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SUSTAINABILITY

Material Risk and Corporate Sustainability: a White Paper

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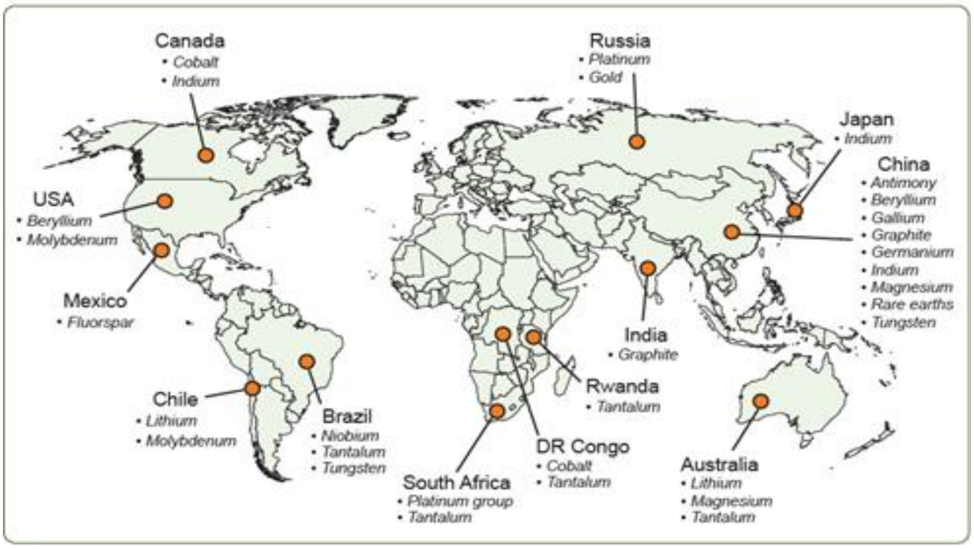

Contents

Image: Critical materials and the main nations from which they are sourced.

1. Introduction and Synopsis

A century ago, developed nations sourced materials locally or from colonies or dependencies under their control. Today, materials are sourced and traded globally, between independent nations, many with their own developed or developing manufacturing base. This change brings with it supply-chain risks that escalate as affluence and demand grow. Concern about these prompts nations to classify risk-prone materials with high commercial or strategic importance as "critical". Many of these critical materials derive from one or a very few source-nations, exposing their supply-chain to further restriction for geo-economic or geo-political reasons.

These supply-chain risks cause concern at the corporate as well as the national level. Sustainability in a material-dependent industry, from a corporate viewpoint, means assurance of stable, affordable raw materials. There are other constraints on material supply. Large price fluctuations can make them unaffordable, forcing substitution by alternatives. A growing body of environmental regulation can stifle extraction and refining of minerals and the metals and chemicals into which they are processed. Legislation in the US, the EU, and other countries prohibits the import and use of materials in which the revenue might be used to fund conflict or civil rights abuse. Pressure for ethical governance within a corporation also comes from share holders and employees.

At a practical level, corporate sustainability means anticipating risk. A recent survey[1] of the CEOs of manufacturing companies in Europe found that over 80% of them saw future raw material shortages and rising material prices as risks to their business. Similar surveys highlight the risks created by the ballooning body of legislation that restricts or bans, for health or environmental reasons, an increasing range of materials and chemicals. Further legislation sets new standards for product safety and consumer protection and prescribes the ways in which products must be treated at end of life. Complying with this legislation can be burdensome and expensive, yet failure to comply can mean loss of business[2]. On the material supply side environmental protection, climate change, and population growth contribute to volatility of supply. A company's engineers and designers contribute to its financial, environmental, and social performance. Awareness of wider implications of materials' choice helps to create a stronger position in a decision-making process. The competencies of a future engineer thus have to include not only technical but also business skills to manage complex projects with an involvement of international supply chains.

There is now an awareness that the long-term financial success of a company depends on securing the resources that it needs to do business: raw materials, human skills, a marketplace for its products, and a reputation that supports and expands market share. Success in this is measured not just in financial terms but in terms of stewardship of the resources on which the company draws and in the welfare of the employees and of the local economy of the regions in which the company does business. This broader view of corporate responsibility recognizes the value of natural and human as well as financial capital. Many companies now publish annual Corporate Sustainability Reports that document progress meeting the criteria of this "triple bottom line". They serve both to inform external stakeholders and encourage internal transparency and accountability. This White Paper explores material criticality and risk, and analyses how CES EduPack[3], and, in particular, its Sustainability database, can inform decision-making to respond to them.

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[1] Government Office for Science UK (2013) "Future of manufacturing: a new era of opportunity and challenge for the UK - summary report", London, available on-line: https://www.gov.uk/government/publications/future-of-manufacturing/future-of-manufacturing-a-new-era-of-opportunity-and-challenge-for-the-uk-summary-report

[2] Granta Design (2013) "Enabling product design and development in the context of environmental regulations and objectives" a White Paper, available on-line: http://www.grantadesign.com/emit/

[3] The CES EduPack Sustainability database is described in Section 5 in this paper and documented more fully in a companion White Paper, "Materials and Sustainable Development", by Ashby and Ferrer (2014).

2. Risk Analyses and Risk Mitigation

Sustainable corporate development requires anticipating and dealing with risk. Material-dependent companies are particularly exposed to risk from supply-chain disruption or breakdown of global markets, from legislation that renders their products uncompetitive or illegal, and from changing perceptions of company responsibilities. Risk can be managed by anticipating where change will occur and planning ways of dealing with it. Managing risk of this sort is part of corporate sustainability strategy. In this section we look briefly at risk associated with materials.

Figure 1. Emerging constraints that pose business risk.

Monopoly of supply and geopolitical risk–critical and conflict materials. Materials are sourced and traded globally. The ores and feedstock needed to make some of them are widely available, allowing a free market to operate smoothly. Others, however, are more restricted; the nations from which they come may limit supply for economic or political reasons. The result is disruptive price fluctuations. Political instability or armed conflict may interrupt supply completely. The supply chain of cobalt, for instance, was disrupted in 2007 by war in the Democratic Republic of the Congo (Figure 2), causing the price to treble.

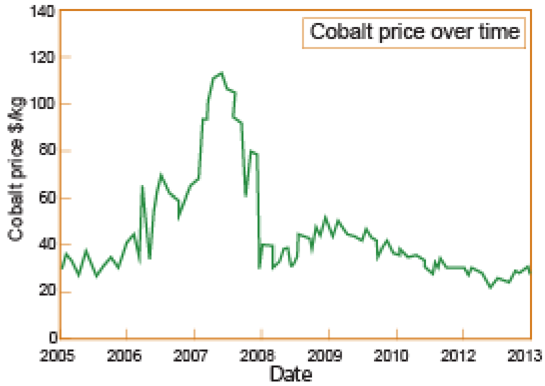

Figure 2 Cobalt price jumped by a factor of 4 when conflict in the Congo interrupted supply (InvestmentMine web site).

The price of rare earth elements (Figure 3) rose by more than a factor of 10 when China imposed restrictions on export in 2011. The price of nickel is set to rise after Indonesia banned exports of metal ores in 2014. Increasingly, ethical concerns inhibit the purchase of minerals from nations in which the proceeds might be used to fund conflict. The US Dodd-Frank act, for instance, creates trade barriers with nations in which ongoing conflict compromises human rights. Many of these are mineral-rich countries (Figure 4). The higher prices stimulate the development of resources in other nations and the search for substitutes, ultimately refilling the supply shortfall, but this process typically takes some years.

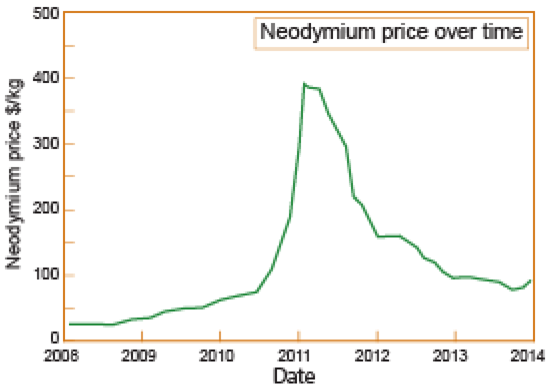

Figure 3. The price of the neodymium over time. Export restrictions in China caused the price spike. (InvestmentMine web site).

