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Eva Barteková and René Kemp

Maastricht Economic and social Research institute on Innovation and Technology (UNU-MERIT)
email: info@merit.unu.edu | website: http://www.merit.unu.edu

Maastricht Graduate School of Governance (MGSoG)
email: info-governance@maastrichtuniversity.nl | website: http://www.maastrichtuniversity.nl/governance

Boschstraat 24, 6211 AX Maastricht, The Netherlands
Tel: (31) (43) 388 44 00

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Critical Raw Material Strategies in Different World Regions*

Eva Barteková[†] René Kemp[‡]

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Abstract

The rising imbalance between increased demand for minerals and their tighter supply has resulted in growing concerns about their criticality. This has in turn stimulated both resource-rich and resource-poor countries to take active role in implementing mineral policy strategies. This paper explains why different world regions responded differently to the global problem of securing stable supply of critical minerals, in particular of rare earths. The paper first provides an in-depth overview of development trajectories of critical mineral strategies through a historical case study analysis of major stakeholder regions - China, the United States, Europe, Japan and Australia. Next, it offers answers as to why they have responded the way they did: how national interest considerations, resource endowment circumstances, countries' historical experience in tackling supply risk and their respective policy styles influenced the development of critical mineral policy choices within a comparative political economy framework. The overall findings show distinctive differences in policy strategies towards critical materials. Whereas Europe opts for a policy dialogue with resource-rich countries, Japan and the United States have a more hands-on approach in research and development initiatives. Australia and China instead, strive to promote domestic mining activities and to protect their resources through resource nationalist policies.

JEL classification: L72, L78, O57, Q34, Q38
Keywords: raw material criticality, rare earths, national policy styles, comparative political economy

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[†]UNU-MERIT/Maastricht University, bartekova@merit.unu.edu

[‡]UNU-MERIT and ICIS - Maastricht University, r.kemp@maastrichtuniversity.nl

1 Introduction

Global population growth, economic growth by developing countries, technological change and government policies have been the main driving forces reshaping the global demand for non-energy minerals in recent years. These trends led to ever increasing consumption, both in terms of total quantity and of variety of minerals used. Particularly affected are specialty metals which are used as input materials for mass production of various technologies due to their specific chemical and physical properties. Yet, these very same properties make specialty metals difficult to substitute in their functional uses. What is more, most of them tend to have relatively small and concentrated markets and are often mined and refined in developing regions, exposing importing countries to political and economic risks. In fact, lack of political stability and resource nationalism by producing countries might have adverse effects for the entire supply chain. Additionally, many of these metals are by-products of major minerals, what further exacerbates their primary supply. Taken together, the imbalance between increased demand and tighter supply has resulted in growing concerns about criticality of these metals and about the impact of their supply shortages on industrialization and green growth.

In particular, a group of metals called rare earths spurred a heated debate over potential implications of such imbalances on countries' competitiveness in general and on deployment of modern technologies in particular. In fact, their special properties of ferromagnetism, superconductivity and luminescence make them key technology components in many electronic applications, such as cell-phones, hard disk drives and computer screens, as well as in various low carbon technologies, mainly in electric motors and batteries of electric vehicles and in some wind turbine generators (Lynas, 2010; Tasman, 2010). Their total demand is relatively small compared to other industrial metals, yet it has been rapidly expanding with the increased deployment of these technologies. In particular, demand for dysprosium and neodymium, the two most critical rare earth elements in terms of their functional uses, have been projected to increase by more than 2600% and 700% respectively, over the coming 25 years (Alonso et al., 2012). Tensions on the rare earth market are caused by China's dominance over mining and production with 89% of global market share (USGS, 2014), as well as by its industrial policies aimed at satisfying own needs for manufacturing higher value added products. Restrictions such as production and export quotas, as well as banning of foreign companies from engaging in the supply chain, led to tighter global supply and increased prices of rare earths. Price hikes like those in 2011, when rare earth crisis burst, brought about significant uncertainty about availability and reliability of supply. These concerns have in turn stimulated the United States, Japan and Europe, which are the main consumer countries and almost entirely import dependent from China, to take active role in implementing mineral policy strategies with view of minimising their vulnerability to supply of rare earths (EC, 2013).

