

Sustainability, Supply Chains, and Defense

Julieanna Powell-Turner ¹ ✉ Email j.powellturner@chester.ac.uk

Clive Murgatroyd ² Email c.murgatroyd@cranfield.ac.uk

¹ CREST at the University of Chester Chester UK

² Cranfield University, Defence and Security Cranfield UK

Section editor Phil Harris ³ Email p.harris@chester.ac.uk

³ Business Research Institute University of Chester Chester UK

Keywords

Sustainability

Environmental

Sustainable supply chains

Circular economy

Recycling

Resilience

Criticality

Procurement

Defense

Rare earth elements (REE)

Fourth Industrial Revolution

Introduction

Integrating sustainability into the supply chain involves continual innovation and commitment from leaders and a realization that it is an indefinite process (Harrington, 2011). Defense supply chains are extensive and complex which require transparency, and long-term commitment rather than short termism that has dominated in the past! To facilitate this change, defense requires leaders to initiate change in the supply chain from a culture where the environment and societal issues have been given little consideration, to one where sustainability is considered throughout.

Sustainability?

Although there is no agreed definition on what sustainability means, there are different views on what it is and how it can be achieved. The concept of sustainability stems from that of sustainable development which was first defined in 1987 by Gro Harlem Brundtland, the Norwegian prime minister at the time. It became common language at the World's first Earth Summit in Rio in 1992 and can be defined as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Since then, there have been many variations but the other most used definition is "A process of change in which the exploitation of resources, the direction of investments, the orientation of technological

development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations” (The World Commission on Environment and Development, 1987). (It is important to note that this definition is a concept taken from the 1987 Brundtland Report.) Chambers et al. (2008) state that “Sustainable development is a dynamic process which enables people to realise their potential and improve their quality of life in ways which simultaneously protect and enhance the earth’s life support systems.” The principles of sustainability are usually described as comprising of three pillars (the three E’s). These pillars are:

(a)

Economic Development

(b)

Social Equity

(c)

Environmental Protection

Balancing the three pillars helps organizations move toward sustainability. However, interpreting what being “sustainable” means to a specific organization will facilitate the identification and prioritization of improvements aligned with the three pillars. The interaction between the three pillars has yet to be fully appreciated or understood by many organizations.

To understand sustainability within the defense supply chain we need to understand what it is, and why it is important.

What is it? According to BSR (2015) the United Nations supply chain sustainability is the management of environmental, social, and economic impacts, and the encouragement of good governance practices throughout the lifecycles of goods and services. It goes further, stating that this includes the integration of environmental and financial practices into the complete supply chain lifecycle, from product design and development, to material selection (including raw material extraction or agricultural production), manufacturing, packaging, transportation, warehousing, distribution, consumption, return, and disposal.

Why is it important? There are reasons for improving the social and environmental impacts throughout the supply chain, even though this can be perceived as a cost, and, the total value to the business can seem weak. BSR in 2010 highlighted the value of sustainable supply chain approaches through the impact on value creation including pricing power, cost savings, and market share. Further to this, business benefits that suppliers accrue through better performance often are not passed directly to buyers, where buyers may benefit through increased stability of supply (BSR, 2010).

With this in mind, true environmental costs need to be identified and accounted for in the supply chain at all stages in the life cycle with supplier engagement and capacity building to improve performance achieving common goals. This would include monitoring and auditing suppliers with a focus on energy conservation, more efficient processes during manufacture, water reduction, packaging and overall resource minimization, efficient networks for logistics, material and product recovery and reuse, remanufacturing, and education to highlight the financial, societal, and environmental benefits all of which aim to contribute to a circular economy. (The circular economy is restorative and regenerative by design with the aim to redefine products and services and design out waste out, while minimising negative impacts. Underpinned by a transition to renewable energy

sources, the circular model builds economic, natural, and social capital (MacArthur, 2013).) Only then can the deficiencies be identified and the process of applying sustainable objectives and targets in the supply chain begin. However, it must be noted that audits do not necessarily create the change to ensure sustainable improvement to practices.

Many companies are increasingly focusing on a two-track process, where due diligence of supplier performance is needed. Further to this, there is a growing emphasis on programs that move beyond monitoring strategic suppliers to enable and support change at the local level, where one process informs the other on an ongoing basis. This goes beyond the local level of an organization and includes the health and well-being of individuals, empowering minorities, geopolitical conflicts, raw material vulnerabilities and risks, increasing environmental disasters (natural and man-made), increasing legislation in the area of conflict minerals, and modern slavery.