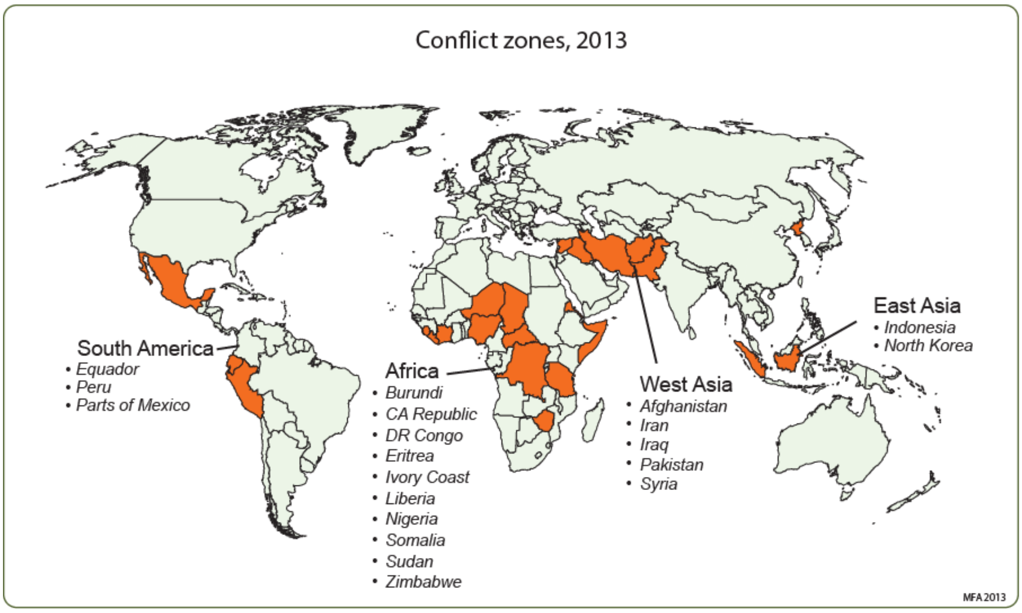

Figure 4 Nations with on-going conflicts in 2013.

Critical materials. Materials are classified as "critical" if access to them could be limited or because they are essential for national security or important economically (Figure 5 and Appendix 1). Governments draw up lists of these critical materials and develop strategies to ensure supply by stockpiling, negotiating exclusive supply agreements, or seeking new sources. The importance attached to critical materials is evidenced by the sheer number of such studies—at least five in the last three years, among them those of the US Geological Survey[4], the US Department of Energy[5], the American Physical Society[6], the European Union[7], and the British Geological Survey[8].

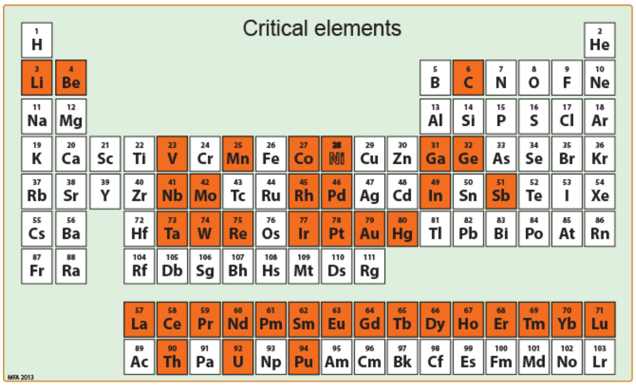

Figure 5. Elements identified as "critical", highlighted in red.

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[4] US Geological Survey (2009), available on-line: http://minerals.usgs.gov/east/critical/index.html

[5] US Department of Energy (2010), available on-line: www.energy.gov/news/documents/criticalmaterialsstrategy.pdf

[6] American Physical Society (2010), available on-line: http://www.aps.org/units/fps/newsletters/201107/jaffe.cfm

[7] European Commission, Enterprise and Industry Section "Defining 'critical' raw materials", available on-line; http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm

[8] British Geological Survey (2012), available on-line: www.bgs.ac.uk/downloads/start.cfm?id=2643

The lists are not identical—"criticality" depends to some extent on the needs and domestic resources of the nation—but they have a great deal in common. The lists act as warnings, alerting manufacturers of potential supply risk. The cover picture of this White paper shows the nations that, at present, control the supply of these critical materials (examples of critical materials are taken from the sources provided in Appendix 1).

The Herfindahl-Hirschman Index (HHI) is a measure of risk when the supply of a material is controlled by one or a very few nations. It is defined as $HHI = \sum_{i=1}^{n} f_i^2$ where f_i is the fraction of the market provided by nation i and n is the number of nations. It ranges from 0 to 1 (Figure 6). Thus if one nation has a complete monopoly of the market, the HHI = 1. If two have equal shares, the HHI = $0.5^2 + 0.5^2 = 0.5$. If the market is served by a very large number of source nations all of which have only a small fraction, the HHI tends towards 0. An HHI value below 0.1 indicates an unconstrained market. An HHI value above 0.25 indicates severe supply-chain concentration. Dependence on materials with supply-chain concentration carries risk of monopoly action, disruption of supply, and volatile pricing.

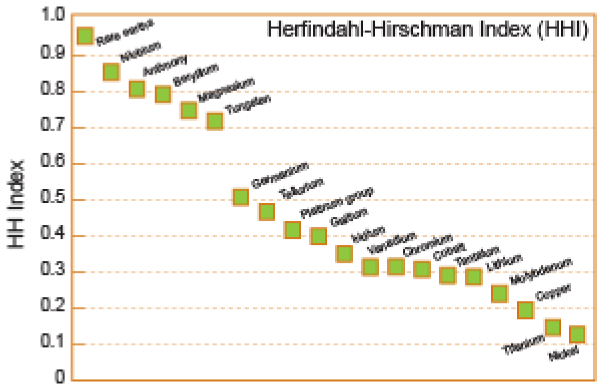

Figure 6 The HHI for a number of critical materials (Data from US Geological Survey, 2010).

Example: restricted access to raw materials[9]***.*** A number of nations are at present in dispute with China over free trade in raw materials. The dispute concerns certain measures imposed by China affecting the exportation of certain forms of bauxite, coke, fluorspar, magnesium, manganese, silicon carbide, silicon metal, yellow phosphorous, and zinc. Before the Panel, the United States, Mexico, and the European Union (the "complainants") challenged four types of export restraints imposed on the different raw materials at issue: (i) export duties; (ii) export quotas; (iii) minimum export price requirements; and (iv) export licensing requirements.

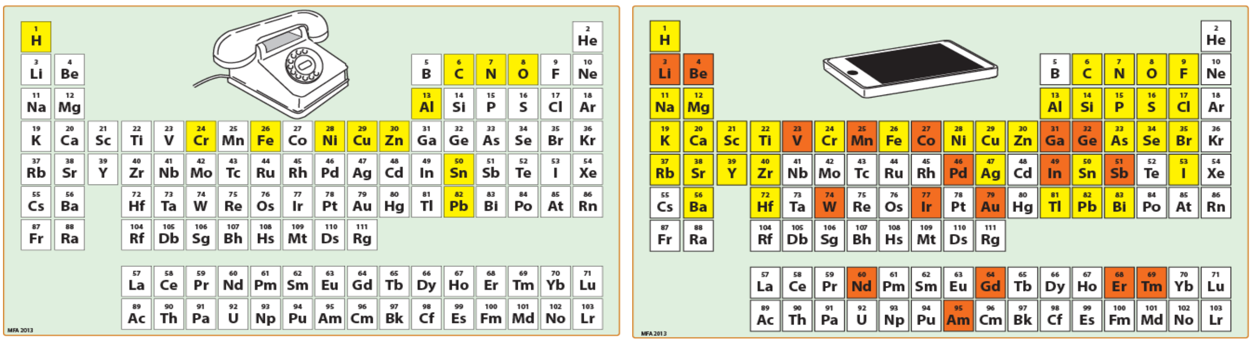

Figure 7 The elements in an electrical device of the 1950s, and those in a present day phone.