Despite their similar objectives, the strategies undertaken differ across regions. While Europe's efforts target policy dialogue with resource-rich countries, Japan and the United States have a more hands-on approach in research and development (R&D) initiatives in substitution, minimisation and improvement of performance of critical material-free functionalities. Australia and China instead, strive to promote domestic mining activities and to protect their resources through resource nationalist policies. In this light, the aim of the present paper is to map out how the issue of raw materials criticality has been taken up within various countries overtime and to explain why countries adopted different approaches in securing stable supply of critical materials, in particular of rare earths. For this purpose, the paper carries out a historical case study type of qualitative analysis across major stakeholder regions - China, the United States, Europe, Japan and Australia - offering a historical perspective on how the trajectories of critical mineral policies developed over time. In the next step, the paper applies a comparative political economy framework to examine the extent to which distinct national policy styles, national interests, resource endowment and historical experience in tackling supply risk shaped the different policy responses by countries.

The rest of the paper is structured as follows: Section 2 discusses the theoretical framework and method of analysis. Section 3 defines the concept of criticality of raw materials and discusses its interpretation by various countries. Section 4 provides a historical perspective of mineral strategies implemented in different world regions, while section 5 offers a comparative political economy interpretation of the differences in these strategies. Section 6 concludes.

2 Theoretical Framework and Method

The present paper attempts to explain why different world regions responded differently to the global problem of securing stable supply of critical minerals, in particular of rare earths. In fact, despite their similar objectives, strategies undertaken by various world regions tend to differ in their foci. This paper argues that policy responses are a result of path dependent processes embedded in countries' national interests, resource endowment and their historical experience in tackling supply risk. Yet, institutional variables also matter greatly for understanding the cross-national differences in policymaking. They include the legal system, the openness of the administrative system and political system, the role of consultation and interest mediation. The institutional factors are captured through the notion of "policy style" which holds that countries have developed distinctive ways for achieving similar goals and standards, through legal traditions, political structures, industrial organisation and cultural attitudes (Kagan, 2000).

The nature of policy styles has been studied by a large body of empirical literature which developed in the second half of the 20th century. The most prominent of these is the comparative political analysis by Richardson et al. (1982) who coined the concept of policy style. They define policymaking and implementation style as *"the interaction between a) the government's approach to problem-solving and b) the relationship between government and other actors in the policy process"*. In an attempt to identify the main characteristics of the ways in which societies formulate and implement policies, they thus devise a matrix of national policy styles based on the government's approach to problem solving, which can be taking either anticipatory (active) or reactive stance, and on the government's relationship to other actors, which can be characterised either as consensus or as imposition. This allows the authors to classify Western European countries across four policy styles. Feick (1992) examines to what extent nations matter with respect to public policy choices, by integrating the findings of comparative studies of social, economic, environmental and occupational health and safety policies of Great Britain, Sweden and United States. In particular, he considers how country-specific variables, such as institutional and organisational structure, cultural orientation and policy style influence policy profiles. According to his definition, policy style *"should capture the characteristics of policymaking and implementation process involving the interaction of actors constrained by institutional prerequisites as well as cognitive and normative orientations, procedural preferences and substantive interests"*. He summarizes the main characteristics of policy style from the literature as pertaining to: 1) conflict resolution (competition/conflict, cooperation/consensus, formality, drama); 2) problem solving (scope, direction, speed, time frame); 3) participation and interaction (openness, participation, atmosphere). Finally, Van Waarden (1995) defines policy style as *"the routine choice behaviour or 'standard operating procedures' which policymakers tend to de-*

velop in the policy process" and states that policy styles are strongly rooted in legal, political and administrative institutions and cultures specific to every nation. Given this embeddedness, policy styles tend to be resistant to changes due to economic and political internationalisation. After ascertaining the most salient characteristics of policy styles of Great Britain, France, Germany, the Netherlands and the United States, he distinguishes between six types of policy styles, some of which overlap with the characteristics discussed by Richardson et al. (1982) and by Feick (1992): 1) liberal-pluralist versus étatist versus corporatist; 2) active versus reactive; 3) comprehensive versus fragmented or incremental; 4) adversarial versus consensual versus paternalistic; 5) legalistic versus pragmatic styles; 6) formal versus informal network relations.