Defense industry and sustainability Companies which operate within defense vary in their approach to sustainability because of sector characteristics, geographical dispersion, culture, commitment, and complexity (Ernst & Young, 2016). The author considers sustainability means different things to different people in different organizations and often departments within those organizations.

One of the main challenges for defense and its industry is defining the balance between the three pillars. This is fundamental for measuring and monitoring progress and identifying good practices. The challenge is compounded by the complicated structure and nature of activities. For example, programs, projects, and business units may use a different balance of the three pillars. Therefore, the defense community must adapt by embedding the same sustainable practices that meet its vision in the short, medium, and importantly, the long term, in view of the projected lifecycle length of many defense equipment solutions. For industry and the supply chain, this presents a tremendous opportunity for defense to meet sustainability requirements by incorporating greater capability, improved functionality, greater endurance, better through life affordability, and innovation into existing and new products and services.

To ensure defense becomes increasingly sustainable, the whole supply chain must be involved in the process of building a sustainable industry. This is challenging because the defense supply chain is a global entity with hundreds of suppliers.

Defense, suppliers, and the supply chain In developing a sustainable supply chain, defense must engage suppliers to be cognizant of the sustainability performance of their acquisitions, and should encourage suppliers to:

(a)

Lead by example

(b)

Set clear priorities

(c)

Remove barriers to sustainable operation of the company

In 2012, the UK Ministry of Defence (MOD) made initial steps to encourage a sustainable supply chain through a commercial policy to apply sustainable procurement principles to all MOD contracts, regardless of size or scope (MOD, 2012). However, in 2018, the challenge still remains to build this

into the MOD and build supplier awareness toward the sustainability issues to be considered in industry, while highlighting the associated benefits (MOD, 2018).

By effectively engaging with suppliers, defense can gain supply chain security for products and services with reduced cost fluctuations. As a result, suppliers gain enhanced corporate reputation and more stable market positions. Open book arrangements between the UK MOD and suppliers have proved to work well because the MOD could demonstrate through an external audit that they were receiving value for money while enabling industry to make a reasonable return from an economic perspective. For prime suppliers in the UK market, there is an opportunity to work with small- and medium-sized enterprises (SMEs) to assist and highlight areas where efficiencies can be realized, and eliminate compound risk provisioning within the supply chain. This can unnecessarily affect overall product affordability.

Defence suppliers face three challenges as they integrate sustainability into the supply chain. The first is traceability and transparency, ensuring materials and sourcing relationships are known and that risks have been identified. Secondly, measuring the impact where tools are developed to measure supply chain sustainability performance over time. And thirdly, engagement and collaboration where defense can work with suppliers and stakeholders collaboratively to embed sustainable sourcing practices (Corporate Citizenship, 2013).

However, transparency and traceability beyond tier 1 is difficult and many companies including defense do not understand the deeper risks in the supply chain. One way of increasing transparency beyond tier 1 according to the author is to encourage suppliers to report into the UN Global Compact Framework, or, adopt the UN sustainable development goals (SDGs) where progress is communicated to all stakeholders (United Nations [UN], 2017). However, accurate information is critical to ensure output is valuable. This is where technology has created more transparency in the supply chain.

The introduction of technology has opened up new areas in supply chain transparency and is starting to play a critical role in enhancing a company's ability to manage sustainability. Solutions varying in complexity are moving from data collection as we know it to the visualization of supplier units. These technologies include focus mapping tools, sensors, artificial intelligence (AI), 5G, and cloud-based systems which provide companies with a better understanding of supplier performance over time. This can provide a company with the performance profile required to make supplier decisions. Many large corporations around the world are adopting standards including ISO14001, (ISO 14001:2015 is the international standard that specifies requirements for an effective environmental management system (EMS). It provides a framework that an organization can follow, rather than establishing environmental performance requirements (ISO, 2015).) ISO20400, (ISO 20400:2017 provides guidance to organizations, independent of their activity or size, on integrating sustainability within procurement, as described in ISO 26000 (ISO, 2017).) and frameworks such as the UN Global Compact Ten which aim to promote environmental and social sustainability with suppliers and reach deeper into the supply chain (United Nations [UN], 2016). In addition, the SDGs (2017) provide a level of ambition for a sustainable supply chain like never before.

The UN Global Compact rank supply chain practices as a key area for sustainability, as it is the biggest challenge for companies to improve performance

What is clear is that defense suppliers are embracing resilience and responsibility in the supply chain throughout the life cycle of goods and services. In particular defense, which has long-term product life cycles, values the notion of resilience in the supply chain. However, Ernst and Young (2016)

found that the concept of resilience has not kept pace with the rising complexity of supply chains and increased frequency of risks, and includes natural disasters, outbreaks from disease, climate change, energy dependency to secure business continuity, resource availability, and commodity prices.