[9] European Commission, Enterprise and Industry Section "Defining 'critical' raw materials", available on-line; http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm

Material dependence. As mentioned earlier, the materials on which industry of the 1950s depended were relatively simple and plentiful. Today, sophisticated products incorporate elements that span most of the Periodic Table. Figure 7 shows two examples. The phone of the 1960s contained just eight elements for the frame, conductors, magnets, springs, and contacts, plus the carbon, hydrogen, and nitrogen of the phenolic or ABS casing. Mobile communication devices of today contain at least 53 elements[10] of which 18, colored red in the figure, are listed as “critical”. The same is true of most consumer electronics, of communication systems and transport, and (above all) of defence and security-related equipment.

Legislation and regulation. An expanding body of legislation, regulations, and standards address the impact of products and the materials they contain on the environment, society, and human health. They affect the entire product lifecycle, from substances used in manufacturing to disposal at the end of life. Table 1 gives examples from across the world covering topics such as reporting and restriction of the use of certain materials, energy usage, conflict minerals, and product disposal at end-of-life. Such legislation creates a considerable burden of compliance and reporting. It also creates risks by rendering key materials or processes obsolete or unobtainable.

Sector	Legislation
Registration and control of hazardous materials and chemicals	EU Registration Evaluation & Authorization of Chemicals Directive (REACH[11])
	EU Restriction of Hazardous Substances Directive (RoHS)
	EU Volatile Organic Compounds Directive (VOC)[12]
	US Toxic Substances Control Act (TSCA)
	California Green Chemistry Initiative
	Norwegian RoHS
	China REACH
	China RoHS
Ethical material sourcing	US Frank-Dodd Act
Energy and product design	EU Energy-using Products Directive (EuP)
	EU Energy-efficient Building Directive (EEB)
	France Grenelle 2 Regulations
Water usage	EU Water Framework Directive
End-of-life and control of waste	EU Waste Electrical and Electronic Equipment Directive (WEEE)
	EU End of Life Vehicles (ELV) Directive
	EU Batteries Directive
	Japanese Household Appliance Recycling Law (HARL)

Table 1. Examples of legislation that affect the use of materials, energy, and water.

[10] Elements in iPhone from Sheffield Hallam University study, cited by http://www.greatrecovery.org.uk

[11] European Commission (EC). Regulation No 1907/2006 of the European Parliament and the Council of 18 Dec 2006: Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH). Official Journal of the European Union. 2006, Vol. 49 (L396), pp. 1-849.

[12] European Commission (EC), Environment Section, available on-line: http://ec.europa.eu/environment/waste/batteries/index.htm

For long-lived products, such as aircraft engines, the possibility exists that the materials it contains may become restricted, requiring that substitutes be found and re-qualification be sought–an expensive imposition. To comply with this legislation a manufacturer must know the chemical background of the materials they use. Many polymers contain flame retardants or plasticizers. Chromium plating involves hexavalent chromium. Ordinary solder contains lead. Rechargeable batteries contain cadmium and long life, low drain batteries contain mercury. Many manufacturing processes involve the use of organic solvents. All of these are, at one level or another, restricted substances. Restrictions can cross national borders. Thus, a Japanese car-maker must comply with European or US legislation if they wish to sell their cars in those nations. In an era of globalization, national legislation has global implications.

Supply-chain risk management with the CES EduPack Sustainability resource[13]

The CES EduPack 2014 Sustainability Database* contains information about this legislation and provides data for managing material-related risks. The materials records of the database provide information about the nations from which materials are drawn and the supply-chain risk under six headings (detailed in Appendix 1):

- *Abundance risk*: the risk to supply associated with the fact that a material is present in exceptionally low concentrations in the earth's crust and oceans.
- *Monopoly of supply risk:* a measure of supply-chain concentration, the degree to which supply derives from one or a very few nations.
- *Geopolitical risk:* the risk that supply might be disrupted by political instability or civil unrest.
- *Environmental country risk:* the risk that environmental legislation enacted by supplying nations might disrupt supply.
- *Conflict material risk:* the risk that the sourcing or production of a mineral may have financed conflict and thus be black-listed under the US Dodd-Frank Act.
- *Price volatility risk:* a measure of the fluctuations in the price of a material, calculated as the percentage difference between the maximum and minimum price (in USD/kg) over the past five years, relative to the minimum price.

The nature of the risk helps guide strategies to stabilize supply.

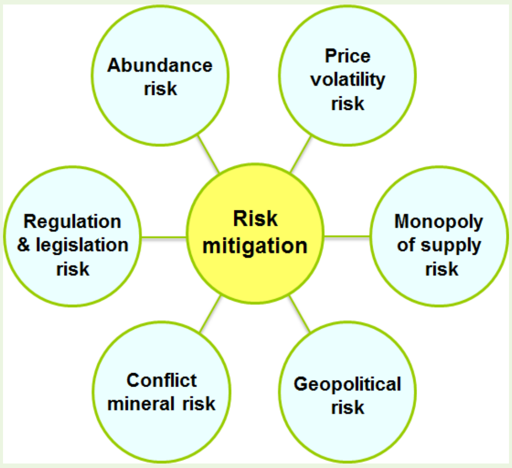

Figure 8. Components of risk.

[13] *The CES EduPack Sustainability Database is documented in a companion White Paper "Materials and Sustainable Development (1): Assessing Sustainable Developments" 2nd edition, January 2014, by M. Ashby and D. Ferrer, available from Granta Design, Cambridge,* http://teachingresources.grantadesign.com/

Understanding and managing social risk. A company with off-shore operations must understand the state of the development, the weaknesses, and the needs of the communities in which they operate. The Nations of the World records provide this background information and help identify ways in which the company can contribute to the society in a country it operates, and has indirect or indirect impacts. As examples, the Nations records give information about literacy, gender-equality (or lack of it), median income, equality of wealth distribution, freedom of speech, and level of corruption.

Managing economic risk. The costs of off-shore material production or manufacture are influenced by the cost of energy and water, and by the level of taxation. The Nations records contain country-specific data for these.

Managing regulatory risk. All major nations have environmental taxes and regulate or restrict the products that can be sold and used within their borders. Products exported to a nation must comply with that nation's laws. The Legislation and Regulations records of the CES EduPack Sustainability Database describe a number of these laws and act as a prompt in planning corporate strategy.

3. Corporate Social Responsibility and Reporting Mechanism[14]

Corporate social responsibility. In the past the primary responsibility of a corporation was to provide an acceptable return on investment to its owners and stockholders. Starting in the 1960s a broader view of corporate responsibilities emerged that includes not only stockholders but other parties as well, including employees, suppliers, customers, the local community, local, state, and national governments, environmental groups, and other special interest groups—its stakeholders. From this developed the concept of corporate social responsibility (CSR), the expectations that society has of a corporation or company. The underlying assumption is that companies have moral, ethical, and philanthropic responsibilities in addition to their responsibilities to earn a fair return for investors and to comply with the law. More specifically, the expectations are:

- *Economic:* that Corporations will produce goods and services that are needed and desired by customers and sell those goods and services at a reasonable price. Organizations are expected to be efficient and profitable, and to act with the shareholder interests in mind.
- *Legal:* that Corporations will comply with the laws that are in place to govern competition in the market. These include consumer protection and product laws, environmental laws, and employment laws.
- *Ethical:* that Corporations will meet societal expectations that go beyond the law by conducting their affairs in a fair and just way. Organizations are expected to make proactive efforts to anticipate and meet the norms of society even if those norms are not formally enacted in law.
- *Discretionary:* that Corporations will meet society's expectation to act as good citizens via philanthropic support of programs benefiting a community, or donating employee expertise, time, and financial support to worthy causes. The larger the corporation the larger discretionary responsibility they carry.

Sustainability reporting. A sustainability report (SR) is a way for a company to report the economic, environmental, and social aspects of what it does and the way it governs itself. The first such reports were published in the 1980s as a way of countering the negative image that some chemical and mining companies had acquired.

[14] A good overview of corporate social responsibility is provided in Encyclopaedia for Business on-line: www.referenceforbusiness.com/management/Comp-De/Corporate-Social-Responsibility.html

Today, sustainability reporting has become a tool for managing change towards sustainable business practice that combines long term profitability with ethical behavior, social justice, and environmental care. If done responsibly, an SR can enhance brand-image and company reputation. It can catalyse change within the company, it helps set new goals, and it increases transparency[15]. But it can also be misused to suggest that a company has an environmental and ethical agenda when in reality little is done─a practice known as "green-washing".

