & Co. KGaA 2006

[141] Annex V – Critical Raw Materials for the EU, EC 2010

Specific responses appear to be focussed on diversification of supply, using less material and substitution in certain applications.[142] However, changing regulations over the use of flame retardants, particularly brominated flame retardants, could have an impact on its demand as its use is tied to these applications. These flame retardants are increasingly coming under close scrutiny from a health and environmental standpoint, and are facing stricter restrictions.[143,144] This may dictate the local demand for this material in the future.

Some feedstock substances are identified within these studies. **Palm oil** was highlighted by the SNIFFER study, linked to the cosmetics industry (see Section 0). One industrial material that has been highlighted at an EU level is **fluorspar**. It has two main applications; metal processing and production of hydrofluoric acid.[145] In this second use it is relied on by the bulk, fine and pharmaceutical chemicals for materials such as fluorinated plastics and refrigerant gases, and no substitute exists. As these are downstream uses businesses may not identify the link with the mineral. As with other materials, the majority of fluorspar is produced in China, though reserves exist globally. As recycling from its major uses is difficult[146], responses to supply issues are likely limited to increasing processing efficiency to reduce losses, or to increase/diversify primary supply. In some cases alternative downstream materials exist, however these may require compromises in performance (e.g. refrigerant gases). International responses are generally linked to overall strategy. Mining of fluorspar was also restarted in 2012 in deposits in Derbyshire.[147] UK consumption of fluorspar is estimated 43,000 tonnes in 2009, though this appears to have reduced significantly in recent years along with production.[148,149]

Fluorspar also highlights issues over **grades of materials**, as high purity acid grade is required as the source for most of the chemical industry. A better understanding of material grades could assist understanding in this area; similarly other materials such as steel, graphite, water purity and the high purity chemicals identified above. More specialised grades of material may experience different influences that a bulk or lower quality grade. This issue is not widely addressed in studies or responses.

5.8.6 Impact of materials issues on sector growth initiatives

Most of the strategic aims of both Life Sciences Scotland and Chemical Sciences Scotland do not involve materials or resource efficiency, but rather focus on ensuring a balanced portfolio of business types and attracting and ensuring that talent is retained. It is unlikely that the material issues highlighted in this report will impact unduly on these sector-specific ambitions.

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142 Mineral Commodity Summaries: Antimony; US Geological Survey 2013

143 Fire Retardant Technologies: safe products with optimised environmental hazard and risk performance, Defra 2010

144 http://echa.europa.eu/en/view-article/-/journal_content/800e9ce8-253b-415e-8972-262879ddf8ce

145 Annex V – Critical Raw Materials for the EU, EC 2010

146 Study into the feasibility of protecting and recovering critical raw materials through infrastructure development in SE England, EPOW 2011

147 http://www.britishfluorspar.com/eng/about-us/

148 Fluorspar, British Geological Survey 2011

149 UK Minerals Yearbook, BGS 2012

The use of critical materials in parts of this sector, such as in the development of catalysts, may affect the aim of the Scottish Government to create circular economies within and across sectors. As described, these materials suffer supply issues and have challenging end of life (e.g. reuse, recycling) issues.

5.8.7 Suggested actions from industry

The participants in this research proposed a number of ways in which the life and chemical sciences sector could be supported by the Scottish Government. These actions include:

- **Invest in industry groups to aid information sharing and sector-wide collaboration.** The diversity of the industry means that direct competition was less of an issue and all wanted to cut costs. The Scottish Government could provide a platform to link these businesses together. Such a platform would provide businesses with better information around resource efficiency and would strengthen levels of materials innovation within this sector, both of which are key components of a more circular economy.
- **Provide initiatives to support the sourcing and production of materials in Scotland and the UK.** Supply chains that are internal to Scotland could be constructed to take the risk out of supplying certain types of specialty materials that are used by this sector. Whilst some of these naturally-occurring materials cannot be sourced from within Scotland or the rest of the UK, others, such as high purity chemicals that are currently purchased primarily from India and China, could be internalised.
- **Improve logistics routes for getting materials into and out of Scotland**, through improved rail and road infrastructure. This action fits with the ambition of the Scottish Government to boost investment in Scotland’s infrastructure by working with Scottish Futures Trust, including maximising investment from the Rail Regulatory Asset Base.[150]

5.9 Manufacturing

5.9.1 Overview

The category ‘manufacturing’ has been used to capture other businesses that produced products that did not fall into other categories. Therefore it is difficult to characterise in the same way as the other sectors, but can be considered as underpinning many of the other sectors within and beyond this study. Companies included here produce goods for the automotive industry, packaging, consumer goods, mechanical equipment, and various products and services that feed into the other sectors.

The manufacturing sector featured in this report includes a wide range of potential business types, namely those that are involved in manufacturing of products that are not clearly aligned with any of the other sectors featured here. As such, there are no sector specific growth aims or actions to be discussed. However, the Scottish Government has established the aim of creating four Enterprise Areas, one of which will be dedicated to the manufacture of low carbon technologies.

[150] The Government Economic Growth Strategy, Scottish Government 2011

10 trade bodies and **50** distinct businesses in the manufacturing sector were contacted during the course of this research, although additional businesses were asked to participate by some of the trade associations. Responses to the questions listed in the pro-forma (either through email, telephone or face-to-face interviews) were obtained from **9** individuals in this sector, working for 2 small sized companies (<50 employees) and 7 medium sized companies (<250 employees). These represented a spread of small and medium sized businesses, with the majority of production occurring within Scotland.

5.9.2 Reliance on raw materials

Raw materials were found to be of vital importance to almost all of the companies (89%) surveyed. Only one stated they were lower than vital, probably due to the way raw material inputs were defined for its particular business.

The materials identified as important to the companies surveyed vary widely with the businesses included in this sector. Materials identified as important included basic inputs such as water and air, which are required for many industrial processes but are crucial for some. Synthetic polymers (including plastics and resins – see Spotlight section) were an area of key importance to many businesses, with a wide variety identified including nylon, viscose rayon, polyester, and polyethylene, required for a variety of products. Other materials identified were steel, paper, industrial minerals, fine chemicals, and fish and soya protein.

It should be noted that other manufacturing businesses are likely to have different needs, and the materials identified represent a selection of materials raised by the survey. Whilst this is true of many sectors, it is likely to be more evident within the manufacturing sector due to wider diversity of companies included.

5.9.3 Raw material issues

Considering the wide range of business types that are included in the manufacturing sector in Scotland, it is surprising that only a small proportion of those interviewed (33%) have experienced material supply issues within the last two years. Furthermore, only around 10% of these businesses believe that the threat or risk to their materials supply has changed in this timeframe. This may mean that these businesses are sheltered from such problems.

The wide range of business types that have responded led to a diverse set of concerns, related to the materials identified above. Rather than focussing on highly specific issues, consistent cross cutting themes have been recognised and are discussed below.

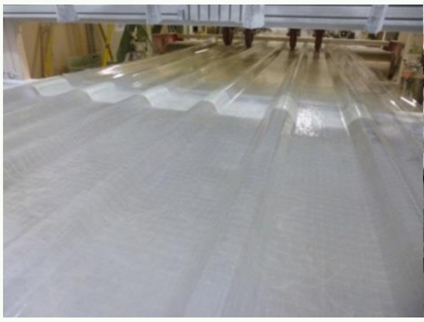
Responses noted that the supply had become unreliable for some materials, including **steel**, **glass fibre**, **polymer materials**, **fish and soya protein**, and (waste) **paper**. In general, this was linked to increasing competition from other countries, combined with inelastic supply or interruptions of feedstocks. In some cases this led to increases in price or supply disruptions such as increased lead times. However, in the case of bulk materials such as metals and plastics some believed this was necessary to ensure a consistent supply of materials. For other materials, for instance plastics that require a specific formulation, bulk purchasing was not an option, with companies having to take on the additional costs.

Spotlight on… thermosetting polymer resins

Rigid plastics are typically either thermoset or injection moulded, the former being less robust than the latter, but also cheaper and more common. Thermoset polymer plastics are typically formed using a liquid polymer resin; powder resins can be used but are far less common. Some end-uses of thermoset polymer resins include: polyester fibreglass used in industrial applications; polyurethanes used as shoe soles, flooring and synthetic fibres; melamine resin used as worktop surfaces; polyimides used in printed circuit boards; and epoxy resin used in reinforced plastics. Common forms of thermosetting polymer resins, such as epoxy, are widely available and are sold at relatively stable prices. However, there are many variants that have widespread end-uses but suffer considerable supply chain issues. One such variant is fire-retardant polyester (FRP) resin.

Some end-uses of thermoset polyester resins require that they have fire retardant properties (in commercial and domestic building construction projects, trains, airplanes etc.). Most thermoset plastics for spaces used or inhabited by humans are required to be fire retardant.[1] Supply of FRP resin is limited to one or two UK distributors, who in turn source from one main supplier. To avoid the potential risk of supplier bottlenecks, the material is largely sourced from Asia. That brings separate issues, including large shipping fees for a route that includes ports in south-east England and northern Scotland and road transport to site. The lead times associated with delivery from an overseas supplier (in this case 2-3 months) mean that businesses using those materials need to keep high stock levels, and plan orders ahead.

Manufacturing plastic products yields some waste, most of which currently goes direct to landfill. The images show a sheet of thermoset fire retardant plastic on the production line and the unavoidable waste that results from cutting and shaping it to the required size.



Theoretical options exist for minimising the amount of end of life waste from polymer plastics. For example, a proportion of the dust that is produced when the plastic is cut and shaped could be collected and mixed with the liquid resin used to produce a subsequent batch. On a national scale, such dust capture and re-use may help manufacturers that use thermoset plastics dramatically reduce waste levels. Before this could happen, there would need to be research on the maximum proportion of dust to resin that would allow the resulting plastic to maintain its fire retardant properties. SME manufacturing businesses do not have the time or budget to conduct this kind of scientific research, but it could be funded by the Scottish Government through a public competition call, or managed by Interface, and expanded to include different plastics with different desirable properties. It is not known, at present, the extent to which this would help to resolve this waste and supply issue.

[1] Fire retardant polyester resins are totally distinct from the chemical hexabromocyclododecane (HBCD), a common flame retardant in insulation, textiles and electronics, which is to be banned in the EU from 2015.

None of the businesses from this sector foresees a change in the current materials supply situation, meaning that these outlined issues, from their perspective, will not change in the short-term.

In response to these issues, many businesses have been able to fully or partially shift to an alternative supplier. Others have signed forward purchase agreements to control the price and supply of materials of particular concern. Other strategies have included identifying alternative materials or seeking to develop local production.

The banning of certain chemicals has also influenced certain businesses, for instance certain fluorinated hydrocarbons for environmental reasons. At present, alternatives for these substances are limited. Generally, substitution of synthetic materials - such as polymer resins - with biomaterial alternatives is currently not feasible, for reasons of function and cost. However, several businesses in this sector indicated a willingness to try such alternatives should their reliability and function be tested beforehand.

5.9.4 Other supply chain issues

In relation to other risks, raw materials were generally considered to be high or very high (72%), though there is some variation across the sector. This disparity did not appear to relate to a group of materials or type of business, but was perhaps linked to the particular circumstances of a business.

Few other consistent threats were identified within this sector, likely due to the wide range of business types, with utilities prices (energy and water) being the most significant.

5.9.5 Wider context

The manufacturing sector incorporates a wide range of businesses and activities, therefore - as with the life and chemical sector - a large range of materials can be identified within the wider literature. This is somewhat reflected in the responses received from industry, which identified a variety of materials, many of them beyond the scope of most criticality analyses.

For the purposes of this analysis, three groups of materials have been highlighted which have specific uses within this sector: structural materials, mechanical equipment and automotive components.

Structural materials, such as **steel** and **magnesium** (used in aluminium alloys) have been widely cited in other sectors, and broader discussions can be found in Sections 5.3 and 5.4.

Cemented carbide tooling is highlighted by several studies, due to the content of **tungsten** and **cobalt**. Cemented carbides are extremely hard and wear resistant composite materials, and these properties mean they are used extensively in machining metals. This application uses around 14% of the world's cobalt supply and 60% of the world's tungsten supply.[151] Concerns have been raised over the supply of cobalt, as over of half of global production originates in the Democratic Republic of the Congo. The majority of tungsten is produced in China. Recycling of these materials is possible and does take place. However as the material is used in small quantities due to its cost, collection of cemented carbides is not efficient,

[151] Annex V – Critical Raw Materials for the EU, EC 2010

and it has been suggested that it could be improved to increase recycling rates of these materials.[152] Other responses are linked to general approaches taken, though conflict free/traceability schemes have been proposed for cobalt.

Metals used in automotive components feature quite strongly in many studies, particularly **antimony** and **lead** used in automotive batteries (though here recycling is extensive and effective). The largest concerns have been highlighted for the Platinum Group Metals (PGMs) **platinum**, **palladium** and **rhodium**, which are irreplaceable in catalytic converters to achieve environmental performance. This is the major use for these PGMs. Concerns over PGMs are generally linked to concentration of supply, mainly from South Africa (61%) and Russia (27%), and their irreplaceability in most applications. All the PGMs are of high value, comparable to other precious metals such as gold and silver. Recycling of PGMs from auto catalysts is relatively well established, and estimated to reach rates of between 50%-60%.[153] In industrial uses rates are close to 90%.[154] The barrier to increasing this is thought to be with collection and end of life treatment of vehicles rather than technology.[152] The value of these materials means that substitute materials have been long been sought; however, they remain irreplaceable in this and other industrial applications. PGMs are of strategic important to many countries, and the USA, Russia and South Korea are known to maintain stockpiles, though they regularly sell these off.