Responsibility in large companies tends to focus on business impacts in the community, environment, and value chain resulting in a supply chain that can respond, and adapt to changing conditions. BAE Systems and Qinetiq in the UK take responsibility seriously, with both companies having Group Corporate Responsibility Directors.

According to PWC (2014), “A company that treats its supply chain as a strategic asset gains competitive advantage through lower costs, higher profitability and better delivery performance.” PWC also states that companies can manage their supply chains more effectively if they focus on five common factors:

1.

Investing in risk management (scenario planning pinpointing disruptions (technology) or unforeseen market disruptions)

2.

Implementing real business analytics (using core transactional systems across the business)

3.

Ensuring it delivers specific outcomes (fine-tuning your supply network to deliver desired outcomes to technology, resilience, security, agility, etc.)

4.

Seeing it as a strategic asset (understanding security of supply or software systems)

5.

Embracing sustainability (applying environmental standards when outsourcing production and demanding reduced carbon and material impacts from logistics providers)

Working Across Defense Functions

However, despite the five factors above, how can defense know which companies treat their supply chain as a strategic asset, whether they understand the risks, have plans to manage and mitigate them, or whether true consideration has been given to sustainability? Defense therefore needs to ensure the supply chain is managed beyond team level to board level as well as integrating across functions, to have any likelihood of incorporating sustainability! This involves managing risks, recognizing efficiencies, creating sustainable products, and building a culture of responsibility.

Working across functions can pose challenges to supply chain sustainability in defense, as requirements managers' and commercial objectives are often not aligned with the sustainability objectives of the environmental function. A lack of internal alignment may therefore have negative impacts on the suppliers' supply chain sustainability performance, as they are not considered.

Commitment from the function, board, and suppliers is critical in setting the correct tone and direction for supply chain sustainability. All should articulate what is required through regular reviews against goals but most importantly hold individuals accountable. It is therefore critical that

project teams (local level), board level (senior executives), and suppliers work closely to achieve sustainable performance.

Before all parties can do this, the supply chain needs to be mapped. Defense needs to understand where suppliers capture the data and attempt to understand the relationships further down the chain. In some instances, regulation will force some companies to identify their impacts further down the chain. Although the author has stated it is difficult to map beyond tier 1, it is possible to go further through the use of shared data systems and buyer knowledge. A generic supply chain can also be used as an illustration of how to identify the gaps.

Procurement Criticality

Defense would be well advised to look at those large categories of procurement that are critical to operations including limited availability of alternative options which impact on supply disruption, that is, material security for large military assets. For each area identified, defense and top tier suppliers should trace the flow of materials and original suppliers. This is very difficult in defense supply chains as they are vast, but if they can map the inputs, raw materials, and products or find other suppliers, their supply chain should be more resilient. Also, understanding where materials originate can help avoid disruption that may result from geopolitical conflicts, changing weather patterns, natural disasters, or resource nationalism. To avoid this scenario many companies have diversified their supplier base to achieve resilience by creating a portfolio of suppliers. Large companies recognize the value in working with a diverse supply chain in different countries to increase business innovation and create a more responsive and competitive supplier base. (Innovation with suppliers can bring more resilient products to market and create long-term relationships with suppliers which may increase revenue.) Companies in Japan have adopted this stance as they experience frequent natural disasters including earthquakes.

To achieve the basic goals of sustainability (both of intra- and inter-generational equity), access to, and security of supply needs to be ensured (Wellmer & Hagelüken, 2015). This includes minerals and energy resources. Added to this, is the multidimensional nature of material security which makes measurement, definition, and assessment of risks and threats problematic (Hoggett, 2013). Regardless of these difficulties, an analysis of future supply chains should be central to any evaluation of material security. A supply chain consists of interconnected sub chains. It is these sub-chains that enable materials to be extracted, manufactured, distributed, used, and remanufactured to meet the consumer/military demand for products and services (Hoggett, 2013). In a secure system, these supply chains need to operate effectively to ensure that the demand for such services/products (assets) can be balanced with sufficient supply, that is, no disruption to supply.

Highly complex supply chains such as those of defense are globally interconnected and more prone to inertia and lock-in (Unruh, 2000, 2002). As systems change, so do supporting supply chains which may be based on the rapid deployment of existing and new technologies as well as changes to the wider associated non-technological social, economic, and political frameworks (Foxon & Pearson, 2008; Foxon et al., 2010). Furthermore, such changes need to occur while dealing with the strengthening of concerns over resource depletion, including accessibility, availability, exportability, the political instability of key regions, continued growth in global demand, and investment in infrastructure (Klare, 2008; Kuzemko, 2012; Scrase et al., 2009; Skea et al., 2012; Powell-Turner, 2012, 2018).