Sustainability reporting is not, at present, mandatory but there are discussions at the EU level to make it so[16]. The Global Reporting Initiative (GRI) provides a framework for doing this, based on the ten Principles of the UN Global Compact[17], listed below. Participants commit to ten principles in conducting their affairs and to publishing an annual Communication on Progress (COP). The vision is to promote a sustainable global economy in which organizations manage their economic, environmental, social performance, and governance in a responsible way. Many corporations now use it. Company performance in sustainability reporting is monitored by independent organizations that award "sustainability indices" rankings that are now of considerable influence. Prominent among them are the FTSE-4Good index, the Dow Jones Sustainability Index and the Business in the Community Index (FEE 2008). Appendices 2 and 3 of this paper have more information.

UN Global Compact

Human Rights

Principle 1: Businesses should support internationally proclaimed human rights.

Principle 2: Make sure that they are not complicit in human rights abuses.

Labour

Principle 3: Businesses should uphold the freedom of the right to collective bargaining.

Principle 4: Eliminate all forms of forced and compulsory labor.

Principle 5: Eliminate the use of child labor.

Principle 6: Eliminate discrimination in in hiring and promotion.

Environment

Principle 7: Businesses should support a precautionary approach to environmental challenges.

Principle 8: Undertake initiatives to promote greater environmental responsibility.

Principle 9: Encourage the development and diffusion of environmentally friendly technologies.

Anti-Corruption

Principle 10: Businesses should work against corruption in all its forms.

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[15] Ethical Corporation (2013) "Full product transparency is the future of reporting", available on-line: http://www.ethicalcorp.com/communications-reporting/full-product-transparency-future-reporting

[16] European Commission (EC), Environment Section, available on-line: http://ec.europa.eu/environment/resource_efficiency/news/up-to-date_news/03062013_en.htm

[17] UN Global Compact, available on-line: www.unglobalcompact.org/cop/index.html

Changing expectation of corporate responsibility. The increasing pressure for Corporate Social Responsibility (CSR) and Sustainability Reporting (SR) has already been described. Proactive implementation of the CSR concepts can bring cost benefits and enhance brand-value. One aspect of "eco-design" is that of reducing waste with saving in material cost. Rethinking the design of products to reduce environmental impact offers opportunities for innovation. Increasing transport efficiency by using light-weight composites, for instance, can increase both fuel-efficiency and performance.

Consumers, often supported by shareholders and Non-Governmental Organizations (NGOs), urge companies to examine the environmental and social impact of their processes and products. Strong performance in this area can be turned to competitive advantage, but environmental claims made on product labels must stand up to scrutiny. Signs of "Green-washing"─making unsubstantiated claims of good environmental and ethical behavior─are now examined closely. There are, for instance, guidelines set by the US Federal Trade Commission[18] on making environmental claims; rigor and quantitative validation are now essential in this area.

All of these issues can result in very significant costs or risks to a business. As said earlier, considering environmental objectives and regulations during product design and development is no longer an "optional extra", it is a business imperative. "Sustainability" has evolved from an abstract concept into a more solid body of genuine business concern. Many of these are congealing in the concept of a *circular materials economy* to which we return in a moment.

It should be remembered that companies are not people. The primary responsibility of a public company remains that of acting maximizing return to its shareholders while acting within the law─but this is not incompatible with the broader view just described. There is increasing realization that eco- and social innovation can create competitive advantage, and that building respect, trust, and loyalty contribute to long-term profitability and sustainability.

[18] US Federal Trade Commission. *Guides for the use of environmental marketing claims.* Part 260.

4. Case studies: Corporate Sustainability Reports

Many companies now issue Sustainability Reports. They vary greatly in content and what might be called attitude: some paint a golden picture; others are more direct about their present shortcomings and aspirations. Appendix 4 of this report lists suggested criteria by which a Sustainability Report might be judged.

Here are brief summaries of Sustainability Reports (SRs) from two companies, both with an international reach. The first is a material supplier; the second a material user. Both reports were highly ranked by leading Sustainable Index organisations. The striking difference between the two companies is the nature of the legal and societal pressures to which they are exposed. The company reaction to these pressures dominates their SR.

Case Study 1: A material supplier.

AngloAmerican[19] is a large mining company with operations in North and South America, Africa and Australia producing iron, copper, manganese, nickel, platinum and diamonds. Mining, in the past, has incurred a negative image of exploitation and environmental negligence. The chairman's opening statement recognises that the role of big business in society is now under close scrutiny and that greater transparency and accountability are needed to demonstrate commitment to being a responsible corporate citizen.

- The mining business, like the oil business, has certain defining characteristics.
- It involves large-scale projects that require significant investments over long time periods.
- The resources that are mined are sometimes in remote, environmentally sensitive, and technically demanding locations, possibly in countries with uncertain political and regulatory situations.
- The resources themselves belong to sovereign states; the companies licence to operate is based on mutual benefit.
- The company's responsibilities extend from the earliest stages of exploration to well beyond the life of the mine itself.
- Mining operations have significant environmental impact that may affect resources used by local and indigenous communities.
- Mining companies employ local people but also attract workers from elsewhere. This can create tensions among stakeholders, potentially jeopardising the company's social licence to operate and the stability needed to operate successfully.

AngloAmerican has issued annual Sustainability Reports since 2000 following the guide-lines of the Global Reporting Initiative (GRI), described earlier. The 2012 Report acknowledges that mining can have significant environmental impacts: it uses large amounts of energy, generates green-house gases, needs a great deal of water, and creates waste that requires containment and treatment. Sustainability Report identifies six key sustainability areas—water, health, safety, community development, climate change, and operational excellence—that represent risks to be managed but can also become opportunities to create value for society. The report lists the stakeholders in their operations, the mechanisms in place to engage with the stakeholders, the concerns they express, and the actions the company has taken to respond to those concerns. It compares its performance in the current year with that in the previous year, demonstrating (in the 2012 report) significant progress in water and energy conservation, community development programs, and investment in local housing and education. Independent assurance of key performance elements of the Report is provided by PricewaterhouseCoopers (PwC) and is highly ranked by the Dow Jones Sustainability Index (the index is described in the Appendix 3 to this paper).

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[19] AngloAmerican "Creating Value with the Future in Mind" (2012), available on-line: http://www.angloamerican.com/~/media/Files/A/Anglo-American-Plc/reports/AA-SDR-2012.pdf

Case Study 2: A material user.

Jaguar Land Rover[20] is a maker of luxury cars. Cars are responsible for about 20% of all the carbon released into the atmosphere[21]. The auto industry is under pressure from national governments to reduce tailpipe emissions and a sector of the public, too, perceives the emissions from large vehicles such as those made by Jaguar Land Rover to be irresponsible. The average life of a car is only 8 years[22], generating further pressure to improve their recyclability. The pressures take the form of

- Financial penalties if increasingly stringent fleet economy and emissions standards are not met.
- Legislation requiring that 85% of the vehicle be recycled at end of life.
- Concerns for potential materials supply-chain and water constraints.

Jaguar Land Rover first started issuing Sustainability Reports in 2009. Not surprisingly, the 2011/2012 report emphasizes the steps the company has taken to improve its environmental performance. The report documents the weight-saving over past years made possible by the extensive use of aluminum and plastic; It details the reduced carbon footprint of manufacture by increased recycle content of the aluminum and the use of bio-reinforced plastic for panels and trim, and of "certified low-carbon leather" for seats. The company plans further weight-reduction and improved eco-performance, aiming for 75% recycle content in the structural aluminum components and the use of CFRP to achieve further weight-saving.

The CEO Statement of the Jaguar Land Rover Sustainability Report emphasises the commitment of the company to add value to the communities in which it operates through training programs. Its global Corporate Social Responsibility (CSR) programme highlights a carbon-offset program that has compensated for 5 million tonnes of CO_2 to date via wind, hydro, and other renewable energy plant in Africa, Asia, Europe, and South America. The company invests in projects that have additional social and economic benefits which, they claim, have helped improved the lives of over 1.2 million people. They donate over £1m per year in cash and kind to charities. The company was awarded the highest (Platinum) level in the Community Corporate Responsibility Index (the index is described in the Appendix 3).