5.9.6 Impact of materials issues on sector growth initiatives

The key aim of the Scottish Government is for sustainable economic growth and manufacturing is obviously key to realising this aim. It is unlikely that the material issues discussed here will affect the realisation of this plan, or its long-term success.

A bigger concern is that the waste produced by this sector, which includes bales of thermoset plastic off-cuts (see Spotlight), will continue to grow in quantity. Thermoset plastic waste is notoriously difficult to deal with at end-of-life and, whilst businesses in this sector are doing all they can to avoid sending this waste to landfill, they have few alternatives at present. Scottish Enterprise is tackling this issue, with support from Zero Waste Scotland, having launched the Scottish Recycling Fund to encourage investment in recycling and reprocessing of materials.[155]

5.9.7 Suggested actions from industry

Several high level policy suggestions related to raw materials were made, which could support the industry:

- **Develop cross-sector dialogue.** Many of the issues faced by these businesses are similar to those found in other sectors. For instance, by bringing together cross-sector groups from all stages of supply chains to discuss common problems, solutions and best practice, there could be a foundation for further actions. The Scottish Government

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[152] Study into the feasibility of protecting and recovering critical raw materials through infrastructure development in SE England, EPOW 2011

[153] A Report of the Working Group on the Global Metal Flows to the International Resource Panel, UNEP 2011

[154] Recycling the Platinum Group Metals: A European Perspective, Hagelüken, C., Platinum Metals Review, 2012, 56, (1), 29–35

[155] http://www.zerowastescotland.org.uk/content/scottish-recycling-fund

could provide a platform to link sectors together. Such a platform would provide businesses with better information around resource efficiency and would strengthen levels of materials innovation within this sector, both of which are key components of a more circular economy.

- **Improve recovery and recycling of waste materials.** Some industries rely on waste streams as input (e.g. paper). These need to meet certain quality standards. Identifying opportunities and developing better infrastructure for handling waste materials without a reducing their quality would benefit some industries and potentially lead to environmental benefits. Such actions are already ongoing under the Zero Waste Plan and ZWS activities, which aligns with The Scottish Government's ambition of a 70% recycling rate for all waste arising in Scotland by 2025.[156]
- **Support R&D into more efficient use of raw materials.** Improving the efficiency of use and recovery of raw materials would help reduce demand, and also reduce costs for businesses. Supporting R&D with this purpose could enable improvements in this area. This action aligns with the Scottish Government's ambition of making businesses more resource efficient.[157]

5.10 Technology and engineering

5.10.1 Overview

The technology and engineering sector is comprised of a wide range of business, including those involved in rugged engineering, data capture, real world interfaces and informatics. The sector is home to nearly 10,000 companies in Scotland, employing around 150,000 people. It has an annual turnover of around £24.5 billion, including exports of £6.5 billion, and is responsible for contributing £10.4 billion of GVA to the Scottish economy.[158]

The Scottish Technology Advisory Group has identified several challenges which it plans to address over the coming years[159], including:

- ensuring that a constant stream of new talent is brought into the sector
- building a brand which reflects the capabilities of the sector
- focusing on international sales as a driver for financial growth
- developing close links between businesses across the supply chain in order to respond to market demands
- promoting collaboration between academia and industry to maximise on-going R&D and resources
- investing in R&D and the commercialisation of ideas, particularly from Scottish universities and research centres.

8 trade bodies and **56** distinct businesses in this sector were contacted during the course of this research, although additional businesses were asked to participate by some of the trade

[156] Scotland's zero waste plan, Scottish Government 2010

[157] Safeguarding Scotland's resources: blueprint for a more resource efficient and circular economy, Action 1 - Scottish Government 2013

[158] Scottish Keyfacts, Scottish Enterprise 2013. Available at http://www.scottish-enterprise.com/knowledge-hub/articles/publication/scottish-key-facts

[159] A framework for action for the technology and engineering sector in Scotland, Technology Advisory Group 2013

associations. Responses to the questions listed in the pro-forma (through email, telephone or face-to-face interviews) were obtained from **7** individuals in this sector, working for 2 small sized companies (<50 employees), 3 medium sized companies (<250 employees) and 2 large sized companies (>250 employees), across a diverse range of business functions.

5.10.2 Reliance on raw materials

Most of the survey participants (86%) identified that raw materials were either vital or very important to their business. M**etals**, **plastics**, **chemicals** inputs and **water** were identified as important materials, though this depended on the particular business surveyed.

Featured metals include steel, aluminium, zinc, copper (see Spotlight section), high purity silicon metal, rare earth elements, as well as some speciality metals. Various plastics were identified including polyethylene, ethylene vinyl acetate, and nylon. In some cases these required specific additives such as fire retardants. Various chemical inputs were identified; for example, acids, cleaning fluids for electronics, and gases. Ultrapure substances were required for certain applications.

5.10.3 Raw material issues

Correlating with the low proportion of businesses in this sector that view raw materials as important to their operations, a low proportion reports being exposed to material supply issues in the last two years. The businesses in this sector that have not been affected by supply issues have ferrous metals (e.g. steel) as their main materials inputs, whilst those that have been affected by supply issues rely on a range of other materials, including **non-ferrous metals** (e.g. copper), **industry-grade and high purity chemicals** and **polymer resins**.

Several responders noted that in general a consolidation of suppliers had taken place, leading to a smaller number of larger suppliers. This had led to difficulties with influencing these producers to provide the desired input material.

Many noted the lack of indigenous supply of raw materials in Scotland, the UK or the EU, feeling that this had led to a magnification of certain issues such as increasing lead times, reducing availability and making the timing of ordering more problematic. For some materials, such as chemical substances, obtaining the correct specification had proved difficult due to the small quantities required.

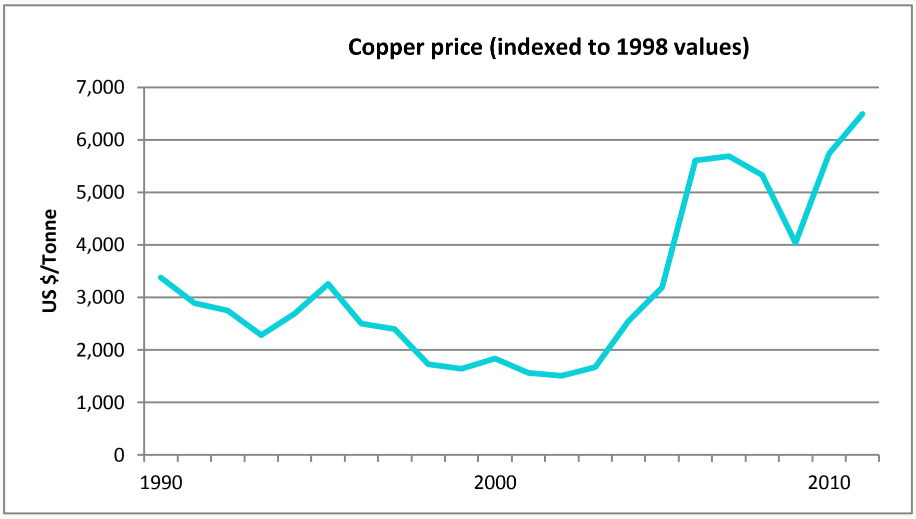
The most common strategy that businesses had used to address these issues was through diversification of sourcing of raw materials. Others had begun to improve recovery of scrap and manufacturing waste to reduce demand for raw materials. In the worst cases the businesses had to reduce production capacity due to restrictions in supply. One company had an in-house team in place to identify and discuss business risks more generally. As part of this it had identified raw materials risks, and was developing a strategy for the business.

Spotlight on… copper

Copper is a commonly used metal across many sectors, and is fundamental to many technologies. Its combination of high electrical and thermal conductivity, malleability, and corrosion resistance make it highly adaptable metal. Within the scope of this study it has particular importance to the technology and engineering, energy, and construction sectors. However, many of its uses underpin activities in other sectors. Within the technology and engineering sector its most important use is in electric cabling and electronic components: therefore it is of fundamental importance to this industry.

Around 16million tonnes of copper are mined globally every year. Mining takes place across the globe, with Chile, Peru and China being the largest producing countries. There is now no mining or production in Scotland or the UK (historically some used to take place in Cornwall). In addition to primary supply, copper has a high recycling rate compared to other materials, partly due to its value, and it is estimated that the global end-of-life recycling rate for copper is around 45%, contributing to a large proportion of total supply.[1]

Concerns were raised by stakeholders across several sectors, particularly the technology and engineering sector, that the price suppliers were charging for copper had increased substantially recently. This is confirmed by looking at the changes in copper price over the past 20 years, with prices rising considerably over the past ten years, dropping only as a result of the global financial crisis in 2008.These price increases are generally attributed to the growth in demand from Asian countries, where large-scale infrastructure projects have led to large increases in demand. The global nature and scale of the copper market means that the impact of these costs is felt across all sectors.



Within Scotland, recycling of copper takes the form of collection and sorting through scrap, with copper and copper-containing products exported for metal recovery elsewhere. Therefore this does not directly impact on the copper supply in Scotland. However, copper recycling has significant environmental benefits, with energy consumption savings estimated at 85% compared to virgin production.

[1] Copper Recycling, International Copper Association 2013

5.10.4 Wider context

Broadly the materials identified as important by industry agree with findings from other studies if differences in scope are considered; speciality metals are highlighted, as are steel-containing alloying agents. This reflects the complexity of modern electronics and engineering companies, and the diversity of this industry. However, materials identified as having issues differed somewhat to those classified as critical in other studies. For instance, polymer resins and high purity chemicals were of most concern. These are generally outside the consideration of other studies.

Other studies link a broad range of critical raw materials to this sector, though these are mainly speciality metals used in electronics. Some materials highlighted include **beryllium**, **PGMs**, **tin** and **tantalum**, which are commonly used in electronic components and printed circuit boards across the industry (e.g. beryllium is used as a copper alloy in connectors, and tin is used in solders), as well as materials used for semiconductors. These are typically low-volume metals, and sourced from only a few countries, leading to concerns over supply.

In new low-energy lighting such as LEDs, **gallium**, **germanium** and **REEs** have been highlighted as critical metals by the European Commission in relation to the implementation of low carbon technologies.[160] **Indium** is also a very commonly identified critical metal due to its irreplaceability in flat panel displays, where it forms part of the indium tin oxide (ITO) transparent conducting layer (TCL). High purity **cobalt**, **lithium** and **graphite** are required for lithium-ion batteries, which are used ubiquitously across electronics and in electric vehicles. **REE**-based magnets (see Section 0 for discussion) are used in small quantities for applications such as speakers, headphones, hard disk drives and other motors.

Interest in this area has generally focussed on electronics and electrical items. Recycling of industrial waste is generally efficient, but by contrast separation from post-consumer waste is challenging as these metals are found in low concentrations within products, and require special separation. Recovery of these metals from post-consumer WEEE has received considerable attention. However, the following aspects are recognised to be important for the implementation of a successful end-of-life recycling system for these metals:

- database of product sales, inventories and expected waste
- product information of components
- collection and sorting logistics
- material flow tracking
- pre-processing technologies
- design: for disassembly, reuse and recycling
- pilot plants and scale-up of recycling technologies.

WRAP recently commissioned a study to understand flows in of critical raw materials in EEE products, and to provide information for waste processors.[161] Within the EU several projects have researched the recovery of metals from lamps and flat screen displays.[162] While this is

[160] Critical Metals in Low-Carbon Energy Technologies, EU JRC 2013 & 2011

[161] Mapping consumption and waste of raw materials in electrical products in the UK, WRAP 2013

[162] For examples see; http://www.sat-research.at/hydroWEEE/, http://www.rhodia.com/en/news_center/news_releases/Rare_earths_130111.tcm

technically possible, it is not generally viewed as economic at present. Similarly, the concentration of indium in flat panel displays is low (a 32” panel only contains around 0.2g of indium), therefore economic recycling is challenging. Printed circuit boards can be processed, though not in Scotland or the UK. Some smelting occurs in the EU by Umicore, which can process electronic scrap, extracting many of these materials.[163] Within the UK and elsewhere, mine tailings have been identified as a possible source metals, for instance indium from tin mines. Substitute materials and technologies are also under investigation, for example using alternative semiconducting materials, or reducing or replacing the amount of indium used in TCLs. These have been funded through national or international schemes.

Battery recycling is another area that has received interest, partly because of EU legislation which requires that 45% by weight of portable batteries must be recycled, with producers required to join compliance schemes which collect and treat battery waste.[164] However, the effectiveness of these schemes for materials recovery is questionable, as much of critical material content is lost in slag or alloyed to other metals. Technology for better separation exists, but at a cost which is substantially higher than the cost of materials recovered.[165]

5.10.5 Other supply chain issues

Only 40% of businesses which identified raw materials issues as amongst their highest risks. Other, generally more important risks were associated with other business costs such as transport and logistics, changes due to legislation (e.g. health and safety, and waste), and in some cases downstream price volatility in markets.

In some cases labour was identified as an issue, though this is likely to be linked to the specialist skill-set required for the particular company.

5.10.6 Impact of materials issues on sector growth initiatives

Planned growth in this sector is laid out in terms of ambitions rather than financial targets. For example, the TAG states six ambitions for sector growth, discussed previously in Section 5.10.1. Scottish Enterprise’s Business Plan (2013-2016) echoes the ambitions of the TAG.