Dealing with such issues may create new risks and opportunities for supply chains (Hoggett, 2013). The need to reverse supply chains and remanufacture, recycle, and reuse, etc. is growing, but there

are huge risks and challenges associated with this in respect to technologies (technical nutrients) and wider cross-cutting issues related to policy, skills, and materials including the circular economy.

Systems and Supply Chains

Supply chains as mentioned earlier are essentially networks or interconnected systems that support a sequence of events/processes from raw material to the final customer. Such a flow involves multiple stakeholders, scales, and locations either directly or indirectly to ensure a product/service is delivered. This is dynamic, not only because of all the interrelationships that exist but because information, money, and resources flow in all directions within the supply chain (Sunil et al., 2004). Further to this, production and sourcing has become more global, and has shifted toward low-cost economies. It is here according to the author where the cross-cutting issues related to policy, transparency, auditing etc. become difficult to manage.

From both a systems and technology perspective, supply chains are central to concerns over material security and energy security. Firstly, existing supply chains can fail, leading to specific energy security problems. Secondly, the need for a systems transition means we need to move from fossil fuel dominated supply chains, toward low carbon and net zero creation; this process of development and transfer will create new risks as the supply chains for newer technologies seek to become established. Thirdly, this risk can be exacerbated by the uncertainty over which technology pathway to follow. There are also the economic consequences as fossil fuels including coal and oil are relatively inexpensive and abundant in supply. However, renewables such as solar and wind are likely to become more economically feasible and mainstream as we move toward the UK governments target of net zero by 2020, reducing overall greenhouse gas emissions (BEIS, 2019)

When a supply chain fails, it can lead to discontinuity in the balance between supply and demand, leading to a loss of material security. The impact will vary depending on the scale of the failure, and the length of time it lasts, as well as the options available for dealing with it, such as reducing demand and re-routing supplies. As well as physical disruptions to supply, a further impact of such discontinuities can be economic, such as the value of lost production from industry, or the failure leading to higher prices across the whole economy (Skea et al., 2012). Supply chain failures can happen for a wide range of reasons, including demand exceeding availability, amounts of materials exported, or capacity constraints where the infrastructure is insufficient to meet demand. The author feels that supply chain failures may represent system shocks and be triggered by natural events, such as typhoons (Philippines, 2013), heat waves (Pakistan, 2018), tsunamis (Indonesia, 2018), bush fires (Australia, 2019), and pandemics including Covid-19 (global, 2020).

Supply of Critical Materials

The introduction of new products using alternative materials including critical materials face a range of internal and external risks that reflect both the maturity of the product and its supply chain. This must be overcome for new innovations and products to be delivered. Understanding these challenges is important, as is the need for companies to build a supply chain. As companies continue to innovate and develop new materials and products, a growing issue for supply chains is for the consistent supply of materials. However, in 2017, scientists identified approximately 300,000 materials, compared with just 12 widely used a century ago (Powell-Turner, 2018). Therefore, the likelihood of finding a like for like replacement material is probably far greater now, than previously.

In the last decade, UK MOD has taken steps to protect Freedom of Action, which means having the ability to act in the country's interests free from intervention by other states or entities. This may mean sourcing from UK suppliers, or entering into arrangements to ensure reliable access to

materials from other countries. This in turn contributes to maintaining Operational Advantage over potential enemies.