[20] Jaguar Land Rover "Our Plan for Sustainability" (2012), available on-line: http://www.landrover.com/imagery/global/downloads/sustainability-report/sustainability-report-2011-2012

[21] USA EPA, Climate Change Section, available on-line: www.epa.gov/climatechange/ghgemissions/sources.html

[22] NBC News "What's the life expectancy of my car?" (2006), available on-line: http://www.nbcnews.com/id/12040753/#.UpTK3mfwjK0

5. Materials and the Circular Economy

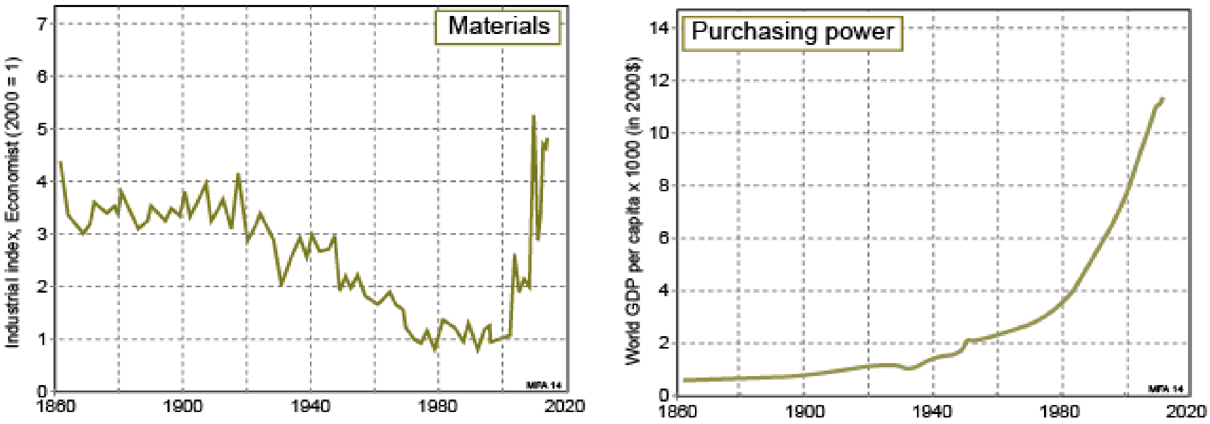

Figure 9. Price of a portfolio of materials and purchasing power (The World Bank, 2014; McKinsey Global Institute, 2011 and Central Intelligence Agency resources).

Before the industrial revolution, materials were expensive and labor was cheap. The number of materials in service was small and their high value relative to labor ensured that the products made from them were maintained, repaired, and upgraded. Material efficiency was normal practice.

Since the industrial revolution, large-scale mining and global trade have allowed material costs to decline[23] (Figure 9); at the same time labor costs have risen. Manufacturing methods (mass production, robotic assembly, and the like) evolved to minimise the use of labor. The availability and low cost of materials encouraged industry to adopt an increasingly open-loop approach to material resources, transforming them into products that are used once then discarded. The flow of materials through the economy followed a linear path summarized as: *take – make – use – dispose* (Figure 10). There is an increasing awareness that this cannot continue.

The global population is increasing. Around three billion consumers from the developing world will enter the middle class by 2030[24], with associated demand for products and services. The stress on the global eco-sphere caused by industrial development already gives cause for concern. And─a more immediate driver─the cost of materials is now increasing considerably faster than that of labor (Figure 9, right-hand side). Increased material efficiency, reducing the resources per unit of manufacturing output, can make non-renewable resources last longer but their loss at the end of product life is a continuing drain. We examine ways to increase material efficiency in the next section, but first we explore the bigger picture: that of establishing a more circular materials economy[25].

[23] World Bank (2013) http://blogs.worldbank.org/prospects/category/tags/historical-commodity-prices

[24] McKinsey Quarterly, February (2014), available on-line: http://www.mckinsey.com/insights/mckinsey_quarterly

[25] Ellen MacArthur Foundation (2014) available on-line: www.ellenmacarthurfoundation.org

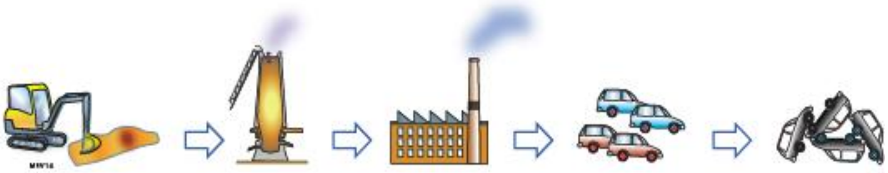

Figure 10. The linear materials economy: *take – make – use – dispose*.

Materials in a circular economy are seen, not as a disposable commodity, but as a valued asset to be tracked and conserved for reuse, in rather the same way that financial capital is invested, recovered in the revenues, then re-invested. Figure 11 introduces the idea. Materials are produced, manufactured into products, which enter service where they remain for their design life. In the circular-economy model, disposal at end of life as landfill or waste is not an option. Instead the product is reused in a less demanding way, or reconditioned to give it a second lease of life, or dismantled into its component materials for recycling. All three of these options retain the materials of the product as active stock (the upper green box on the Figure 11). It may be impractical to recycle perishable materials; those that are bio-degradable can be composted, returning them to the bio-sphere; those that are combustible are incinerated with energy recovery; only the remaining residue goes to landfill. The more material that can be retained within the green "Material stock" box the upper part of Figure 11, the less need be added by primary production. Indeed, if design evolves to use materials more efficiently it may be possible to function, at least for a time, with no primary production at all.

The *circular economy* means more than just efficient recycling. Taken literally, it means relying on renewable energy, tracking materials through the economy so that their location is known, and choosing and using them in ways that allows their reuse with as little reprocessing as possible. The concept goes beyond the mechanics of production and consumption of goods, moving from the idea of *consuming* of materials to one of *using* them, somewhat in the way properly-managed land is used for agriculture without consuming it. Taking the ideal further, the circular economy is restorative, rebuilding social and natural as well as economic capital. It demands a different approach to design of products and systems in order to retain or regenerate materials during several manufacturing cycles[26] and to reduce demand on the use of strategic critical materials. It is an important part of a resource efficient and low-carbon economy, reducing costs and supply risks and generating value[27].

[26] Ellen MacArthur Foundation (2014) available on-line: www.ellenmacarthurfoundation.org

[27] TSB "Resource Efficiency: New Design for a Circular Economy" (2013), available on-line: https://www.innovateuk.org/competition-display-page/-/asset_publisher/RqEt2AKmEBhi/content/resource-efficiency-new-designs-for-a-circular-economy

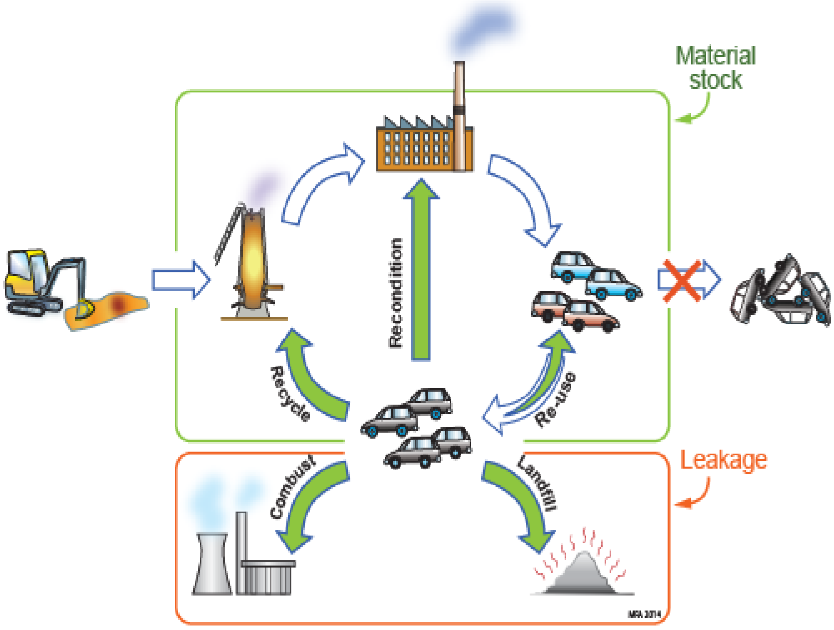

Figure 11 The circular economy. The aim is to retain materials in the "Material stock" box by reuse, reconditioning and recycling, minimizing leakage into the Waste box.