The main materials issue that may hinder the realisation of these ambitions relates to the consolidation of suppliers of several types of materials important to this sector, including for copper and high purity chemicals. Specifically, this material issue will impact on this sector’s ability to develop efficient supply chains that are able to react quickly to a changing market demand, which is an aim of the TAG.

The reducing quantity (and corresponding increasing price) of some materials, such as REEs, may also make it difficult for the TAG to foster collaboration between some specialist businesses, simply because they may be competing for the same materials. Collaboration may also be difficult to achieve between businesses that operate in the same sales markets, but this relates to downstream activity rather than materials issues.

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163 http://www.preciousmetals.umicore.com/PMR/

164 http://www.environment-agency.gov.uk/business/topics/waste/139264.aspx

165 Recycling of Tracked Li-ion EV batteries, TRL, Oakdene Hollins, Axeon and the University of Sheffield 2013

Many of the materials used by this sector - such as copper, steel and aluminium - have high recycling potential. However, others such as REEs and high purity chemicals are, at present, difficult and expensive to recycle. These latter materials may impact on the wider ambition of the Scottish Government to achieve 70% recycling of all waste by 2025.[166]

Elsewhere, a lack of workers with relevant skills, identified in part by this research, provides a means for the TAG to promote this sector as an attractive option to youngsters and achieve their aim of ensuring that a constant stream of talent is brought into this sector.

5.10.7 Suggested actions from industry

A number of ways in which the technology and engineering sector could be supported by the Scottish Government were proposed. These actions include:

- **Improve communication between Government and business on key issues.** This could be achieved through clearer, better signposted, information and through industry groups discussing supply chain issues. For example, CE markings are becoming mandatory in Scotland from 1 July 2014[167], but most steel manufacturers will struggle to meet the deadline. They say that clearer advice from relevant government bodies would have helped them to prepare for this deadline, especially since most companies are not affiliated with trade groups who would otherwise supply information on such regulatory changes. Increasing dialogue directly between government and business (rather than between government and industry or trade groups) would fit well within the Scottish Government's ambition of providing a supportive environment for Scottish businesses, as described in the Government Economic Strategy.
- **Give more support for start-ups and early stage SMEs**; for instance through grants, and other funding, targeting raw material and other related issues. This action aligns with the Scottish government's aim of investing in a supportive business environment.[168]
- **Create an internal supply chain network between the various businesses and sectors in Scotland.** This would be aimed at informing how waste from one stream can be used as inputs to another stream. It exists, in part, but is only a 'free-cycle' approach. Other aspects such as fostering information sharing between businesses would also be involved here, which fits with the TAG's aim of improving collaboration between businesses in this sector.[159]
- **Invest in R&D and technical knowhow.** Providing technology and skills to address raw materials issues such as recycling, development of alternative materials, and improved material efficiency. This action fits with the TAG's aim of increasing investment in R&D as well as their ambition of bringing constant streams of new talent into this sector.[159]
- **Assist the development of internal raw material supply.** Building and reinforcing existing supply chains based on the existing raw material assets within Scotland could provide benefits across a wide range of industries. This action aligns with the TAG's aim of developing links between clusters of companies within different sub-sectors to be able to react quickly to market demands.[159]

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[166] Scotland's Zero Waste Plan, Zero Waste Scotland 2010

[167] http://www.istructe.org/news-articles/2014/industry-news/bm-trada-warns-of-structural-steel-ce-marking-dead

[168] The Government Economic Growth Strategy, Scottish Government 2011

5.11 Textiles

5.11.1 Overview

The approximately 600 textile and leather businesses in Scotland export their products to over 150 countries. Around 10,000 people are employed by this sector in Scotland, which contributes around £350million to the Scottish economy annually.[169]

Short-term strategic ambitions for this sector include increasing export sales by 50% by 2016[170], increasing total Scottish sector turnover by 3% by 2015, and increasing expenditure on R&D by 2% by 2015.[171] These ambitious targets are a reflection of the observation that the sector has been highly resilient despite the economic downturn.

8 trade bodies and **15** distinct businesses in the textiles sector were contacted during the course of this research, although additional businesses were asked to participate by some of the trade associations. Responses to the questions listed in the pro-forma (either through email, telephone or face-to-face interviews) were obtained from **6** individuals in this sector. These companies are all involved in the manufacture of textile products, including leather, synthetic and natural fibre items, and are all of a medium (<250 employees) or large (> 250 employees) size.

5.11.2 Reliance on raw materials

The textiles sector in Scotland covers a range of products, including interior fabrics, clothing and leathers for the fashion and automotive industries. The wide range of products manufactured by the textiles sector requires a wide range of raw materials as inputs. These include: wool and wool-blend yarns for fabrics; cashmere for luxury clothing items; synthetic chemical fibres, such as aramid, polyester and acrylic for woven technical textiles; raw and crust bovine hides for leather products; a variety of chemicals and compounds for cleaning, dyeing and adding other properties to textiles; and water, which is used throughout the manufacturing process.

Raw materials are of great significance to this sector, as evidenced by the fact that 100% of the businesses asked consider raw materials to be vital to their operations.

5.11.3 Raw material issues

Natural fibres, such as wool, silk and cashmere, are subject to supply issues primarily driven by increased global demand. These supply spikes, whilst causing a shortage in supply, raise market prices. For example, wool sold at auction on the Australian market spiked from around £6.50/kg to around £8.50/kg during the first half of 2011. This was the effect of lower than normal levels of yarn production due to a prolonged period of warm weather. During the consultation, businesses manufacturing woollen and cashmere products

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169 Scottish Keyfacts, Scottish Enterprise 2013. Available at http://www.scottish-enterprise.com/knowledge-hub/articles/publication/scottish-key-facts

170 Business Plan 2013 2016, Scottish Enterprise 2013

171 A strategy for the textiles industry in Scotland 2011-2015, Textiles Scotland 2011

suggested that raw material costs now comprise around 40% of a product's sales price, and that they are unable to pass increasing costs on to customers.

In an attempt to mitigate this variation in quantity and price, many Scottish manufacturers of natural textiles are turning to blended products. The main natural fibre (e.g. cashmere) can be blended with other cheaper natural fibres such as silk, cotton or even wool. Whilst this will reduce the quality of the product, it will also reduce the raw material cost. The result is a different kind of product that can be sold into a different market.

Specialty chemical synthetic fibres, such as polytetrafluoroethylene, polyphenylene and aramid appear to be most affected by supplier reliability issues. Manufacturers of synthetic textiles largely source the constituent fibres or fabrics from the regions where they are cheapest. Feedback from these businesses indicates that they regularly change suppliers due to orders not being delivered on time or in the correct quantity. The price of these synthetic materials seems to be more stable than natural fibre markets, although businesses in the synthetic space suggest that a higher proportion of their product sales price is made up of raw material costs, at around 60-80%.

Businesses involved in the earlier stages of textiles production - those that clean, dye and protect the fibres or weave them into usable fabrics, for example - use a range of **chemicals** in their processes. Consultation with these businesses suggests that these chemicals are generally freely available, being supplied by international chemicals companies such as DuPont and BASF, and that prices are also fairly stable.

Water is also a vital material to most businesses in the textiles sector, even if it is only used to wash products through their manufacture. Early-stage textiles companies, such as dyers or tanners, require substantial quantities of water. Whilst the cost of supply is a constant concern, a bigger issue may be the waste water that results from such processes. This waste water must be treated before it can re-renter the municipal supply. In most cases Scottish textiles companies have this waste water collected by tanker and transported to regional treatment facilities. However, if scale allows, a better alternative may be to use biological agents to treat the waste water on-site before releasing the cleaned water into a freshwater course, with approval from SEPA.

Bovine hide was a raw material input highlighted by several companies in this sector; this is discussed in the following Spotlight section.

All of the respondents in this sector believe that they have been exposed to material supply issues within the last two years, with the vast majority agreeing that the level of threat and risk to this supply is increasing. A large part of this relates to consolidation of customers and increased import duties. As such, these businesses do not believe that their materials issues will lessen in significance in the near future.

Spotlight on… bovine leather

Genuine leather-based goods (as opposed to synthetic leather-like goods) are mostly made from bovine (cow) hide. This hide can be purchased in two forms, depending on the facilities of the business that will use the material. Raw bovine hides typically come direct from the abattoir, and will require cleaning, tanning or dyeing and drying before they can be used on the production line. Raw hides have a short shelf life, of the order of days rather than weeks, so Scottish leather-makers prefer to source their raw hides from within the UK or Ireland. Availability of raw hides does not appear to be a big issue, though spikes in demand from foreign markets can lead to short delays in the delivery of this material and subsequently impact the ability of Scottish leather-makers to deliver orders. Price volatility is far more of a concern, with the market price of a single raw hide increasing from around £35 to around £70 during the course of 2013. To counter this volatility, businesses are staring to negotiate long-term contracts with suppliers, and putting cost escalators into contracts with customers that link the selling price to the market price of the raw material.

The other form of hide, crust bovine hide, can be imported from great distance as it has already been treated and dried. Crust hides are a stable commodity with a shelf-life of the order of months or even years without the need for additional processing. These hides are heavily affected by the global demand for leather, and Scottish leather-makers face competition for premium crust hides, principally those that are exported from Germany and South America. The hides that are purchased from great distances are subject to long lead times, which is a factor of shipping duration as well as lengthy drying times, on the order of two weeks, required to make the product suitable for storage and long-distance transport.

The images show the difference in appearance between cleaned raw bovine hides (left) and crust bovine hides (right), as they arrive for processing at a leather product manufacturer.


Whilst most bovine hide costs can be passed on to customers (leather products being a luxury item that downstream actors are willing to pay for) businesses are concerned that a continuation of this price trend over the next year or two may turn some to synthetic leather products. However, there appears to be confidence that, as demand for leather products from foreign countries stabilises, so will the market price.

5.11.4 Other supply chain issues

Of the participating textile industry members, 83% consider raw material risk to be either high or very high in comparison to other risks in their supply chains.

In addition to the outlined raw material risks, businesses in the leather industry face significant threat from synthetic counterparts. This risk is outside of the supply chain, but can have a large impact on a business's downstream operations if contracts are lost to such competitors. Whether genuine or synthetic, leather producers who supply the automotive sector are at risk of a contracting customer base through the consolidation of manufacturers into parent groups. Industry consolidations, which regularly occur in the automotive sector, mean that suppliers must compete against each other for a smaller number of customer contracts. However, the rewards for success are far greater under these conditions.

The most consistent risk across this sector is noted as being foreign exchange rates, which influence the price at which these products can be sold in international geographies. Hence, foreign exchange rates can dictate the margin a business makes on a sale and therefore impact overall profit or loss. Foreign exchange rates are a particular concern for those at the non-luxury end of the textile market, where raw material costs and exchange fluctuations cannot be passed on to customers.

5.11.5 Wider context

There is a poor overlap between the materials for the textiles sector identified in this study and those identified in other studies; unsurprising given the differences in scope and the Scottish textile sector's historical focus on animal-based raw materials such as leather, wool and cashmere). However, there is some alignment with the chemical sector, as textiles use inputs such as pigments which use some of the metals commonly identified as critical (e.g. cobalt; see Section 5.8).

Some, albeit limited, alignment with studies on natural fibres such as **cotton**, **rubber** and man-made fibres such as **polyester** can be seen, although these are clearly important inputs into the industry, and lack of recognition in other studies is partly a reflection of their scope.

Cotton and rubber have been highlighted by the BIS study, as the UK is reliant on imports of these materials. In the case of cotton, competing demand from an international market is highlighted as the biggest risk, particularly related to spun and woven cotton. Rubber is highlighted due to its concentrated production in South East Asia (primarily Thailand and Indonesia), though concerns are mainly linked to tyres where it is currently non-substitutable. Concerns directly related to the textiles industry are not widely identified.

5.11.6 Impact of materials issues on sector growth initiatives

Bovine leather products sold into the automotive sector suffer from a contracting customer base. A reduced number of customers (caused by take-overs in the automotive industry) can impact sector turnover, as the number of customer contracts is falling and the competition between global leather manufacturers increases. This issue could impact the ambitious growth target for this sector of 3% by 2015.[172] If these customers are largely based abroad it may also hinder the sector's ability to increase export sales by 50% by 2016.[173]

The issue of rising material costs within this sector, particularly for natural fibres, may push companies to become more resource efficient. Given the right support from the Scottish government, which is an aim described in the Economic Growth Strategy, textiles companies may be keen to counter the impact of increasing material costs by making savings in other areas, possibly by adopting less energy-intensive manufacturing processes or improving capture of waste streams for use as inputs to their own or others' product supply chains.