This is also a growing area of work in the EU, which included a review of critical raw materials needed to support the EU economy (ECEI, 2010, 2015) as well as critical metals to support the EU's SET (Strategic Energy Technology) Plan (Moss et al., 2011). The EU reviewed the list of critical raw materials in 2011, 2014, 2017, and 2020 (EU, 2020). The 2014 report by ECEI revealed that relatively small changes in supply and demand could result in other materials quickly becoming critical. The EU looked at critical metals based on an analysis of market dynamics, global supply, and demand forecasts. They identified 14 important metals based on the level of supply in 2011, 20 in 2014, 27 in 2017, and 30 in 2020, five of which were considered to be at high risk of shortage from the heavy and light rare earth elements including indium, neodymium, and dysprosium. Indium is particularly important for flat screens and touch screens, and neodymium and dysprosium being important for small and powerful permanent magnets (head up displays, ballistic missiles, etc.) (EU, 2020). Of the metals identified in the EU reports, rare earth elements (REE) are indispensable for many digital applications. Research on the availability of, and access to, REE has grown in recent years, reflecting the fact that global demand has increased. In 2018, governments, industries, and academics raised concern about future demand outstripping the supply of REE, which are crucial for many advanced technologies (MOD, 2018). As global demand for more agile equipment and low carbon technologies increases, and we move toward the growth of renewables and low carbon economies, so will the demand for some REEs raising concerns over price, availability and geopolitics as reserves and production are increasingly concentrated, mainly within China, which produces approximately 90% of global demand (Powell-Turner, 2012). These concerns were exacerbated by the use of export quotas in China, which have increased over the last decade for REEs in their elemental form, and which saw prices rise ten-fold (Powell-Turner, 2018), and as China controls a large percentage of the market they can leverage, through overproduction and price manipulation, and repel competition. In 2015, China relaxed REE export rules and flooded the market. Prices fell, forcing Molycorp, owner of the only functioning REE mine in the United States (Mountain Pass in California), to file for bankruptcy (Roskill, 2017). Further to this, "Black Swan" events like COVID-19 underscore potential supply chain disruptions that can occur when products such as REEs are concentrated in one country (Rosenstreich, 2020). In 2017, Mountain Pass was bought by MP Materials, a consortium comprising US investment funds, JHL Capital Group, QVT Financial, along with Shenghe Resources from China. MP Materials restarted production at Mountain Pass in 2018 where they produce over 36,000 tonnes per year of light REE oxide (Argus, 2020). This is sold to China as there is not the infrastructure available in the United States to process this material. A supply chain transition has to happen, although the production of oxides in the United States is unlikely to happen overnight. With the growth in the electric vehicle market, the author believes that industry is going to demand an alternative source of supply, and this should pave the way for a more diverse and competitive supply chain.

It is suggested that geological scarcity for REE in absolute terms is not an issue and according to the United States Geological Survey (USGS), we have enough REEs to last 100s of years "We are suffering from policy, not geology." Also, back in 2011, the Geological Society said that it was the range of technical, financial, environmental, and regulatory challenges that existed in the creation of new REE reserves which could result in disruptions in supply over the next decade, not availability. The author believes this is still the case in 2020. According to the British Geological Society [BGS] (2017), global concerns have continued to grow over the long-term availability of secure and adequate supplies of "critical" raw materials. This is because of their growing economic importance and high risk of supply shortage required for the fourth industrial revolution. The "fourth Industrial Revolution" is using a

combination of novel technologies (e.g., digital systems and devices; renewable energy and energy storage; electric mobility; autonomous vehicles) that are being deployed at an unprecedented scale and speed. These technologies utilize a wide range of minerals and metals, which are provided by global supply chains that are vulnerable to disruption (BGS, 2017).

Materials Recovery

It is also apparent that recycling and recovering REE from some products is problematic and costly, given that they are often used in small quantities; and given their unique properties, substitution is often not an option (Powell-Turner, 2012, 2018). Effective recycling requires sophisticated knowledge of the components present in the end-of-life (EoL) products stream and this cannot be achieved with mixed recycling in broad categories. EASAC (2016) is satisfied that the case for moving toward a product-centric approach for collection and recycling is strong and should feature in the development of EU policy. This could increase levels of recovery at EoL providing feedstock for specialized recycling. Options include deposit schemes, including return and recycling costs in the purchase price, trade-in which offers a financial reward for return, or contractual obligation, all of which play toward a circular economy. Of course, metals may also be recovered during processing and manufacturing. However, UNEP found in its review of recycling around the world for 60 metals that EoL recycling rates are very low due to collection and technological separation of materials (United Nations Environment Programme [UNEP], 2010). Still, in 2020, the European Commission (EC) said it was concerned over dependence on a few countries for raw materials that present a high supply risk. In response to this the EC has set up the European Raw Materials Alliance (ERMA). ERMA will look to secure and diversify raw mineral supply chains and in particular improve its exploitation of secondary raw materials with methods to reuse, repair, and recycle products that contain rare earth elements. This is critical as the electric vehicle, digital movement, and the renewables sectors grow exponentially. Further to this, Geomega Resources Inc and Hatch Engineering in the United States are developing a disruptive separation technology with a focus on the permanent magnet industry to recycle neodymium, praseodymium, terbium, and dysprosium (Barker, 2020). Geomega are building a demonstration recycling plant in Quebec, Canada, that allows for the separation of REE as well as recycling REE from industrial waste before applying it to the mining industry. It is anticipated that Geomega can contribute to recovering high value materials which can re-enter the supply chain. In addition, the industry has an open system where materials and products are lost or leak from the system. A closed system is therefore required to ensure effective recycling where materials and products are returned to centers where they can enter the recycling and recovery chain to be remanufactured and reused as part of a circular economy.