That is the ideal. Ideals have value; they set a target, something to be worked towards even if perfect fulfilment is not possible. At an achievable level the circular economy draws a sharp distinction between the consumption and use of materials. It is the driver for replacing the *'take – make – dispose'* model by the *'functional service'* model in which manufacturers retain ownership of their products and, where possible, act as service providers, selling the use of products, not their one-way consumption. This shift has direct implications for product design, some of which are listed next.

Design for leasing and sharing. Service design means that the ownership of products and their components and materials remains in the hands of the product-maker. It is in the interest of the maker to make the product last as long as possible and to allow reuse of all or a part of it rather than scrapping it. This, in turn, drives higher specifications of design and choice of materials that increase life and durability.

Design for long life. One Swiss mechanical watch-maker promotes its precision (and expensive) products thus. *"You never actually own a* (brand name) *watch – you simply look after it for the next generation"*. That nicely sums up the ideal of the circular materials economy. It also exposes its vulnerable side: if new technology provides–as digital watches did–a more accurate, less expensive way of measuring time, watches that rely on mechanical movements are exposed to threat. Design for long life must be balanced against the environmental and social gains and the lower prices made possible by new technologies.

Design for reuse. Products or their components and sub-systems can be taken back to be reused or restored for resale, allowing a longer functional life. The function may change (old school buses re-used as camper vans, shipping containers reused for housing) but their materials remain in service.

Design for material recovery. Many materials are recycled already, but the process is inefficient, driving up costs, and contamination with impurities reduces the quality of the recycled material. Products with short lives such as drink cans, disposable cups, or packaging should be designed for efficient recycling. That means avoidance of material combinations that cause cross-contamination, automated disassembly and separation, with identifying codes or colors to help sorting.

All of these provide opportunities of increased sustainability.

The CES EduPack Sustainability Database* and Sustainability Reporting

The CES EduPack Sustainability Database* and associated resources are designed to support the teaching of Sustainable Development in engineering courses, particularly those that are materials-related.

It is developed around a structured method for analysing projects that aim or claim to be sustainable. It encourages exploration of cross-curricular issues, providing future engineers, designers, and material scientists with a vocabulary and an understanding of some of the current social and environmental challenges that we face today.

The tool facilitates students in their discovery of how the global availability of the key resources is closely linked with the economic prosperity, social welfare, and environmental impact. It is visual, easy to use, and it encourages broad thinking. It introduces the concepts from the sustainability and corporate social responsibility discourses, such as geopolitical risk linked to supply, physical scarcity, co-production risk, price volatility and wider social factors, based on the resources corporates use to operate.

Central outcomes enabled by the CES EduPack Sustainability resources are:

- Familiarity with the key global challenges and policies, which shaped the sustainability debate and influenced behavior of corporations;
- Acquisition of the vocabulary necessary to communicate with representatives of various disciplinary fields and decision-makers;
- Acquisition of knowledge about various economic, social, and environmental impacts related to materials;
- Comprehension of materials related industry risks.

** The CES EduPack Sustainability Database is documented in a companion White Paper "Materials and Sustainable Development (1): Assessing Sustainable Developments" 2nd edition, January 2014 by M. Ashby and D. Ferrer, available from Granta Design, Cambridge, available on-line: http://teachingresources.grantadesign.com/*

6. Summary and Conclusions

Over much of the last century material supply was not (with occasional exceptions) a major issue. Trade tended to be national rather than global. Material prices, in real terms, were static or falling. There was relatively little control over the way materials were used or what happened to them at the end of product life.

Today the picture looks rather different. The increasing complexity of products creates a dependence on a larger number of elements, some comparatively rare. These are sourced globally and used to make products that are traded on a global scale. Manufacturing nations increasingly compete for exclusive rights to minerals resources world-wide in order to safeguard their industrial capacity. New and expanding legislation controls many aspects of manufacturer responsibility, product design, material usage, and material disposal. The public, shareholders, and government increasingly judge corporate success not just in financial terms but in terms of stewardship of the environment and welfare of its workforce and that of the local economy of the communities in which it operates. Corporations respond by issuing Sustainability Reports detailing their attention to Corporate Social Responsibility (CSR).

Thus manufacturing decision-making process in this century will require:

- Adapting to, and complying with, environmental and other material-related legislation;
- Managing the material supply chain, particularly where "critical" materials are involved;
- Contingency planning to cope with material constraints and price volatility;
- Business models appropriate to a Circular economy.

This White Paper explores a changing approach to materials in a context of sustainability, including risks coming from changing economic and social factors. The Paper highlights the ways in which corporate strategies could be evolving in the near future to react to materials-related challenges. This implies a changing a role for product designers and engineers in the decision-making process.

The CES EduPack Sustainability Database can help to inform decision-making regarding the choice of materials to manage and mitigate risks and for sustainability reporting purposes (e.g., CSR reports). The Database can support the teaching of sustainability concepts, and help to increase transferable skills such as teamwork, system-thinking, and stakeholder analyses. Students will learn how to integrate social and environmental awareness into the decision-making process at every stage of the product life-cycle.

The Sustainability Database has an accompanying White Paper on "Materials and Sustainable Development", describing a methodology for assessing sustainability credentials of a "green" technology, with an emphasis of stakeholders involvement[28].

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[28] Available from Granta Design Teaching Resources (2014), http://www.grantadesign.com/education/teachingresources.htm

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8. Appendices

Appendix 1. Criteria for material criticality.

The mineral resource bases from which many materials are drawn are so large and widely distributed that the health of the supply chain is not a concern. The resource bases supporting the steel and aluminum industry are examples – both are vital to the economy, but it is the resource of energy rather than that of material that could limit their production. But there are others that are a cause of concern. They are the materials for which the known reserves are limited in size or are localized in countries from which supply cannot be guaranteed, or both. Governments classify materials as "strategic" or "critical" if their supply is concentrated in one country or could be restricted by few corporate interests, and because they using in products that are important economically or for national security. There is another, equally important, aspect of materials criticality that should not be forgotten: the ease or difficulty of finding a lower-risk substitute for a material with high criticality.

Two factors combine to make a material "critical":

- It enables the superior performance of a product in ways that cannot easily be substituted by another material, and
- Risk exists that its supply could be disruption or restricted, making it unavailable or prohibitively expensive.

'Material' includes simple elements such as iron, aluminum, or neodymium, as well as alloys composed of quantities of different elements. Risk may arise from imbalance between supply and demand, from regulation that may restrict legal extraction, from geopolitical instability in producing nations, or from environmental and ethical considerations.

EU Critical Materials list

Antimony

Beryllium

Cobalt

Fluorspar

Gallium

Germanium

Graphite

Indium

Lithium

Manganese

Molybdenum

Niobium (Columbium)

Governments react by drawing up or commissioning lists of "Critical" or "Strategic" materials, among them US Geological Survey (2009) (http://minerals.usgs.gov/east/critical/index.html), the US Department of Energy (2010) (www.energy.gov/news/documents/criticalmaterialsstrategy.pdf), the American Physical Society (2010) (http://www.aps.org/units/fps/newsletters/201107/jaffe.cfm) and the British Geological Survey (2012) (www.bgs.ac.uk/downloads/start.cfm?id=2643). These lists act as warnings, but the reasons for criticality, and thus the ability to foresee how it will evolve, are lost. For that reason we report a set of metrics that six metrics that, taken together, give a more detailed picture of the nature of the risk to supply. All are measured on a 5 point scale of *very low, low, medium, high* and *very high risk*. The metrics are:

Abundance risk: the risk to supply associated with the fact that a material is present in exceptionally low concentrations in the earth's crust and oceans. A five-point scale ranging from <0.01 ppm (very high) to very low (>10,000 ppm). It is based on data from the United States Geological Survey (http://minerals.usgs.gov/minerals/pubs/commodity/) and the British Geological Survey (www.bgs.ac.uk/).