The difficulty of recycling some materials, such as synthetic fibres, may impact the aim of 70% recycling of all Scotland's waste by 2025.[174] However, it does present opportunities to improve recycling technologies in this area and to drive increased re-use of fashion textiles from primary consumers into the commercial and third sectors. This opportunity is in line with the Scottish Government's ambition of increasing the supply and demand for quality reusable items, as described in their blueprint for a more resource efficient Scotland.[175]

5.11.7 Suggested actions from industry

The participants in this research proposed a number of ways in which the textiles sector could be supported by the Scottish Government. These actions include:

- **Develop a sector-wide risk management strategy for upstream partner closure**. Many Scottish textiles businesses rely on a small number of dyeing or tanning businesses, some of which are also based in Scotland. The textiles industry, particularly those using natural fibres, would like to be consulted by Scottish Government in the development of a mitigation strategy should these important upstream partners cease to operate. This aligns with the Scottish Government's aim of investing in a supportive business environment.[176]
- **Provide advice on material efficiency measures**. The textiles sector can increase margin through more efficient use of their raw materials. Whilst all businesses strive to gain the most value from their supplies, some businesses in this sector are keen to engage with universities and government-backed research bodies to learn more about material efficiencies in manufacturing. This kind of support is provided by RES, though the businesses asked in this survey were unaware of it, suggesting more can be done to promote the efforts of RES. This action may help the Scottish Government achieve its ambition of providing advice and support to help businesses grow, as described in the Economic Growth Strategy.[176] Textiles Scotland also has an aim of leveraging technical academic work through the Scottish Academy of Fashion, which this action may contribute to.[172]
- **Introduce sector-specific labels to support domestic and foreign sales**. Scottish textiles businesses believe that the introduction of certain product labels would be of

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172 A strategy for the textiles industry in Scotland 2011-2015, Textiles Scotland 2011

173 Business Plan 2013 2016, Scottish Enterprise 2013

174 Scotland's Zero Waste Plan, Zero Waste Scotland 2010

175 Safeguarding Scotland's resources: blueprint for a more resource efficient and circular economy, Actin 11 - Scottish Government 2013

176 The Government Economic Growth Strategy, Scottish Government 2011

benefit to sales in both the domestic and foreign markets. Such labels might include a 'genuinely natural' label to identify those products that are made of natural rather than synthetic materials, or a 'made in Scotland' label to differentiate a product from those made under less stringent conditions. However, many labels already exist in the textiles sector, so careful integration with these would be required. This action would align with the objective set out in the Scottish Enterprise Business Plan 2013-2016 to generate additional industry growth through increased exports, building on the sector's reputation abroad.[177]

[177] Business Plan 2013 2016, Scottish Enterprise 2013

6 Conclusions and recommendations

6.1 Conclusions

Conclusions can be drawn from the cross-sectoral and individual sector analysis:

- Industries in Scotland view raw materials as crucial inputs to their businesses. Therefore, continued access to these materials is essential to meet the aims of the Government Economic Strategy, and sector strategies.

- Scottish businesses are aware of, and are experiencing, issues related to their raw material supply. These issues are viewed as amongst the most important to the businesses surveyed when compared to other supply chain issues. However, businesses are often unaware of wider concerns in industry, trade bodies and Government, instead viewing their concerns from an isolated perspective, depending on their position in the supply chain.

- Materials that have undergone some processing/refining have been identified as important by this consultation, which is indicative of the respondents' positions in the supply chain. The issues associated with these materials (such as price volatility and increases and supply disruptions) are seen across a wide range of material types, some of which are thought of as fairly commonplace. These issues also correlate with those identified in other studies, despite the materials identified by this consultation not being the same bulk raw materials that are identified in top-down studies.

- Four raw material inputs were identified as important across all sectors: steel, water, copper and plastics. For steel and plastics, issues are often linked to obtaining the correct grades or qualities (e.g. high-grade steel for wind turbine or pipeline construction). Issues with copper are associated with price changes in global markets, and resulting barriers to access. A reliable and cheap source of large volumes of water was identified as an issue in several sectors. However the impact may be greatest on sectors in which water quality was of greater importance, particularly in the food and drink sector and chemicals sectors.

- Grade and quality of materials are considered important to many businesses. This issue is often outside the consideration of higher level studies, which focus on bulk materials. This information could provide opportunities for more specific interventions, such as specialist manufacturing.

- Responses to raw materials issues vary. Most companies (82% of those that have existing materials issues) have taken proactive measures, such as developing new supply options, tasking personnel with monitoring situations, or researching alternative materials. Others (12% of those that have existing materials issues) have been less responsive, mainly choosing to pay the market price or live with upstream disruptions) and may view these issues as 'part of the industry'. There may be opportunity here to help these companies move towards more circular business models, including improved resource efficiency and higher materials reuse/recovery/recycling rates.

- The analysis shows that raw materials present clear opportunities and threats to the Government Economic Strategy, sector growth plans and circular economy plans, and low carbon targets. There may also be an impact on critical national infrastructure, such as energy, transport and communications. On one hand raw materials inputs are essential for growth across the sectors and the associated issues could harm development within sectors, particularly the aerospace, defence and marine, and energy sectors. On the other hand mitigating the associated issues could strengthen these sectors, and provide opportunities to meet goals such as increased competitiveness, more resilient supply chains, waste reduction targets, higher resource efficiencies and circularity within the economy.

- There are clear links between critical raw material issues and circular economy actions; issues surrounding materials supply can act as a driver for obtaining a more circular business model. This is particularly true for materials where recycling is less viable (e.g. in WEEE) but possibilities exist for remanufacturing, re-use and product life extension. These activities could also create an indigenous, proxy supply of raw materials, through displacement of product rather than materials. These actions would also increase the efficiency of raw material use.

6.2 Recommendations

The following policy-level recommendations are based on the discussions held with businesses through the course of this research. These are also aimed at supporting the targets of the Government Economic Strategy, and supporting such initiatives as zero waste to landfill and enabling the circular economy.

6.2.1 Raise the profile of raw materials issues

Raw material issues were of high concern to almost all the businesses responding. However, responders were often not aware of wider issues within the sector or economy. Raising awareness of these issues across sectors and government will highlight that raw material risks are of broad concern and not isolated within specific instances or businesses, and also highlight actions which could be taken.

This research has identified that other countries and regions use a range of mechanisms to raise the profile of raw materials issues. These include holding workshops with industry organisations to highlight specific issues in different sectors. This could work for a number of Scottish sectors, most notably to highlight supply issues that businesses within those sectors are experiencing with the aim of making other businesses in those sectors more aware of the main issues.

Account managers at the Enterprise Agencies who have a responsibility to keep in contact with the businesses that they manage may also be able to do more to raise awareness amongst their contacts. These account managers should be equipped with the key issues on raw materials for each sector, as identified in this and other reports, possibly in the form of sector and cross-sector materials factsheets. These could also include case studies on, or examples of, effective management of these materials, for instance improving recovery of tungsten carbide from SMEs, best practice of supply chain management, or reducing water usage in the food or manufacturing industry. These factsheets can then be used to inform discussions between the account manager and the businesses they manage, and could even be used by Business Gateway staff that deal with SMEs. There may also be a role for SEPA and ZWS or RES here, particularly around resource efficiency advice.

As part of this recommendation a study should be commissioned to delve deeper into the risks associated with critical infrastructure provision in Scotland. For example, this report has highlighted the for an equivalent installed energy capacity, solar and wind facilities require up to 15 times more concrete, 90 times more aluminium, and 50 times more iron, copper and glass than fossil fuel or nuclear energy installations. Such a study would help to clarify the impacts on planned infrastructure developments in Scotland.

Holding events within higher education and research, aimed at educating students and researchers regarding the materials issues identified in this report, would help to create an understanding of these issues that extends beyond the business world. This would also impart a sense of the importance that raw materials have, and demonstrate the direct and indirect benefits of raw material production. The Scottish Government, its Enterprise Agencies and ZWS should work with Education Scotland to maximise opportunities for learning around resource efficiency and the circular economy. This action would fit directly with the aim of the Scottish Government to create a culture of resource efficiency in Scotland, specifically by engaging and educating the public.[178]

This recommendation revolves around making businesses and the future generation of business leaders aware of the potential issues faced by different sectors and product groups, and potential opportunities. The following four recommendations are focused more on actions designed to solve many of the specific materials issues highlighted throughout this report.

6.2.2 Interventions to bring supply chain organisations together

This research has identified the need to create knowledge groups to communicate and attempt to resolve the issues associated with certain materials that are important to different sectors and for which serious issues have been identified. The idea of material-specific working groups is not new; the Green Growth Steering Group, which has contributed to action on steel; or sector-driven schemes such as the Scotch Whisky Association's closed-loop glass group.

Working groups to bring organisations within and across sectors together to identify common issues could lead to the implementation of valuable initiatives. It is likely that such initiatives would be led by relevant materials organisations or trade associations, with advice and support on key materials issues provided by an appropriate Agency. For example, some industries, such as sub-sea development for oil and gas projects, rely on the use of high quality raw materials. Quality is often an issue, especially for raw materials which are mainly used by other sectors with lower quality requirements. Steel is a very good example of this. An initiative for this material may be to provide a means for all sectors in Scotland in which steel is used to have access to the correct grade of steel required in their operations. The

[178] Safeguarding Scotland's resources: blueprint for a more resource efficient and circular economy, Action 18 - Scottish Government 2013

most effective way of implementing an initiative such as this would require further research, which should be conducted in collaboration with the affected businesses.

Besides steel, this report has identified other materials for which materials working groups could be established. These include timber, water and copper; see Section 5.2.2 for a detailed discussion on these materials that are of cross-sector significance. We recommend a series of pathfinder initiatives across these materials aimed at developing a successful approach.

6.2.3 Incentivise sustainable supply chains

Sustainable supply chains support much of the Government Economic Growth Strategy, for example initiatives on the circular economy. Businesses that implement measures such as reduced resource inputs and materials substitution within their supply chains should be rewarded for their efforts. Whilst this report has highlighted sectors in which materials are used according to these principles, it has also highlighted situations where primary materials are used in place of recycled options (e.g. the use of primary aggregate materials above recycled aggregates) and where previous virgin materials are not used for their most value added purpose (e.g. using virgin timber as feedstock for bioenergy rather than as construction materials, as indicated by industry). This could be achieved through developing a hierarchy of uses for internal material resources, which is used to inform policy decisions; for example, a hierarchy for wood and timber resources or for water uses from different sources. This approach has been proposed by the Institute for European Environmental Policy.[179]

The aim of this recommendation would be to incentivise businesses for using renewable raw materials, improving materials efficiencies, using materials that are socially and environmentally beneficial, or for using local raw materials. This could be through direct actions such as economic instruments or putting legislative frameworks in place on grounds of environmental benefit. This is the direction of policy at a European level: The Roadmap to a Resource Efficient Europe calls for action to get prices right and reduce environmentally harmful subsidies.[180] Both of these aspects are being explored in various studies by the Scottish Government and its Agencies.[181]

Examples of materials for which incentives could be offered (subject to findings from ongoing fiscal studies) include:

- Renewable raw materials in the chemicals sector. Some international companies, such as P&G and BASF, have already begun to substitute petrochemical based substances with renewable alternatives in some products.
- Topsoil, along with other materials used in the construction sector, could be included in an extension of the existing Aggregates Levy, or have an aligned scheme adopted, providing incentive to use materials with high recycled content. This could have real

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179 http://www.ieep.org.uk/

180 Roadmap to a Resource Efficient Europe, European Commission 2011

181 For example, the Fiscal Instruments Study which is underway; SEPA is soon to procure a study on regulatory instruments for a more circular economy.

impact across Scotland if these materials were adopted for the majority of domestic, industrial and municipal construction projects.

- Processed or recycled timber, or timber that comes from dedicated biofuel forests, for use as bioenergy feedstocks (rather than using virgin timber).
- Incentivising copper recycling (sorting, separation and processing) from currently under-tapped sources such as WEEE, to further help develop an internal, reliable source of this metal. This could be further linked to the production of formed products such as cabling or piping, (dependent on industry requirements), to supply internal industry. Achieving minimum economic scale compared to global processors will be an important challenge.
- High grade steel production could be developed through a small scale plant with flexible production; this could potentially be linked to a research organisation. Recycled materials from Scottish sources, such as oil and gas production, could be used as inputs where possible. However, this action should link with the on-going study into the steel industry within Scotland, which is assessing the broader viability of steel production and which indicates that achieving minimum economic scales of production and dealing with overcapacity in global steel production are important challenges.

6.2.4 Knowledge exchange platform for supply chain strategy

Businesses work hard to ensure that the knowledge captured through their activities is retained and used effectively. This research has found that the majority of businesses are employing similar responses to materials issues. However, some are engaged in proactive measures such as materials substitution, resource efficiency strategy and moving to more circular business models. This research has also identified a desire of businesses within and across sectors to learn from the successful supply-chain approaches of others, and similarly for those with successful approaches to educate other businesses (although this ideal of effective knowledge exchange is the exception rather than the rule).

The creation of a knowledge exchange platform focussing on effective supply chain strategy is therefore recommended. The platform would enable similar-sized businesses in different sectors to learn from successful supply-chain approaches, including raw materials sourcing strategies, stock management, innovative business models and demand forecasting.

Knowledge is transferrable and should be shared through cross-sector platforms. For example, the aerospace sector has robust supply chain methods, for materials quality checking and demand forecasting in particular, that it would happily share with other sectors, especially suppliers. The objective is to increase supply chain robustness in important sectors.

This recommendation would also help the Scottish Government achieve the objectives of strengthening levels of innovation within businesses, as defined in the Economic Growth Strategy[183], and of helping to equip businesses with better information around materials, as defined in the blueprint for a more resource efficient and circular economy.[182]

6.2.5 Continue to develop links between research organisations and businesses

[182] Safeguarding Scotland's resources: blueprint for a more resource efficient and circular economy, Action 5 - Scottish Government 2013

Through discussions with businesses from across a wide range of industrial sectors, this report identified a common theme; namely, that these businesses do not (typically) gain real value from the excellent research that occurs throughout Scottish universities and research centres.