Interruption and Resilience

Securing supply chains for critical equipment and low carbon technologies is based on how future patterns of demand are satisfied through different supply routes. There will be adjustments over time, but this may not be a smooth process leading to both price increases and supply disruptions (Moss et al., 2011). A further consideration is competition for materials, between countries based on their plans and support for particular low carbon technologies, as well as competition between different sectors, including defense, for the same materials. REEs are a good example of the latter, given that they are widely used across a range of emerging high-tech applications (Powell-Turner, 2012, 2018). However, there is uncertainty over the timing and potential level of impact of material shortages within supply chains. For example, Phillips (2011) highlights that in the case of REEs, despite China using export quotas and exporting REE in component form, these do not include downstream goods that use them, such as magnets. The author believes that the scarcity of some

elements is not fully known and some technologies may not be constrained as China for example is producing equipment using these materials for export.

Although scarcity does not appear to currently be a major supply chain barrier, it may well change with the price of some materials impacting the economics of some equipment/products and services. Bottlenecks may emerge if demand significantly increases for some materials including those for fuel cells, electric vehicles, and battery production.

Reducing risk and vulnerabilities will continue to be a key issue for supply chain confidence. This will require support for innovation through to creating investment confidence and increasing the willingness and number of companies that enter, and build a supply chain, increasing its capabilities and capacity. This can bring additional benefits to defense, such as increasing options and availability, reducing the length of lead times, and reducing costs through the development of diverse and vibrant supply chains which enable learning and encourage competition. It is recognized that risks increase if a supply chain is reliant on a limited number of companies, countries (if you have the choice), or markets. So, it follows that from a material security perspective, a supply chain is likely to be more resilient if the number of companies, networks, connections, etc. is large. This creates alternative options for bringing forward technologies at an affordable cost, to deal with shocks and stresses on the system, providing materials or alternative products from other suppliers.

Therefore, developing resilient supply chains requires a policy approach that seeks to reduce internal risks and threats to material security. This includes those which are more international, requiring an assessment of the local, national, and international dimensions that exist within supply chains relating to technologies, skills, materials, and competition.

While the benefits described above are often overlapping and difficult to measure, there is growing evidence that sustainable supply chains contribute to business value, although we need to continue our efforts to build a better understanding of the business value created. Of course, an unsustainable outcome is not value for money!

Final Remarks

We live and operate in a very dynamic world where the future for sustainable supply chains and sustainability functions is difficult to predict. However, it is likely the future will rely on primarily qualitative analyses and complex quantitative models and techniques which focus on day-to-day risk monitoring and evolution as much as on disruptive, low-probability scenarios.

It is likely that transparency and traceability will continue to evolve as technology solutions provide for the collection, tracking, monitoring, and management of data including the latest 5G. It is also likely that supply chains will widen so accessibility is eased, and an infrastructure is created to recycle and recover those high value materials for future requirements. This should help manufacturers and related companies procure, secure, and proactively move to a more resilient supply chain. It is also likely that procurement will move beyond cost to create economic and social value. This should enable the defense supply chain to move to a circular economy where products, components, and materials are available, and kept at their highest utility and value at all times, where securing access along the chain does not create problems for operations, training and delivery. Ultimately, the author believes that as an organization, defense needs to consider total through life costs of ownership, supplier value, and be a smarter customer by driving innovation in the supply chain.

References

Barker, K. (2020). Disruptive technology for rare earth elements recycling. Q&A with Geomega's President and CEO, Kiril Mugerman May 2020. <https://www.recyclingproductnews.com/article/33835/disruptive-technology-for-rare-earth-elements-recycling>. Accessed 24 November 2020.

British Geological Society. (2017). Critical raw materials. <https://www.bgs.ac.uk/geology-projects/critical-raw-materials/>. Accessed 20 November 2020.

Brundtland, G. (1987). Common future: Report of the World Commission on Environment and Development. <https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf>. Accessed 10 November 2020.

BSR. (2010). The business case for supply chain sustainability. A brief for Business Leaders. December 2010. https://www.bsr.org/reports/Beyond_Monitoring_Business_Case_Brief_Final.pdf. Accessed 10 November 2020.

Chambers, T., Porritt, J., & Price-Thomas, P. (2008). Forum for the future "Sustainable wealth creation within environmental limits". <https://www.yumpu.com/en/document/read/19686886/sustainable-wealth-creation-forum-for-the-future>. Accessed 10 November 2020.