Monopoly of supply risk: a measure of supply-chain concentration, the degree to which supply derives from one or a very few nations. It is based on the Herfindahl-Hirschman Index (http://www.justice.gov/atr/public/guidelines/hhi.html)

Geopolitical risk: the risk that supply might be disrupted by political instability or civil unrest. It is based on a combination of the Herfindahl-Hirschman index and the World Bank's Worldwide Governance Indicator for the producing nations (http://info.worldbank.org/governance/wgi/index.asp)

Environmental country risk: the risk that environmental legislation enacted by supplying nations might disrupt supply. It is based on a combination of the Herfindahl-Hirschman index and Yale Universities' Environmental Performance Indicator (http://epi.yale.edu/)

Conflict material risk: the risk that the sourcing or production of a mineral may have financed conflict. Use of a mineral with a high risk carries a requirement under the US Conflict Minerals Law (section 1502 of the Dodd-Frank Act, 2010) for an independent traceability audit of the material's supply chain (http://www.sec.gov/about/laws/wallstreetreform-cpa.pdf).

Price volatility risk: a measure of the fluctuations in the price of a material, calculated as the percentage difference between the maximum and minimum price (in USD/kg) over the past five years, relative to the minimum price. Price fluctuations may reflect imbalance between supply and demand or (for materials that are energy intensive) originate in fluctuations in the price of energy (http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report_en.pdf).

Appendix 2 The Global Reporting Initiative (GRI)

The Global Reporting Initiative (GRI) promotes the use of sustainability reporting as a way for organizations to become more sustainable and contribute to sustainable development.

http://www.globalreporting.org

The GRI encourages reporting under three categories:

- *Economic:* financial results, market presence, and procurement practice
- *Environmental:* use of materials, water and energy; emissions; and compliance with environmental legislation
- *Social:* labor practice, human rights, society, product responsibility, which broadly, adherence to the UN Global Contract.

Appendix 3. Indices of Corporate Sustainability.

A number of data-gathering organisations rank corporate reporting on their policy and practice by measures of stewardship of the environment, social responsibility, and financial health. The rankings for a given corporation are rolled up and reported as a Sustainability Index. The various Indices are summarised below. Most require a subscription for access; one–the CR Index–provides open access.

- *The FTSE4Good Index* claims to be an objective measure of the performance of companies in meeting globally recognised corporate responsibility standards. It is used as a guide for environmentally and socially responsible financial investment http://www.ftse.co.uk/Indices/FTSE4Good_Index_Series/index.jsp ;
- *The Dow Jones Sustainability World Ind*ex identifies global sustainability leaders through their Corporate Sustainability Reporting. It is based on a consistent improvement in their strategies for climate change, energy consumption, human resources development, knowledge management, stakeholder relations, and corporate governance http://djindexes.com/sustainability/?go=literature and http://www.sustainability-indices.com/
- *The Community's Corporate Responsibility (CR) Index* ranks companies on their environmental impact, their social contributions, and the extent to which responsible business is integrated into their strategy. http://www.bitc.org.uk/our-services/benchmarking/cr-index

Appendix 4. Assessing Sustainability Reports

Corporations publish Sustainability Reports (SRs) to demonstrate their acceptance of the principals of corporate social responsibility (CSR). How much of what they say is true? Is it largely green-washing? The Global Reporting Initiative (GRI) provides a framework for reporting but not ways to evaluate accuracy. Ploeg and Vanclay[29] propose a Reporting Assessment Checklist. Here is a simplified version.

[29] Van der Ploeg, L and Vanclay, F., "Credible claim or corporate spin? : A checklist to evaluate corporate Sustainability reports" J. Env. Assmt. Pol. Mgmt. **15**, (2013), available on-line : http://www.worldscientific.com/doi/abs/10.1142/S1464333213500129

- Is the report clear, concise, and intelligible to the relevant stakeholders?
- Does the company use an established reporting framework, such as the GRI (See Appendix 2)?
- Does the report explain how the company incorporates Corporate Social Responsibility and sustainable development into its internal organizational strategy and that of its suppliers?
- Does the report identify the stakeholders and their expectations and concerns?
- Does the report explain what the company is doing to meet stakeholder concerns?
- Does the report provide adequate evidence (e.g., data) to support the claims that it makes?
- How does the report establish the credibility, for example through independent assurance by the FTSE, the DowJones, or the CR Index of Corporate Sustainability?

9. Exercises

E 1. An influential investor in a small company making household products insist that the company issue a Sustainability Report (SR), following the Global Reporting Initiative (GRI) guidelines. Briefly, what is the GRI?

Answer. A search on Global Reporting Initiative retrieves a brief description of the guidelines, plus information about Sustainability Performance Indicators. The Initiative reads:

The Global Reporting Initiative (GRI) is a non-profit organization that works towards a sustainable global economy by providing sustainability reporting guidance that is used worldwide. The Reporting Framework enables greater organizational transparency about economic, environmental, social, and governance performance in the areas listed below.

Economic performance indicators include company turnover, profit, and volume of trade. Economic accounting and reporting is a well-established area and is almost universally practiced.

Social performance indicators concern the company's impacts on the social systems within which it operates, e.g., labor practices, human rights, and broader issues affecting consumers, community, and other stakeholders in society.

Environmental performance indicators (EPI) concern the impacts of the company's operations on natural systems, including ecosystems, land, air, and water as measured by indicators such as greenhouse gas emissions, water consumption, and waste output.

E 2. The CEO of a small company making specialized copying equipment becomes aware that competitors issue Environmental Product Declarations (EPDs) for their products. His board is concerned that failure to follow suit may lead to loss of sales. What is an EPD?

Answer. A search on Environmental Product Declarations retrieves the following.

An EPD *is a standardized (ISO 14025/TR) tool to report the environmental performance of a product or system. The declaration is based on a Life Cycle Assessment of the environmental impacts of a product or service, such as raw material acquisition, energy use and efficiency, content of materials and chemical substances, emissions to air, soil, and water and waste generation.*

It also retrieves the standard, ISO 14025/TR, which stipulates that the LCA must follow the ISO 14040 family of procedures and must be independently validated.

E 3. The web site CSRwire (http://www.csrwire.com/reports) gives access to Sustainability Reports from a large number of companies. Select one of the companies that either provides or uses materials, survey the report, and write a half page summary of what you find.

E 4. Emerson is a manufacturing company that uses materials on a large scale. Track down the Emerson Sustainability Report for the previous year (that for the current year will not yet be complete), survey its content, and write a half-page précis of the points that strike you as significant in Emerson’s operations.

E 5. Look up the Sustainability Report from Apple. Write a list of the stakeholders mentioned in it. Identify any claims made to do with materials choice. Which countries are mentioned in the report? Are they countries you think will be good places to work over the next 3 years? What timescales are mentioned in the report? Is Apple thinking long-term?

E 6. The Herfindahl-Hirschman Index (HHI) is a measure of risk when the supply of a material is controlled by one or a very few nations. It is defined as

$HHI = \sum_{i=1}^{n} f_i^2$ where f_i is the fraction of the market provided by nation *i* and *n* is the number of nations.

The table lists the world production of tungsten by nation.

Calculate the HHI index for tungsten based on these values. Does the result suggest supply-chain constraint?

Tungsten-producing Nation	**Tonnes/year 2011**
China	60,000
Russia	3,100
Canada	2,000
Portugal	1,300
Bolivia	1,200
Austria	1,100
Other countries	3,400
World	**72,000**

Minerals.usgs.gov/minerals/pubs/commodity

Answer. The fractions of world production from each supplier nation are listed. The value of the HHI calculated from them is 0.67. This indicates that tungsten is exposed to very severe supply-chain concentration with associated risk of disruption of supply and price volatility..

Tungsten-producing Nation	**Tonnes/year 2011**	**Fraction f_i**	**f_i^2**
China	60,000	0.83	0.69
Russia	3,100	0.043	0.0019
Canada	2,000	0.027	0.0008
Portugal	1,300	0.018	0.0003
Bolivia	1,200	0.017	0.0003
Austria	1,100	0.015	0.0002
Other countries	3,400	0.047	0.0022
World	**72,000**	**HHI =**	**0.67**

E 7. The Herfindahl-Hirschman Index (HHI) is defined in Exercise (E6). The table lists the world production of manganese by nation. Calculate the HHI index for manganese based on these values. Does the result suggest supply-chain constraint?