Improving these linkages will allow businesses (particularly SMEs) to better benefit from the technical research capacity within Scotland, allowing industry problems to be understood and resolved in collaboration. Better links will also provide students and staff at these universities and research organisations with access to Scottish businesses, with the potential that these businesses could host student secondments or post-qualification internships and potentially help fund research that can be used by the business and wider sector(s).

The Scottish Government has a strategic aim of creating a skilled, educated and creative workforce to ensure that the Scottish economy remains competitive and resilient.[183]Improving links between research organisations and businesses will help to achieve this aim. Interface, which provides a central point of access to the expertise available in Scotland's Higher Education and Research Institutions, should be involved throughout.

The Scottish Government could engage with organisations such as the International Metal Study Groups, to gather information on markets and future developments to feedback to industry.

[183] The Government Economic Growth Strategy, Scottish Government 2011

Annexe A: Summary of reports

This Annexe provides a summary of the scope and methodological approach of the twelve reviewed reports, as well as summaries of the individual reports reviewed as part of this work. These discussions are summarised in Section 3 of the main report.

Summary of scope and methodologies

The scope of materials considered, the approach and the output differs between the twelve studies reviewed due to the context in which each is produced. Some are limited solely to metals, others broaden this to minerals, and others consider a much wider range of materials such as wood and plastics. However, all studies the focus on non-energy, non-food raw materials, differentiating these from energy materials such as petrol and other petrochemical fuels, gas and food crops. There will inevitably be some overlap when the scope is broadened; for example, wood can be a construction material or a fuel, and petrochemicals are a major energy source as well as an important feedstock for the chemical industries. However, the studies recognise this distinction and note that competition for use is a further risk. In this current study, a broad definition of raw material input has been used for the industry consultation; not all studies align with this approach.

The approach studies take varies considerably within this sample; for example, conducting a criticality analysis within a given context, or seeking to identify and discuss issues. Where a group of materials is assessed, the methodology differs depending on the context and purpose. Despite this, there are some materials that are commonly identified as critical; for example, gallium (electronics, lighting and photovoltaics), indium (flat panel displays), platinum group metals (PGMs: autocatalysts, industrial uses), and rare earth elements (REEs: magnets, lighting, industrial uses).

In contrast to the approach taken in this study, most take a 'top-down' approach - using data from literature and other sources to assess the criticality of materials, and identify risks. This current study takes a 'bottom-up' approach by directly surveying industry organisations to garner their experience of these issues. This approach will inevitably result in some differences.

Other research related to raw materials attempts to assess the impact of criticality across sectors, or business as a whole. This research may take a specific list of CRMs, use expert opinion, or not specify particular materials at all, again depending on the scope of the work.

1. Study 1 - Raw Materials Critical to the Scottish Economy, Sniffer, 2011

This study sought to understand future resource risks faced by Scottish business using a top-down methodology (i.e. analysis of high level data linked to material applications, sectors and other factors). This built on a wider piece of work for the UK; however, it provides a more specific view for the Scottish economy. Analysis also identified resource issues which pose the greatest threat (or opportunity) to businesses, to understand the scale and nature of these threats.

The scope of the work analysis included 27 pre-selected metals, minerals and abiotic materials, which were scored against several criteria. Energy raw materials were excluded.

This was used to identify the 12 materials with the highest priority. These are: aggregates, cobalt, copper, fish, indium, lead, lithium, palm oil, phosphorus, rare earth elements, timber, and tin. The impact of potential issues associated with these was discussed across seven business sectors (Table 7). Whilst these sectors do not map directly onto those in the present study, they follow a similar pattern with slightly different assignments of sub-sectors. For instance, wind turbines were considered under engineering in the SNIFFER study, but are included under energy in the present study.

Table 7: Comparison of sectors analysed in the SNIFFER and the present study

SNIFFER Study (2010)	Present (2014)
Agriculture, fisheries and forestry	Forest and Timber Technologies
Chemicals Sector	Life and Chemical Sciences
Construction	Construction
Electronics and IT Hardware Engineering Automotive	Technology and Engineering Aerospace, Defence and Marine Manufacturing
Food and Drink	Food and Drink
	Energy (Oil , Gas & Renewables)
	Textiles

The report showed up a number of findings relevant to business and government, highlighting the threat to the economy of resource scarcity (particularly of those resources identified); for example, that sustainable energy generation relies on many of the critical raw materials, or that the agricultural industry relies on imported phosphorous. Overall, an urgent need to act on resource issues was clearly stated, particularly for those identified as critical to Scotland. A number of mitigation strategies were identified, which are also highlighted as opportunities:

- Necessity for greater awareness by business and Government of resource issues, particularly along the length of supply chains. The importance on acting on information gathered was also highlighted.
- Improvement of (hitherto poor) data from Scottish businesses on raw materials issues; for instance, by identifying factors which influence scarcity/supply of raw materials.
- Preservation of primary resources through more efficient extraction and processing methods was identified.
- Alignment of raw materials strategy with the Scotland’s Zero Waste plan to enable recovery of critical raw materials.
- Development of more efficient recycling of materials, as well as closed loop systems.
- Development of alternative materials, enabling substitution of materials
- Design of products to enable recycling to allow recovery of materials, reducing waste to landfill and reducing environmental impact.
- No indigenous production of many of the materials exists, and often a few key players are responsible for the global production.
- Cooperation at a UK and EU level to understand the specific needs at each level and to coordinate activities
- Investment in alternative supplies of materials and securing longer term supply contracts.

Learning from this study

This earlier study on critical raw materials focused on the Scottish economy (using a different methodology); therefore the findings are directly relevant to this present work. Some of the opportunities highlighted by the 2010 study are, for instance: raising awareness across government and industry, gathering data directly from industry (linked to this work), and aligning a raw materials strategy with the Zero Waste Plan.

2. Study 2 – UK Resource Security Action Plan, Defra/BIS, 2012

The UK's Resource Security Action Plan was launched by the UK Government in 2012 as its response to raw material issues. The Plan focussed on responses to concerns over the availability of some raw materials to the private sector, and the consequent impact on the economy. The increased competition for resources was highlighted as a fundamental issue, as was its impact on the environment. This work was not itself an analysis of critical raw materials, rather a strategy document identifying responses to reduce resource risks.

The materials scope of the Action Plan was abiotic and biotic materials (which were not covered by existing policies on energy and food). However, no specific list of critical raw materials was drawn upon, as it was acknowledged that this could change depending on context, industry and with time. Instead the approach taken was to facilitate business action where there was greatest scope to reduce risk and environmental impact, and to capture value for the UK economy. A consensus between different studies on identifying several speciality and precious metals was highlighted.

High level conclusions and recommendations were made, including identifying the potential risk and opportunity related to resource security for the UK. It was acknowledged that different sectors experienced different impacts across the UK. A framework for business action to address resource risks was outlined, identifying opportunities and actions which focussed on resource efficiency actions and making greater use of the UK's indigenous resources. The Actions identified below aimed to build this framework for businesses to grasp:

- Develop a critical resources dashboard to provide companies with information on resource risks.
- Improve capture of data on WEEE being treated by waste management companies and other players.
- Analyse flows of materials in EEE to provide insight into the flow of critical raw materials through parts of the UK economy.
- Form an industry-led consortium to bring together interested parties to address opportunities and concerns.
- Seek opportunities to streamline REACH to reduce costs to businesses to reduce uncertainties in supply for some materials.
- Provide funding to establish the feasibility of new approaches to closed loop processing. This will target enabling businesses to extract value from domestic and commercial waste streams (e.g. through re-use and recovery).
- Investigate the application of Individual Producer Responsibility more generally to WEEE to recover resources, and combat illegal trade in WEEE.
- Promote WEEE re-use activities through the re-cast of the WEEE Directive.

- Set up demonstration trials to highlight potential for improving recovery of critical materials in WEEE.
- Press for Implementing Measures under the Ecodesign for Energy Related Products Directive to address more efficient use of resources, as well as provide a level playing field for producers through fewer but more stringent standards.
- Ensure that the UK plays an active role in discussions at an EU level, specifically the EU Transparency and/or Accountability Directives.

Review of international resource strategies

The study provides a review of selected international response to materials concerns, and analyses the published strategies of 10 counties and the EU.[184] At a high level, the purpose of these studies is to ensure that economies are not impacted by the raw material shortages. Approaches include: securing stable supplies of primary raw materials, reducing reliance on raw materials, increasing re-use and recycling, and promoting sustainable utilisation of raw materials. However, specific approaches depend on the situation and priorities of the area. For example, each of the strategies identifies a different group of materials (Table 8). The scope of these studies is typically limited to metals, and in some cases minerals.

Table 8: Materials of interest related to the identified studies

Country	No.	Materials
Australia	4	Niobium, REEs, Tantalum, Vanadium
Canada	8	Aluminium, Copper, Gold, Iron, Lead, Molybdenum, Nickel, Silver
China	10	Aluminium, Antimony, Iron, Mercury, Molybdenum, REEs, Tin, Tungsten, Vanadium, Zinc
EU	14	Antimony, Beryllium, Cobalt, Fluorspar, Gallium, Germanium, Graphite, Indium, Magnesium, Niobium, PGMs, REEs, Tantalum, Tungsten
Finland	13	Chromium, Cobalt, Copper, Iron, Lithium, Manganese, Nickel, Niobium, PGMs, REEs, Selenium, Silver, Tantalum
France	14	Cobalt, Copper, Gallium, Germanium, Gold, Indium, Lithium, Magnesium, Nickel, Niobium, REEs, Rhenium, Selenium, Tantalum
Germany	20	Antimony, Beryllium, Bismuth, Chromium, Cobalt, Fluorspar, Gallium, Germanium, Graphite, Indium, Lead, Magnesium, Niobium, PGMs, REEs, Rhenium, Silver, Tantalum, Tin, Tungsten
Japan	6	Cobalt, Manganese, Molybdenum, Nickel, Tungsten, Vanadium
Netherlands	30	Antimony, Arsenic, Beryllium, Bismuth, Cadmium, Cobalt, Gallium, Germanium, Gold, Indium, Lead, Lithium, Mercury, Molybdenum, Nickel, Niobium, PGMs, REEs, Rhenium, Selenium, Silver, Strontium, Tantalum, Tellurium, Thallium, Tin, Tungsten, Vanadium, Zinc, Zirconium
South Korea	15	Arsenic, Cobalt, Gallium, Indium, Lithium, Manganese, Molybdenum, PGMs, REEs, Silicon, Tantalum, Titanium, Tungsten, Vanadium, Zirconium
United States	6	Cobalt, Gallium, Indium, Lithium, REEs, Tellurium

NB PGMs = Platinum Group Metals, REEs = Rare Earth Elements

[184] Full list includes Japan, Netherlands, China, South Korea, Australia, Canada, Germany, France, Finland, United States, and the EU.

Policy responses are split by business and R&D focus, and differ between strategies. This is particularly evident for resource suppliers (e.g. Australia) and resource consumers (e.g. Japan). However, key themes can be identified; these are split by business and R&D. Key policies to influence business include:

- Improve financial support for external mineral exploration and exploitation.
- Improve conditions for indigenous exploration and exploitation, e.g. streamlining permitting.
- Enable recycling and re-use of products containing certain materials.
- Establish partnerships with supplying countries and businesses, e.g. such as free trade agreements or MOU.
- Encourage the development of transparency and stewardship schemes.
- Stockpile certain materials.

Key policies to influence R&D include:

- Find substitutes for certain materials, e.g. batteries, magnets.
- Develop products which are designed to enable recycling, re-use and other resource efficiency actions.
- Develop recycling technologies, targeting specific applications such as magnets.
- Improve materials efficiency in products.
- Improve the efficiency and environmental impact of mining and extraction activities.

Learning from this study

This study directly influences Scotland through the actions and outputs of the RSAP; for instance, through mapping materials flows in WEEE and identifying funding for closed loop processing. However, the recommendations are not as comprehensive as in other studies identified, and focus on specific actions. The review of international responses is also of relevance to this work, as it provides a wider picture on the strategies in dealing with raw material issues (e.g. strategies that may be appropriate for the Scottish economy, such as enabling indigenous supply, developing partnerships with supplying countries or businesses, researching innovative technology for materials substitution or to enable recycling, and improving the design of products). However, most studies focus on raw mineral resources, which may not fully align with the materials identified within this study.

3. Study 3 - The Future Impact of Materials Scarcity on the UK Manufacturing Industry, BIS, 2013

The UK Government's Foresight programme was set up to assist the Government in thinking systematically about the future. It was used to stimulate and inform the development of more effective strategies, policies and priorities at national and international levels. This programme had several themes including manufacturing, identity, climate change, farming, etc…

In the 2013 Future of Manufacturing Project, materials security issues were considered due to the importance of raw materials to many sectors of the manufacturing industry, and the high dependence on imports for many raw materials. Future issues faced by the UK manufacturing industry as a result of possible raw material limitations of supply were assessed within the research paper, and possible mitigation strategies identified. These were examined for the short term (to 2020) and, where possible, the long term (to 2050).

The work identified the UK manufacturing industries that were both important to the UK economy and most vulnerable to supply insecurity. It also identified manufacturing industries that could become important to the UK economy in the future and that could suffer from supply risks. Therefore the scope of the work covered the UK manufacturing industries individually and, rather than being an assessment of criticality of materials, this work identified possible future risks linked to certain materials and mitigation options.

The materials scope used covered 18 abiotic and biotic non-energy, non-food materials. The EU CRMs 2010 list (see Study 6), which comprised 14 metals and industrial minerals, was used to define the abiotic materials. The biotic materials considered were cotton, plastics, rubber, and wood when used in a non-energy related capacity (though use in energy generation apparatus is within scope).