Corporate Citizenship. (2013). Supply chain sustainability shift. Embedding sustainability into supply chain management. <https://corporate-citizenship.com/wp-content/uploads/CC-SUPPLY-CHAIN.pdf>. Accessed 10 November 2020.

Department for Business Energy and Industrial Strategy. (2019). UK becomes first major economy to pass net zero emissions law. <https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law>. Accessed 10 November 2020.

Deutsche Welle (DW). (2020). EU presents new strategy on 'critical raw materials'. September 2020. <https://www.dw.com/en/eu-presents-new-strategy-on-critical-raw-materials/a-54806176>. Accessed 20 November 2020.

ECEI. (2014). 'Critical raw materials for the EU'. Report of the Ad-hoc Working Group on Defining Critical Raw Materials. European Commission Enterprise and Industry. file:///C:/Users/jpowellturner/Desktop/Papers/crm-report-on-critical-raw-materials_en.pdf. Accessed 10 November 2020.

Ernst and Young. (2016). The state of sustainable supply chains – Building responsible and resilient supply chains. https://d306pr3pise04h.cloudfront.net/docs/issues_doc%2Fsupply_chain%2Fstate-of-sustainable-supply-chains.pdf. Accessed 20 November 2020.

European Academies Sciences Advisory Council (EASAC). (2016). Priorities for critical materials for a circular economy. November 2016. German National Academy of Sciences. http://www.academias.fi/wp-content/uploads/2017/01/EASAC_Critical_Materials_web_complete.pdf. Accessed 25 November 2020.

European Commission. (2020). Critical materials. https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en. Accessed 24 October 2020.

Foxon, T., Hammond, G., & Pearson, P. (2010). Developing transition pathways for a low carbon electricity system in the UK. *Technological Forecasting & Social Change*, 77, 1203–1213. <https://doi.org/10.1016/j.techfore.2010.04.002>.

Foxon, T. J., & Pearson, P. (2008). Overcoming barriers to innovation and diffusion of cleaner technologies: Some features of a sustainable innovation policy regime'. *Journal of Cleaner Production*, 16, 148–161. <https://doi.org/10.1016/j.jclepro.2007.10.011>.

Harrington, R. (2011). Challenges and benefits of implementing a sustainable supply chain. November 2011. http://www.confectionerynews.com/Processing-Packaging/Challenges-and-benefits-of-implementing-a-sustainable-supply-chain?utm_source=copyright&utm_medium=OnSite&utm_campaign=copyright. Accessed 04 September 2020.

Hoggett, R. (2013). *New challenges in energy security. The UK in a Multipolar World* (pp. 161–181). Palgrave Macmillan UK

Klare, M. (2008). *Rising powers, shrinking planet: The new geopolitics of energy*. New York: Metropolitan Books.

Kuzemko, C. (2012). 'Security, the State and Political Agency: Putting "Politics" Back into UK Energy'. A conference paper for the PSA Annual Conference, Belfast, 2012

MacArthur, E. (2013). Towards the circular economy – Economic and business rationale for an accelerated transition. volume 1 <https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf>. Accessed 10 November 2020.

Messeccar, C. (2020). Q&A series: How to build an RE supply chain – Part 2 June 2020. <https://www.argusmedia.com/en/news/2110557-qa-series-how-to-build-an-re-supply-chain%2D%2Dpart-2>. Accessed 24 November 2020.

MOD (UK). (2012). Sustainable Procurement on the MOD Estate. <https://www.gov.uk/guidance/defence-infrastructure-organisation-estate-and-sustainable-development#sustainable-procurement-on-the-mod-estate>. Accessed 15 September 2020.

MOD (UK). (2018). Global strategic trends. The Future Starts Today. Sixth Edition. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/771309/Global_Strategic_Trends_-_The_Future_Starts_Today.pdf. Accessed 10 November 2020.

MOD (UK). (2018). Sustainable procurement guide – An introduction to Sustainable Procurement in DE&S. <https://www.asems.mod.uk/sites/default/files/documents/EMP/Sustainable%20Procurement%20V2%20Intro%20Guide.pdf> Accessed 15 September 2020

Phillips, D. (2011). 'Rare Earth Metals'. POSTNOTE 368 (House of Parliament Office of Science and Technology). https://www.parliament.uk/globalassets/documents/post/postpn368rare_earth_metals.pdf. Accessed 15 September 2020.