Answer. Following the same method as that of Exercise (E6) gives a value for the HHI of 0.13. This value suggests a slight degree of constraint.

Manganese-producing Nation	**Tonnes/year 2011**
South Africa	3,400
China	2,800
Gabon	1,500
India	1,100
Brazil	1,000
Ukraine	340
Mexico	170
Other countries	1,400
World	**14,000**

Minerals.usgs.gov/minerals/pubs/commodity

E 8. A company specializing in road-repair relies on cobalt bonded tungsten-carbide cutting tools for stripping road surfaces. The CEO of the company is considering investment in a supplier of these cutting tools to ensure supply. Both cobalt and tungsten appear on the European Union list of critical materials (Appendix 1).

The Herfindahl-Hirschman Index, (Figure 6) for tungsten is 0.7; that for cobalt is 0.3. Both values are high, tungsten particularly so, indicating severe supply-chain concentration. This carries the risk of price fluctuations, confirmed in the case of cobalt by Figure 2. A search reveals that tungsten price has been less volatile; it has risen by a factor of 1.5 between 2010 and the present day. The CEO of the company is concerned about this and asks for a study of the risk that investment in the company might carry. Investigate what substitutes could be found if the supply cobalt or tungsten was restricted.

Answer. A web search brings up the following information.

The largest single use of tungsten is in tools for metal cutting and mining; these are also a major market for cobalt. The high HHI of both. Thus, the investment plan carries risks of disruption of supply and price volatility. There are, however, alternatives to cobalt bonded tungsten-carbide tools; and example is boron carbide bonded with a nickel-chrome alloy. These, too, are critical materials, but with lower HHI. The economic uncertainty can be reduced by establishing links to suppliers of alternative cutting tool materials.

E 9. Germanium is listed as a critical material. Investigate why it is given this classification and what substitutes could be found if germanium supply was restricted.

Answer. The USGS Minerals Reports list cobalt production and the countries of origin. The same information can be found in the Germanium record in CES EduPack Materials Universe database (see the adjacent table). Almost 70% of the world's germanium is sourced from a single nation: the Peoples' Republic of China.

Germanium has unique optical, electro-optical and semi-conducting properties, used in fiber optics, lenses for infra-red optics, high-efficiency electronics, solar cells and light-emitting diodes. Alumina and silicon-based alternatives exist, but are less attractive. Thus germanium is classified as "critical" for two reasons; first because of extreme supply-chain concentration and second because of its special performance in information technology and strategic applications.

Germanium-producing Nation	Tonnes/year 2011
China	80,000
Russia	5,000
United States	3,000
Other countries	30,000
World	**118,000**

Minerals.usgs.gov/minerals/pubs/commodity

E 10. Platinum is listed as a critical material. Investigate why it is given this classification and what substitutes could be found if platinum supply was restricted.

Answer. The USGS Minerals Reports list platinum production and the countries of origin. The same information can be found in the platinum record of the CES Edu Materials Universe (see the adjacent table). Almost 72% of the world's platinum is sourced from a single nation: South Africa.

Platinum used as catalysts for auto exhaust and in the chemical industry. There are no viable substitutes for platinum in these applications. Thus the metal is classified as "critical" both because of the supply chain concentration and because it performs an important role in the economy for which no alternative exists.

Platinum -producing Nation	Tonnes/year 2011
South Africa	139,000
Russia	26,000
Canada	10,000
Zimbabwe	9,400
United States	3,700
Colombia	1,000
Other countries	2,500
World	**192,000**

Minerals.usgs.gov/minerals/pubs/commodity

E 11. Manganese is listed as a critical material. Investigate why it is given this classification and what substitutes could be found if manganese supply was restricted.

Answer. The USGS Minerals Reports list manganese production and the countries of origin. The same information can be found in the manganese record in CES EduPack Materials Universe (see the adjacent table). Supply is well distributed between a number of nations, giving no special cause for alarm.

Manganese is essential to iron and steel making, which accounts for 90% of present demand. It acts to combine with sulfur and oxygen, and it acts as a strengthening agent. Steel containing 8 to 15% of manganese can have a high tensile strength; those with 12% manganese are uniquely tough.

Manganese-producing Nation	Tonnes/year 2011
South Africa	3,400
China	2,800
Gabon	1,500
India	1,100
Brazil	1,000

There is no known replacement for manganese in providing this combination of properties.

Thus the critical status of manganese derives from its unique properties as an alloying element in steels.

Ukraine	340
Mexico	170
Other countries	1,400
World	**14,000**

Minerals.usgs.gov/minerals/pubs/commodity

E 12. Rhodium is listed as a critical material. Investigate why it is given this classification and what substitutes could be found if rhodium supply was restricted.

Answer. The USGS Minerals Reports list rhodium production and the countries of origin(see the adjacent table). This is another element with supply-chain concentration: 72% of the world supply comes from a single nation. That would not be a concern if there were substitutes for rhodium, but it performs one unique function for which no substituted is known: its role in removing oxides of nitrogen is automobile catalytic converters; over 80% of all rhodium is used in this way. It catalyses the reaction

$$2\ NO_x \rightarrow x\ O_2 + N_2$$

No substitute has been identified.

Rhodium-producing Nation	Tonnes/year 2011
South Africa	128
Russia	26
Zimbabwe	11.5
Canada	6.5
United States	3.7
Colombia	0.7
Other countries	2.5
World	**179**

Minerals.usgs.gov/minerals/pubs/commodity

E 13. Would the CES EduPack Eco Audit tool help in preparing a company's Sustainability Report?

Answer. A search on GRI in CES EduPack retrieves a brief description of the guidelines, plus information about Sustainability Performance Indices. The entry for Global Reporting Initiative reads:

The Global Reporting Initiative (GRI) is a non-profit organization that works towards a sustainable global economy by providing sustainability reporting guidance that is used worldwide. The Reporting Framework enables greater organizational transparency about economic, environmental, social, and governance performance in the areas listed below. Economic performance indicators include company turnover, profit, and volume of trade. Economic accounting and reporting is a well-established area and is almost universally practiced. Social performance indicators concern the company's impacts on the social systems within which it operates, e.g., labor practices, human rights, and broader issues affecting consumers, community, and other stakeholders in society.

Environmental performance indicators (EPI) concern the impacts of the company's operations on natural systems, including ecosystems, land, air, and water as measured by indicators such as greenhouse gas emissions, water consumption, and waste output.

The Eco Audit tool gives an indicator of energy use and CO_2 emissions associated with product manufacture, use, and disposal. It thus provides information for the EPI mentioned in the GRI guidelines.

E 14. The CEO of a small company making specialized copying equipment becomes aware that competitors issue Environmental Product Declarations (EPDs) for their products. His Board is concerned that failure to follow suit may lead to loss of sales. What is an EPD? Would the CES EduPack Eco Audit tool help in drafting one?

Answer. A search on EPD in CES EduPack retrieves a description of Environmental Product Declaration:

An EPD is a standardized (ISO 14025/TR) tool to report the environmental performance of a product or system. The declaration is based on a Life Cycle Assessment of the environmental impacts of a product or service, such as raw material acquisition, energy use and efficiency, content of materials and chemical substances, emissions to air, soil, water, and waste generation.

It also retrieves the standard, ISO 14025/TR, which stipulates that the LCA must follow the ISO 14040 family of procedures and must be independently validated. This is an expensive undertaking. An indication of the form the output would take can be found much more quickly using the CES EduPack Eco Audit tool.

E 15. What is the risk level assigned to Molybdenum (important for high-temperature alloys) in the British Geological Survey ranking of material criticality? Compare this with the five risk metrics in the CES EduPack Sustainability Database to find out the reasons.

Answer. The British Geological Survey assigns molybdenum a risk ranking of 8.6/10, very high. Critical materials status

• Abundance risk level	Medium
• Sourcing and geopolitical risk level	High
• Environmental country risk level	Medium
• Price volatility risk level	Very high
• Conflict material risk level	None

Notes, accessible by clicking on each of these headings in a CES EduPack record, explains how each of these is assessed.