The report concluded that there were very few, if any, scarce resources. However, differentiation was made between mineral, biotic and hydrocarbon-based resources. For example, risks associated with availability of mineral resources were linked to aspects such as geopolitical risk or growth in demand. Biotic resources faced threats from availability of suitable land, and hydrocarbon resources faced increasing prices.

Specific recommendations were made on these to the UK Government and to businesses, focussing on reducing the import dependency and increasing the resource efficiency of critical raw materials with the aim of mitigating future risks. These were sorted into five key areas: primary raw material production, substitution, raw materials knowledge base, waste prevention, re-use and recycling and sector-specific actions. These are summarised briefly below.

Primary raw material production

These recommendations focussed on developing indigenous (UK or EU) supplies of raw materials, for example quantifying reserves, improving efficiencies of materials processing, and exploring options for alternative rubber producing crops. In addition, the promotion of cooperative international strategies was highlighted.

Substitution

The approach recommended was to substitute high risk materials with lower risk materials to reduce requirements in certain sectors. However, each was to be considered on a case-by-case basis. Substitution may have involved reducing the amount of a material required (dematerialisation), replacing the material directly, replacing the system, or entirely swapping a product.

Raw materials knowledge base

The lack of understanding of risks for biotic materials compared to abiotic materials was highlighted, and suggested as an area to develop. The flow of materials in the economy was highlighted as a way to identify relative dependency on raw materials and products or components with these materials embedded in them. This was tied to having a wider appreciation of risk along supply chains, including issues related to traceability and provenance.

Waste prevention, re-use and recycling

Several strategies were identified to improve aspects of end-of-life treatment. These ranged from policy options to technological development: the adoption of more sophisticated waste recovery targets to recover small volume but important materials, the development of technologies to enable recycling and re-use of complex products, and the encouragement of remanufacturing and re-use as a means of avoiding dissipation of small concentration materials.

Sector-specific actions

Sector-specific issues were highlighted for the following industries: aerospace, automotive, batteries, catalysts, cemented carbide tools, chemicals, construction, electrical equipment, electronics and ICT, flame retardants, low-carbon technologies, photonics, packaging, steel and steel alloys, and textiles. Of these, three were discussed in detail:

- Aerospace (rhenium in superalloys): Strategies for reducing rhenium risk in the aerospace industry were identified; substitution in or of alloys, improved recovery, and stockpiling as a temporary measure.
- Automotive (electric vehicles): Improvement in battery recycling technology to increase recovery rates of materials, shifting away from meeting the legislatively required minimum. Strategies to mitigate risks associated with rare earth motors were highlighted as securing alternative supplies, minimising demand in magnets and seeking substitute motor types.
- Low Carbon Technologies (wind turbines and lighting): Rare earth elements were used in both wind turbines and lighting. Diversifying supply, and putting a framework in place for end of life recovery (possibly through circular economy actions), were highlighted.

Learning from this study

This study was UK-based, and focussed on the manufacturing industries; therefore the recommendations are relevant to this study. It should be borne in mind that this study looked at the long term, therefore some of the findings and recommendations may be outside the scope of this present work. It also formed part of much larger study, providing an overview of the future of the manufacturing industry as a whole.

However, as with the present study, this is one of the few studies that compared mineral, hydrocarbon and biotic based resources. Differing risks were associated with these resources, which require consideration in responses. A key finding was that there are very few truly scarce resources in the long term, and it is other short to medium term factors which have a greater influence on supply risks.

Five key response areas were identified that are relevant to Scotland, as all of these approaches are possible in some form; for instance, diversifying supply, developing knowledge base for raw materials in Scotland, or developing resource efficiency strategies in key applications. In addition, sectors were identified which tie into the economic plan for Scotland, with specific actions highlighted (e.g. renewables, construction and aerospace). Strategies identified for these sectors are relevant to this work.

4. Study 4 - Study into the Feasibility of Protecting and Recovering Critical Raw Materials through Infrastructure Development in SE England, EPOW, 2011

This study identified actions to improve the recovery of CRMs from end of life products. Though the study focussed on a region in England, the scale and nature of the study means the findings are appropriate on a UK- and EU-level.

The analysis used a pre-defined set of CRMs from the EU critical raw materials study (14 metals and minerals, see Study 6). Analysis of the applications of these materials identified 12 industrial sectors where these materials were most relevant based on use data: aerospace, automotive, batteries, catalysts, cemented carbide tools, chemicals, construction, electrical equipment, electronics and it, flame retardants, optics, packaging, steel and steel alloys. The uses in these sectors were analysed, and potential recovery options identified through a screening exercise.

Ten opportunities, linked to specific applications, were highlighted as having high potential for recovery of CRMs (Table 9). These were divided into three categories: growing existing markets through strategies such as improved end of life recovery, implementing new recovery activities and technologies, and potential future prospects for recovery.

Table 9: Ten opportunities for CRM material recovery highlighted by the EPOW study

	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

A further eleven opportunities were identified as having medium potential for increased recovery. When all opportunities were analysed against the relevant materials, the 14 CRMs were split into two groups: those for which recovery has potential to reduce demand (antimony, cobalt, indium, magnesium, PGMs, REE, tungsten), and those for which other options may be more suitable (beryllium, fluorspar, gallium, germanium, graphite, niobium tantalum).

More broadly, common factors which hindered recovery were highlighted, which were often linked to the small quantities CRM use compared to other materials, or their dispersed usage:

- Inefficient collection at end of life.
- Separation is unfavourable for recovering CRMs.
- Dispersion of materials into low concentrations making recovery difficult and uneconomic.

- Uncertainty over quantities and qualities in waste streams limits investment in new recycling activities.

Based on the analysis, a series of recommendations was made to increase the recovery of critical raw materials in general:

- Improved end-of-life collection.
- Development of advanced sorting techniques for waste, moving away from shred and sort.
- Implementation of new technologies to recover CRMs.
- Linking of agents along supply chain, from design phase through disposal, to increase understanding of the issues.
- Design for disassembly to improve the ease of sorting and separation of parts containing CRMs.
- More sophisticated waste recovery targets, moving away from weight based measures.
- Alignment and enforcement of existing regulations to provide a more solid framework for processors.
- Remanufacturing and re-use as activities which sit alongside other resource efficiency actions.

Learning from this study

This study identified where possible actions could be made to improve the end of life recovery of the EU 14 CRMs (see Study 6). Many of the high level recommendations can be applied at an EU, national or regional level, with approach tailored to suit. For instance, waste recovery targets can be implemented at each level, but the specific approach may vary. Other recommendations are perhaps broader, such as linking agents along the supply chain, requiring wider involvement from business and governments.

Of particular relevance to this work are the recommendations for improving end of life recovery, through better design, collection and separation. Providing more evidence for the composition of waste would improve business confidence in recovery processes, which could increase recovery rates. Measures such as improving collection and separation can be made at a regional and national level within Scotland. However, the study also identified that certain initiatives (for instance the recovery of indium) may only work on an EU or multiple country scale due to the small quantities and value of material involved.

This work was done at the sector-level, and there is some alignment between the sectors between studies. Of most relevance are those linked to wind turbines, where recovery of magnets could be an important source of material in the future, and better recovery of materials from aircraft could have an impact on supply.

5. Study 5 - Inquiry into Strategically Important Metals, UK Government, 2011

As a result of growing concerns over supply risks of metals which are viewed as strategically important to the UK, a report was ordered by the Science and Technology Committee of the House of Commons. The report included formal minutes, and oral and written evidence.

The scope of the discussion was relatively broad, with "strategically important metals" used to describe the metals of interest (non-metals are outside the scope of this work). The definition specifically included PGMs, REEs and other main group elements that are of importance to the UK - such as specialist metals essential for advanced manufacturing, low-carbon technologies and other growing industries. Specific specialist metals mentioned were antimony, beryllium, chromium, cobalt, gallium, germanium, gold, hafnium, indium, lithium, magnesium, nickel, niobium, rhenium, tantalum, titanium, tungsten, and vanadium.

Several aspects related to materials supply were investigated, including domestic extraction, trade and geopolitics, social and environmental impacts of metal extraction, and metal use efficiency. Discussions were used to form conclusions and recommendations for the UK.

Overall it was concluded that strategic metal reserves are unlikely to run out; however, the perception of scarcity has led to increased speculation and volatility in price and supply. Therefore greater information on the situation around strategic metals was required. In addition it was highlighted that the UK was highly dependent on imports for many materials, and globally there may have been only one or two suppliers of certain speciality metals. The following actions were recommended:

- Ensure 'joined up' thinking within government on resource issues to support businesses.
- Undertake a review of metal resources in finished and semi-finished goods and waste in the UK. This will help to identify routes to the recovery of strategic metals, and will also allow the economic potential of recovery and recycling to be understood.
- Embrace a cradle-to-cradle approach for products, including design for disassembly to allow product re-use and remanufacturing. This will enable small quantities of materials to be recovered and used efficiently.
- The Government should actively work towards the export of strategic materials, particularly in scrap and WEEE. This has environmental as well as resource benefits.
- The Government should develop a better understanding of domestic mineral resources, through classification of strategic metal reserves. Exploitation should take a route whereby the lowest environmental impact is achieved.

Learning from this study

Though this analysis is UK wide, the high level recommendations are also relevant to the Scottish economy. Actions such as better communication and knowledge sharing, identification of routes for recovery, developing cradle-to-cradle products, and understanding domestic resources are all relevant to this work. However the recommendations are quite broad, therefore their purpose requires consideration within the context of this study to ensure appropriate action at a Scottish level.

6. Study 6 – Critical Raw Materials at EU Level, European Commission, 2010 & 2014

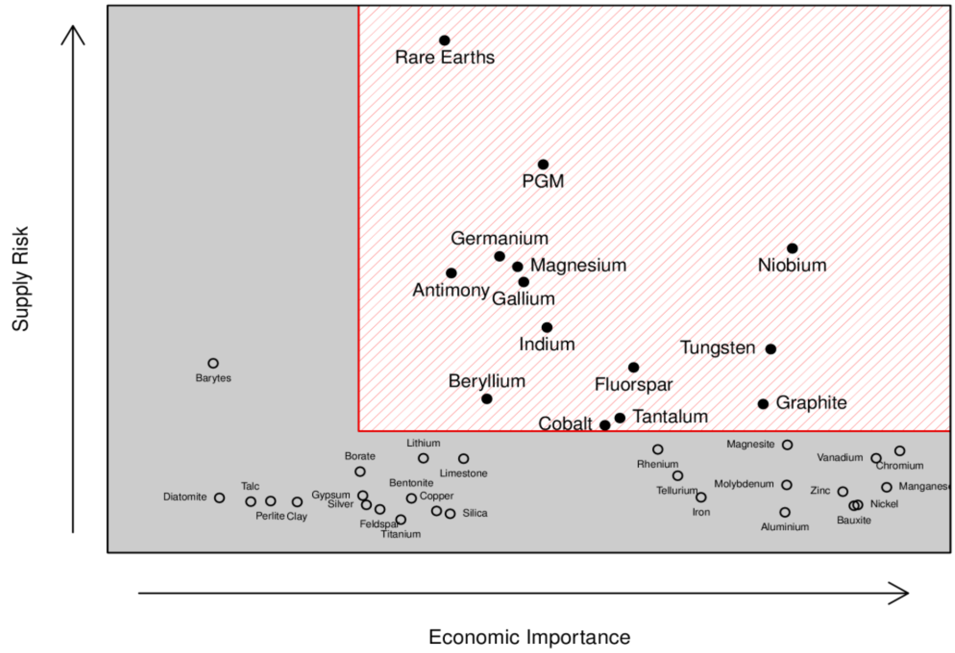
The European Commission's response to concerns over access to raw materials was to launch the Raw Material Initiative (RMI) in 2008. The RMI sits on a three-pillared strategy:

- Ensuring a level playing field in access to resources in Third Countries.
- Fostering a sustainable supply of raw materials from European sources.
- Boosting resource efficiency and promoting recycling.

As part of this work, a study identifying the materials critical to the EU was published in 2010; this study is currently undergoing an update. The update will assess a set of materials which are important to the EU, and identify those which are considered the most critical relative to each other. The original study was an output of the EU's Ad Hoc Working Group on defining critical raw materials (AHWG), which brought together experts in the raw material sector. This assessment will be repeated at regular intervals to ensure it remains up to date, with the results of the next study published in early 2014.

The scope of the 2010 work comprised 42 raw materials, which included metals and minerals. These were evaluated using a measure of economic importance to the EU against supply risks (based on country governance and environmental performance). 14 materials were identified as critical to the EU: antimony, beryllium, cobalt, fluorspar, gallium, germanium, graphite, indium, magnesium, niobium, PGMs, REEs, tantalum, and tungsten (Figure 10).

Figure 10: Results of EU 2010 Critical Raw Material Analysis



Source: EU CRM study 2010, representation of data by Fraunhofer ISI

The next study is in press at time of writing, but the scope has expanded to include a wider range of abiotic materials and three biotic materials (natural rubber, pulpwood, and sawn softwood). In total 54 materials are included in this new study.

As part of the previous study the AHWG made recommendations relating to several areas, outlined below. Whilst a list of critical raw materials was produced as part of the study, these actions generally apply across all raw materials:

- **Improving data availability on raw materials,** through actions such as developing consistent statistical information, preparing a European Raw Materials Yearbook, encouraging LCA work for raw materials, and analysing the impact of emerging technologies on demand of raw materials.
- **Policy actions to improve access to primary resources,** such as supporting findings on best practices on land use planning and permitting. It was recommended that the EU

promotes exploration activities, research of mineral processing, good governance and sustainable exploration.