Powell-Turner, J. (2012). 'Will future resource demand cause significant and unpredictable dislocations for defence on a global scale?'. Presentation at New Energy Security Challenges, 10th May 2012, Royal Geographical Society, London.

Powell-Turner, J. (2018). *Global Strategic Trends. The Future Starts Today*. Sixth Edition. P39. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/771309/Global_Strategic_Trends_-_The_Future_Starts_Today.pdf. Accessed 10 November 2020.

PWC. (2014). *The runway to growth – Using market understanding to drive efficient innovation in the aerospace, defence and security industry*. <https://www.pwc.com/gx/en/aerospace-defence-and-security/publications/assets/the-runway-to-growth-using-market-understanding-to-drive-efficient-innovation.pdf>. Accessed 10 September 2020.

Rosenstreich, M. (2020). *Citizens for National Security. Rare-Earth Elements: A National Security Crisis*. November 2020. https://www.realcleardefense.com/articles/2020/11/17/rare-earth_elements_a_national_security_crisis_649952.html. Accessed 24 November 2020.

Roskill. (2017). *Rare Earths: Mountain Pass sold to Chinese-led consortium*. June 2017. <https://roskill.com/news/rare-earths-mountain-pass-sold-chinese-led-consortium/>. Accessed 24 November 2020.

Scrase, I., Wang, T., MacKerron, G., McGowan, F., & Sorrell, S. (2009). *Introduction: Climate policy is energy policy*. In I. Scrase & G. MacKerron (Eds.), *Energy for the future – A new agenda*. Basingstoke: Palgrave Macmillan.

Skea, J., Chaudry, M., & Wang, X. (2012). *The role of gas infrastructure in promoting UK Energy Security*. *Energy Policy*, 43, 202–213.

Sunil, C., & Meindl, P. (2011). *Supply chain management: Strategy, planning and operation* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

The Geological Society. (2011). *Rare Earth Elements. A briefing note by the Geological Society of London*. December 2011. <https://www.geolsoc.org.uk/~media/shared/documents/policy/Rare%20Earth%20Elements%20briefing%20note%20final%20%20new%20format.pdf>. Accessed 15 September 2020.

United Nations. (2016). *WHITE PAPER. The UN Global Compact Ten Principles and the Sustainable Development Goals: Connecting, Crucially*. https://d306pr3pise04h.cloudfront.net/docs/about_the_gc%2FWhite_Paper_Principles_SDGs.pdf. Accessed 15 September 2020.

United Nations. (2017). *The Sustainable Development Goals Report 2017*. <https://unstats.un.org/sdgs/report/2017/>. Accessed 24 November 2020

United Nations and BSR. (2015). *Supply chain sustainability: A practical guide for continuous improvement*. Second Edition. https://d306pr3pise04h.cloudfront.net/docs/issues_doc%2Fsupply_chain%2FSupplyChainRep_spread.pdf. Accessed 15 September 2020.

United Nations Environment Programme (UNEP). (2010). *Metal stocks in society – Scientific synthesis*. https://wedocs.unep.org/bitstream/handle/20.500.11822/8438/Metal_Stocks_EN.pdf?sequence=1&isAllowed=y. Accessed 15 September 2020.

Unruh, G. C. (2000). *Understanding Carbon Lock-in*. *Energy Policy*, 28(12), 817–830. [https://doi.org/10.1016/S0301-4215\(00\)00070-7](https://doi.org/10.1016/S0301-4215(00)00070-7).

Unruh, G. C. (2002). Escaping Carbon Lock-in. *Energy Policy*, 30(4), 317–325. [https://doi.org/10.1016/S0301-4215\(01\)00098-2](https://doi.org/10.1016/S0301-4215(01)00098-2).

Wellmer, F., & Hagelüken, C. (2015). The feedback control cycle of mineral supply, increase of raw material efficiency, and sustainable development. *Minerals*, 5(4), 815–836. https://www.researchgate.net/publication/284903528_The_Feedback_Control_Cycle_of_Mineral_Supply_Increase_of_Raw_Material_Efficiency_and_Sustainable_Development. Accessed 24 September 2020.



DSPACE

<https://dspace.org/>

Sustainability, supply chains, and defense: The Palgrave encyclopedia of interest groups, lobbying and public affairs

Powell-Turner, Julieanna; Murgatroyd, Clive

2021-02-06

Palgrave Macmillan

<https://doi.org/10.1007/978-3-030-13895-0>

Powell-Turner JW, Murgatroyd CA. (2021) Sustainability, supply chains, and defense. In: The Palgrave encyclopedia of interest groups, lobbying and public affairs, Palgrave Macmillan, Cham