- **Trade and investment** were highlighted as an important area for raw material supply, and included recommendations on maintaining EU Policy of trade agreements, engagement with extra-EU countries, raising awareness of export restrictions, and increasing the coherency of EU policy in this area.
- **Recycling of raw materials and raw material containing products** was identified as an important area to develop, for example through better collection of end of life products, improvement in effectiveness of recycling chains and systems optimisation, and preventing illegal exports of end of life products containing CRMs.
- **Improvement in overall materials efficiency of the critical raw materials,** through developing substitutions for certain applications, minimising the use of CRMs in some applications, developing smart production techniques to reduce CRM use, and minimising raw materials losses in productions.

In addition to these recommendations, the results of the study (and particularly the list of critical raw materials) has been used widely across many initiatives related to raw materials and criticality, both at an EU and Member State level (for example, see Studies 3 and 4). At an EU level, FP7 funding has been linked to finding substitutes for the CRMs and the recently launched European Innovation Partnership on Raw Materials seeks to address many of the issues raised by this study and the Raw Materials Initiative more widely.

Learning from this study

This study provided an overview of the critical raw materials for the EU as a whole, considering metals and minerals. The approach used allows the whole economy to be considered within one study; however, certain key materials in sectors may be overlooked due to the methodological approach and purpose of the work. However, the intention of the study was to raise awareness across all materials, not just those identified as critical. A similar intention may be sensible for this present study.

As with many of the other studies, the recommendations from this study are relatively broad, identifying high level responses. These can be considered within certain types; e.g. maintaining access to primary supply, advancing recycling, or improving material efficiency. In general, these responses are all relevant to this work. However, as before, it is important to consider the context of each of the study to provide more specific actions matching the requirements of this work.

7. Study 7 - Critical Metals in Strategic Energy Technologies, EU JRC, 2011 & 2013

The purpose of these two studies was to assess bottlenecks and risks associated with metal supply which could influence the implementation of the European Union's Strategic Energy Technology Plan (SET-Plan) for low carbon energy technologies. The SET-Plan outlines the EU's strategy for the implementation of energy generation and distribution technologies required to meet carbon emission reduction targets in the EU for 2020 and beyond. The demand for metals was assessed for the 17 priority technologies as outlined within the SET-Plan (six priority technologies in the first study and the remainder in the second). This information was used to identify where metal supply issues or risks might occur as a result of introduction of these low carbon technologies on a scale required by the SET-Plan

In all, the SET-Plan requirements of 60 metal elements were assessed (iron, aluminium and radioactive metals were excluded), and a further 32 metals were assessed to identify where bottlenecks may impact on the implementation of the technologies. Bottlenecks for these significant metals were assessed using four criteria falling into two categories to assess an overall risk factor associated with their future supply:

- Market factors:
  - likelihood of rapid global demand growth for the metal
  - limitations on expanding production capacity in the short- to medium term.
- Political factors:
  - supply concentrated from a limited number of countries
  - political risk of associated with major supplying countries.

This assessment was performed qualitatively, assigning each as 'high', 'medium' and 'low' based on factors including reserves, production, key applications, processing routes, dominant production countries, price developments, and supply and demand forecasts. This resulted in a classification of criticality for the metals (Table 10).

Table 10: Criticality ratings of shortlisted raw materials for both JRC studies

High	High-Medium	Medium	Medium-Low	Low
REE: Dy, Eu, Tb, Y	Graphite	REE: La, Ce, Sm, Gd	Lithium	Nickel
REE: Pr, Nd	Rhenium	Cobalt	Molybdenum	Lead
Gallium	Hafnium	Tantalum	Selenium	Gold
Tellurium	Germanium	Niobium	Silver	Cadmium
	Platinum	Vanadium		Copper
	Indium	Tin		
		Chromium		

The study considered three ways of mitigating the supply-chain risks for the critical metals, with an EU focus:

- **Increasing primary supply:** The development of REE mines in the EU was suggested, along with increasing extraction from existing mining wastes. For gallium and tellurium, the data indicate that Europe already has a degree of self-sufficiency; however, opportunities may exist to create further refineries to boost recovery of these materials.
- **Reuse/recycling and waste reduction:** Development of opportunities and initiatives for the recovery of post-consumer waste streams, for example from HDD magnets and lighting phosphors.
- **Substitution:** Investigate reduction and substitution of the critical metals in the low carbon technologies and more widely.

Other findings from the work included concluding that implementing policy at an EU level was advantageous for international trade, setting regulations and disseminating best practice. However, it was recognised that Member States will sometimes have their own particular national interests, and have a key role in implementing EU regulations in their national settings. In addition, better coordination and knowledge exchange between EU and Member State initiatives may be valuable.

A number of topics were identified for further research related to technological uptake; for example, development of scenarios for different technology mixes, application of similar work to other sectors such as aerospace and defence, improving statistics on recycling of metals, and assessing the impact of greater traceability and transparency in reducing raw materials supply risk.

Policy actions were identified to mitigate raw materials risks for the EU pathway to decarbonisation; these fall into six categories:

- **Data collection and dissemination**
- **Resource efficiency**
- **International cooperation**
- **Primary supply**
- Design & innovation
- Stockpiling & procurement

Learning from this study

This study directly addressed low carbon energy technologies, which includes one of the key sectors targeted for growth in Scotland. However, the scope only extended to metals used within these technologies. The metals of most concern are several of the REEs, gallium and tellurium. These particular metals are linked to the production of wind turbines, solar panels and low carbon lighting technology. Opportunities, particularly for magnets, arise from increasing/diversifying supply, improving recovery and substitution. However, it is also important to consider where Scottish companies sit in the supply chain before identifying opportunities for Scotland to ensure they are relevant to businesses.

8. Study 8 - Critical Materials Strategy, US Department of Energy, 2011

This report was prepared by the Department of Energy (DOE) in the US due to concerns over the short (to 2015) and medium term (to 2025) supply of material supply risks associated with the deployment of wind turbines, electric vehicles (EVs), solar cells and energy efficient lighting.

The methodology pre-selected 16 metals for assessment against different short and medium term risks. These metals were cerium, cobalt, dysprosium, europium, gallium, indium, lanthanum, lithium, manganese, neodymium, nickel, praseodymium, samarium, tellurium, terbium and yttrium.

Within the assessment, some attention was given to the US specifically; however, the study used international scenarios and roadmaps to determine future materials demand. These scenarios were used to construct estimates for the material consumption for each of the key materials to 2025. The study then assessed the criticality of the materials using two criteria, which were comprised of weighted factors scored out of 4:

- Importance to clean energy: clean energy demand (75%) and substitutability limitations (25%)
- Supply risk: basic availability (40%), competing technology demand (10%), political, regulatory and social factors (20%), co-dependence with other markets (10%), and producer diversity (20%).

Supply risk was considered for the short term (to 2015) and for the medium term (to 2025).

In the short term, five rare earth metals (dysprosium, neodymium, terbium, europium and yttrium) were identified as critical. Other elements (cerium, indium, lanthanum and tellurium) were found to be near-critical. The relative criticality alters slightly in the medium term; however, the same metals remain critical.

The outcomes of this study have been used to inform the DOE's strategy for addressing critical materials challenges. This is defined by three pillars:

- Diversification of global supply chains, through developing multiple sources of materials, both within the US and other countries.
- Developing materials and technology substitutes.
- Reducing demand through enabling recycling, re-use and more efficient use of materials. This includes research and policy measures.

The DOE responses are mainly R&D focussed due to their strategy, which relates R&D to each of the three pillars highlighted. The need for a systems-based approach which can apply across a supply chain was also identified, as well as the need for Government agencies to coordinate activities, with an inter-agency working group on critical raw materials used as a mechanism to achieve this.

Learning from this study

As in Study 7, this analysis focussed on the metals used for low carbon technologies. The findings are broadly the same as the EU study, identifying similar metals as the greatest materials risk to implementing these technologies. A similar set of recommendations is made, including diversification of supply chains, developing substitutes and improving recycling, re-use and materials efficiency. Similar strategies could be applied to the Scottish renewables sector, with appropriate implementations for the Scottish Economy.

9. Study 9 - Research Priorities for More Efficient Use of Critical Materials from a US Corporate Perspective, General Electric, 2010

This study, produced by GE, took a manufacturing company's perspective on criticality of raw materials. Within this study GE identified that its activities use 70 of the first 82 elements in the periodic table. Therefore the purpose of the analysis was to identify the materials that GE uses which are most at risk of supply constraints or price increases, and take actions to minimise the risks. Some of the information contained in the methodology, and more especially in the results, is proprietary and was not fully published.

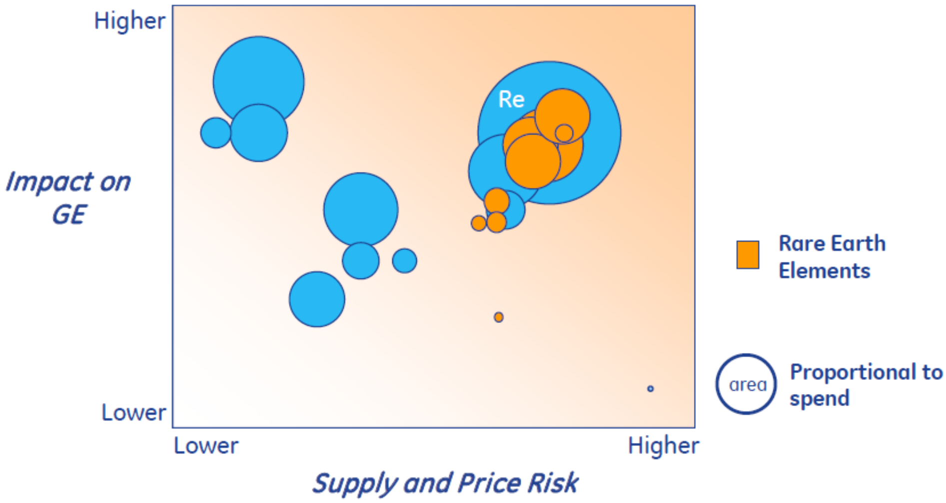
An initial screening focussed the study on 24 elements, based on annual purchase value within GE. From this list, 11 (minor metal) elements were selected for detailed risk analysis, on the basis that these non-commodity elements could have significant price deviations due to constrained supply. As with other studies, GE's methodology used two axes: impact of restriction on GE, and supply and price risk. Both of these had a number of sub-risks, each of which was rated with a score of between 1 (very low) and 5 (very high). These sub-risks were then averaged to determine an overall score for that axis. The sub-risks were:

- **Impact of restriction on GE:** GE % of world supply, impact on GE revenue, GE ability to substitute and ability to pass through cost increases.

- **Supply and price risk:** abundance in the earth's crust, sourcing and geopolitical risk, co-production risk, demand risk (growth), historic price volatility (last five years only) and market substitutability.

Of the eleven elements selected for the risk analysis, seven were designated as being critical and identified for further development planning internally (Figure 11). However, only rhenium was specifically identified, and some REE highlighted. However, rhenium was highlighted as the most critical, due to its use in superalloys, primarily in GE's high efficiency turbine engines. REEs and tellurium were also among those thought to have been identified as being critical; however, GE regarded the results as being proprietary and the full list was not available for review within this report. In addition, further analysis and factors were known to have been considered which were relevant to GE's on-going business.

Figure 11: Results of GE's criticality analysis



Source: GE Presentation, Trans-Atlantic Workshop on Rare Earth Elements and Other Critical Materials for a Clean Energy Future, 2010

Generic options for OEMs to address metal supply changes were outlined, linked to three aspects of risk mitigation:

- **Sourcing:** Volume materials buys, diversification, hedging, global sourcing, strategic inventory reserves.
- **Manufacturing:** Maximize recycling of manufacturing scrap, use of recycled materials, minimise use of at-risk process material
- **Engineering/R&D:** Design for ease of recycling and re-use, material design, substitution (material and system).

Each of these responses was identified as different timescales for impact, and each addressed factors associated with broadening sources, optimizing usage or redesign of materials. It was highlighted that each element and each application would require a unique mix of these options, though specific examples were not provided. However, while the full analysis is not available, an indication of interest, approach and outputs from a corporate perspective provides useful insight.

Learning from this study

This study demonstrates that analysis can usefully be performed for a company in addition to the sector- or economy-wide analyses performed elsewhere. This also allowed the company to understand the risks and develop suitable mitigation strategies for its supply chain. Whilst the full analysis is not available, this report demonstrates the broad approach and some of the results, which are comparable to other criticality studies. Therefore a company (or group of similar companies) could undertake an analysis of this type if it was particularly concerned over understanding raw materials risks. This could be appropriate for certain key businesses or sectors within the Scottish economy, enabling a better understanding of specific raw material issues, allowing materials to be prioritised, and appropriate and specific responses to be developed.

10. Study 10 - Resource Revolution: Meeting the World's Energy, Materials, Food and Water Needs, McKinsey, 2011

This high level report discussed the possible outcomes of predicted increases in the price of natural resources, including energy, food, water, and materials, over the next 20 years following several decades of price decreases. Rather than being a criticality assessment as such, this work discussed the changing global factors influencing prices and risks associated with these resources. These discussions were made in the context of changing business risks and opportunities associated with a shift from existing resource-intensive growth models. Five areas were discussed relating to the supply and demand of these resources:

- The shift from progressively cheaper resources that underpinned global economic growth during the 20th century.
- The possibility of entering an era of high and volatile resource prices due to tighter markets. Several concerns were considered:
    - Growth of middle class in emerging markets.
    - Increased demand for resources combined with more challenging conditions for supply.
    - Increased interdependence between resources.
    - Environmental factors influencing production.
    - Concerns over inequality.
- Meeting future demand would require expansion of supply; however this could be more challenging than in the past.
- Instigating a step change in resource productivity to reduce demand was likely to be needed to meet growing demand.
- The need for additional efforts to address climate change and universal access to energy.

These concerns were used to highlight the complex situation that policy makers and businesses were faced with when dealing with these issues. The report identified the need for organisational awareness and action; for example, the need for an integrated approach across Governments is highlighted and land use concerns could fall between agriculture, forestry and the environment, as well as other stakeholders.

Three key areas of action for governments were outlined aiming at high level interventions to provide more favourable conditions for investment:

1. **Strengthen price signals.** Decreasing uncertainty in future resource prices would provide confidence to investors to seek out opportunities to invest. It is proposed that subsidising certain resources (water, energy, agriculture) and setting a carbon price would increase the attractiveness of these sectors to private-investors. Providing greater certainty over renewable energy schemes would give confidence to investors in this area, and potentially increase returns making investment more attractive.
2. **Address (non-price) market failures.** Dismantling of various market barriers by governments was highlighted as a way to reduce failures in resource markets; for example, giving clarity to property rights, or increasing the availability of capital (through mechanisms such as loan guarantees) to encourage financial institutions to lend. This could involve the sort of collaborative approach between multiple parties seen in some countries. Removal of barriers to innovation was also outlined, as innovation is necessary to meet future resource challenges; for instance, actions to provide a stable macro-economic environment, facilitate vigorous competition, develop more open international trading rules, and implement greener government procurement rules were described.
3. **Build long term resilience.** Measures to develop longer term societal resilience to resource challenges were outlined. These included raising awareness of resource related risks and opportunities, creating appropriate safety nets to mitigate impacts on poorest members, and educating businesses and consumers to modify behaviour.

Changes to business strategy due to increasing resource risks were highlighted, requiring a shift from capital and labour costs to focussing on resource productivity. This required that businesses understood the risks associated with their particular circumstances and sector, and that appropriate mitigations were taken; for instance, developing a clearer understanding over how resources may influence their profits, identifying new growth opportunities and technology discontinuities, and appreciating how new stresses may occur in risk management.

Opportunities for specifically increasing resource productivity were highlighted within this work - linked to energy (excluding shale gas and renewables), land, water and steel production. The 15 priority opportunities identified were:

1. building energy efficiency
2. increasing the penetration of EVs and HEVs
3. increasing yields on large-scale farms
4. reducing land degradation
5. reducing food waste
6. improving end-use steel efficiency
7. reducing municipal water leakage
8. increasing oil and coal recovery
9. urban densification (leading to major transport efficiency gains)
10. improving irrigation techniques
11. higher energy efficiency in the iron and steel industry
12. shifting road freight to rail and barge
13. increasing yields on smallholder farms
14. improving power plant efficiency.
15. increasing transport fuel efficiency
16.

Learning from this study

This forward looking study looked at potential issues in the future, linked to changes in the supply of raw materials. This study was at a high level, considering a wider set of materials than most analyses, such as water and food. Several actions are identified for governments, whilst these at a high level, they support the findings of many of the other studies and are likely to be relevant for the Scottish economy if correctly applied. Fifteen strategic opportunities are identified; many of these will be relevant to Scotland in the context of this work if an appropriate way to implement them can be found.

11. Study 11 - Minerals and Metals Scarcity in Manufacturing: the Ticking Timebomb, PWC, 2011

This document discussed growing concerns over access to raw materials due to demand increased linked to growing global population, rising GDP, and changing lifestyles. Executives of major manufacturing companies were surveyed to gauge their opinions and understanding of minerals and metals scarcity, and potential impact in coming years. This survey covered seven manufacturing sectors; automotive, aviation, chemical, energy & utilities, high tech, infrastructure, and renewable energy.

The document did not specifically carry out an analysis of which materials are critical, though dimensions of scarcity were identified:

- Physical (not accessible, depletion of reserves).
- Economic (price volatility, market developments).
- Geopolitical (export controls/barriers, conflict regions).

Instead, responses on six topics linked to resource security were gathered; the conclusions from these are summarised below:

- **Importance of materials scarcity:** Minerals and metals scarcity were identified as important issue in these industries, and were considered more important compared to issues such as energy scarcity, water and land use. However, awareness across stakeholders was perceived as being poor.
- **Scale and future of risk:** Materials scarcity was identified as a business risk that is significant now, and will grow over the next five years. Sectors particularly affected were renewable energy, automotive, energy and utilities and aviation. However, companies also perceived this as an opportunity.
- **Impact of scarcity:** Companies expected the impact of scarcity to be felt across supply chains due to the crucial nature of certain metals and minerals and for this to particularly affect the renewable energy and infrastructure sectors. It was believed that impacts would increase in the near future, particularly in the Asia/Pacific region and particularly in the chemical, energy & utilities and high tech sectors.
- **Causes:** The rapid increase in demand for certain materials was perceived as the primary cause for scarcity. However, scarcity was also is linked to supply constraints limiting availability to meet this growing need. Here economic and political influences were perceived as having a greater influence than physical influences over the timescales considered.
- **Readiness:** The state of “preparedness” to mitigate the impact of scarce materials varied across sectors. For instance, based on company policy, renewable energy and automotive sectors indicated a high level of preparedness, whereas the chemical and high tech sectors were less well prepared.
- **Mitigation:** Several mitigation strategies were highlighted for businesses, with more efficient utilisation of resources (resource efficiency) viewed as the most plausible response to scarcity by the responders. Cooperation across supply chains was highlighted as an important mechanism for reducing impacts of materials scarcity.

> Other important strategies were identified as supplier diversification, more R&D, and geo-diplomacy. Information, substitution and regulation were considered as required as well. Strategies relating to primary production were viewed as less important.

Overall the analysis of the survey found that, at a global manufacturing industry level, the awareness of materials supply issues was good, and that most sectors surveyed had a good understanding of the issues and the causes behind these issues. The level of preparedness varied across businesses and sectors, perhaps indicative of the different nature of the businesses found in each. Awareness of mitigation strategies was also good across the businesses surveyed, with many identifying internal actions such as resource efficiency, substitution and R&D as important actions. However, a clear need was identified for policymakers to play a role in actions such as developing geo-political and trade solutions, as well as in implementation of regulations. Development of primary supply was viewed as less important by the responders, perhaps due to the timescales considered.

Learning from this study

This study highlights the impact to business and its concerns related to raw materials, with the observations coming directly from an industry perspective. The approach taken, and the range of sectors covered, is similar to that in this study, though different company types are likely to have been approached. The report identified several business strategies for mitigating the impact of raw material scarcity that can be applied in an appropriate way for this work; for example, supporting companies to improve resource efficiency, to invest in relevant R&D and to improve communications along supply chains. However, it was also identified that policy makers also need to play a role through supporting actions.

12. Study 12 – Lanthanide Resources and Alternatives, UK Department for Transport, 2010

This study evaluated the impact of supply constraints for REEs on the uptake of EVs and wind turbines in the future from a UK perspective. The key REEs used for these applications are neodymium, dysprosium and terbium (for the permanent magnets in wind turbines and EVs) and lanthanum (for the NiMH batteries in some EVs, particularly HEVs). Scenarios for technology uptake and supply were constructed to evaluate imbalances, and identify mitigation strategies. As the material and technology scope of the work was predetermined, no criticality analysis was performed; however, the study identified that shortages were expected for key metals such as dysprosium and terbium. Supply of neodymium was predicted to be a limiting factor for the penetration of REE magnet-based generator wind turbines for energy generation unless there is a very strong growth in the long-run supply.

Mitigations strategies were identified; these included using alternative technologies to eliminate or reduce the quantity of REE used in EV motors and wind turbines. This was believed to be most likely to occur through alternative motor and generator technologies rather than new magnetic materials. Alternative Li-ion based battery technologies were identified as direct replacement for incumbent NiMH batteries. Recovery of REE was identified as a possible area for growth. Some development of hard disk magnets was identified; however, this is limited by yield and cost. At the time of the report reprocessing this material into new magnets was difficult. However, recycling was identified as becoming more relevant in the future as large magnets become available from end of life EVs and wind turbines.

It was identified that, within the UK, primary supply was unlikely to be viable, nor was there academic expertise or industrial capacity for fundamental magnet development. Research into magnet recycling was identified. It was recommended that the Government supported an application-focused development of REE magnets, and of whole lifecycle management (through product life extension, remanufacturing, re-use, and recycling). These actions could take a collaborative approach with the EU, USA and Japan.

Learning from this study

This analysis closely looked at two specific technologies; wind turbines and electric vehicles, finding that resource constraints may influence the implementation of these technologies in the future. As with other studies, several mitigation strategies were identified, including recovery of scrap materials, collaboration with other countries, and developing recycling expertise. Each of these could be viable for Scotland in the future, and are relevant to the Economic Growth Plan.

Annexe B: Supporting Data

Survey pro forma

Scottish Enterprise Study: Important Materials to the Scottish Economy

As a business based in Scotland we ask a few moments of your time to think about the questions below relating to raw materials' issues. Responses can be discussed over the phone, p***lease let us know if there is a convenient time to do so by contacting Dan Skinner;*** dan.skinner@oakdenehollins.co.uk ***or 01296 423 915. Alternatively please complete the form yourself and return via email to Dan.*** Data supplied will be anonymised and only used as part of a wider analysis.

Raw materials could include metals and minerals, agricultural and food inputs, construction materials such as bricks and timber, and basic components. Finished products, energy materials such as oil, gas, coal and biomass are excluded.

Company and Contact Information

Company:	Click here to insert	Postcode:	Click here to insert
Contact Name:	Click here to insert	Position:	Click here to insert
Contact Details:	Email/Telephone		
Industrial Sector:	Select a sector	Other?	Please describe
Main Product(s):	Click here to insert		
Company Size: (Scottish based)	Select a size	What proportion of your production is Scottish based?	%?

Reliance on raw materials

What are the main materials (or components) that your business is reliant on?	Please outline here
How important are raw material inputs to your business?	Please select one
Which materials are most important to your business and why? (please consider factors such as risk to business as well as cost)	Please discuss up to three

Raw materials issues

In the past 2 years has your business been affected by issues relating to material supply? E.g. uncertainty of supply, price changes, etc…	Yes/No?
For the materials your business relies on, are you aware of any changes in (1) frequency of occurrence of threat to supply or (2) size of risk to supply?	(1) Yes/No? (2) Yes/No?
If yes to any of the above;	

• Which materials have been most affected?[185]	Please add up to three
• What are the specific issues faced? • How have they affected your business?	Please describe here in as much detail as possible
• What has your response been?	Please describe here in as much detail as possible
• Have you, or would you consider using industrial biotechnology as a solution?	Please describe here
Do you foresee the existing situation for material supply changing? If so, for which materials and over what timescale?	Please describe here
What is your longer term strategy for managing raw materials issues?	Please describe here
What and where are other risks along your supply chain?	Please describe here
How does raw material risk compare in terms of importance?	Please select one
What are the risks you would rank above material risk, and why?	Please describe here

Wider concerns over raw materials

Critical raw materials that experience a high importance to business and a high supply risk have been defined at a Scottish, UK and EU level. Which of these studies and discussions are you aware of?	Please describe here

Opportunities and threats to the Scottish economy

Are there any <u>opportunities</u> to business arising from issues/risks relating to raw materials?	Please describe here
Are there any <u>threats</u> to business resulting	Please describe here

[185] Please consider raw materials in the broadest sense.

from issues/risks relating to raw materials?	
Where is support for raw materials supply issues most needed? E.g. research and development, sector initiatives, investment	Please describe here
What could the Scottish Government do to support Scottish industry? E.g. investment, industry groups, develop internal supply chain	Please add up to three

Other comments and site visits

Further comments	If you have any further comments please insert them here or use the next page
Would you be willing to discuss this in more detail over the phone or host a site visit?	Please Select

Thank you very much for your time. We will keep you informed on progress of this project.

Please return completed questionnaires to:

Dan Skinner, Oakdene Hollins, dan.skinner@oakdenehollins.co.uk, 01296 423 913

Contact details for the survey:

Scottish Enterprise: Clair Wright, Scottish Enterprise, Clair.Wright@scotent.co.uk,

SEPA: Lorna Walker, SEPA, lorna.walker@sepa.org

Further comments
Please add further comments here

About the authors

Adrian Chapman PhD MRSC, Senior Consultant

Adrian has a PhD in Green Chemistry and experience in technology transfer. His research has included case studies on the environmental impact of recycling and reuse strategies for a range of products, and advice to the EU on materials security of rare earth metals. He is a lifecycle assessment practitioner, using SimaPro and EcoInvent, and is registered by the Carbon Trust to carry out carbon footprint analyses to PAS 2050 methodology.

Dan Skinner PhD, Technical Consultant

Dan is a practitioner of SimaPro software for performing LCAs and has a background in computer programming and data analysis, including extensive experience of VBA scripting. His MSc is in the Science of Natural Hazards from the University of Bristol and his PhD in Environmental Risk is from Cranfield University. Dan is a Member of the Society for Risk Analysis.

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