Earlier institutional work has acknowledged the role of policy styles in environmental regulation. The most prominent is the book by Vogel (1986) about environmental regulatory styles in the United States and the United Kingdom in the 1970s and 1980s, about which he concludes that despite the similarities in their legal systems, there are important differences in policy styles across the two. In particular, the American approach is rigid and rule oriented, making use of environmental standards, allowing no self-regulation by industry and prosecuting companies. Contrary to this, the British approach is flexible and informal, with almost no emission standards in place, with an important role for industry self-regulation and few cases of prosecution. The author concludes that the effectiveness of the British environmental regulation through voluntary compliance has achieved similar results as the adversarial approach adopted by the US which produced greater resistance from business. On a similar note, Kagan (2000) discusses the contrasting styles of environmental regulation, regulation of employment and of financial institutions in the United States and Japan. His review reinforces the views that the American regulation is adversarial and legalistic, and describes the Japanese regulation as being more informal and less legalistic. In fact, in Japan the policies are formulated through informal interaction between government and industry associations and are implemented through informal administrative guidance and voluntary plans by companies. Also, regulatory officials believe that consultative and educational style results in better compliance and are thus less inclined for punitive action. Löfstedt et al. (2001) re-examine the environmental regulation in European and American contexts and acknowledge the changing nature of their policy styles over time. While the American style can still be largely characterised as adversarial and the European style as consensual, in Europe the environmental regulation has become stricter whereas in the United States it has turned less contentious but not comparatively stricter. The authors conclude that one of the main drivers for this fundamental change lies within trust. In fact, American regulators appear to be more trusted than ever, while public distrust toward regulators is on increase in the EU. Similarly, Hung Lo et al. (2000) derive China's policy style from an analysis of Shanghai's environmental impact assessment system in terms of policy ideology, policy content, regulatory process, public participation and policy consequences. The authors describe China's policy style as active, highly legalistic and adhering to procedural formalities, but at the same time shaped by informal political activity, especially from municipality leaders and bureaucratic agencies in charge of economic and urban development. Also, the policy style is discretionary and agency-dominated with complete lack of institutional channels to open consultation and public participation. Especially in the latter sense, Chinese policy style in environmental regulation differs substantially from that of industrialised countries. Finally, O'Neill (2000) analyses regulatory styles of Britain, Germany, France, Australia and Japan in the context of hazardous waste trading as part of a broader system of environmental regulation. In terms of access to policy process and mode of policy implementation, the author finds strong similarities between Australia and Germany. Despite the differences in their federal structures, both are characterised by high levels of government control. Yet, Australia is also known for its open system of regulation, accommodating the involvement by electorate and environmental groups on the level of commonwealth government. Indeed, the latter have been seen to have fundamentally altered policy outcomes. The commonwealth government follows a neo-corporatist approach and has balanced government-industry-society relations.

Informed by the empirical literature reviewed above, about policy styles differing across nations, this paper carries out an in-depth analysis of critical mineral strategies adopted by different world regions. This is done by, first reviewing the academic and grey literature on raw material criticality and comparing the different definitions across countries. Next, a qualitative analysis of historical developments is carried out in order to map out how the issue of raw materials criticality, in particular that of rare earths, has been taken up by main stakeholders - China, the United States, Europe, Japan and Australia. This part is followed by a comparative analysis of national policy styles. This interpretative part discusses how countries' institutional contexts, their national interests, resource endowment and respective historical experiences in tackling supply risk affected the adoption of different strategies. The ultimate aim of the paper is to map out the distinct priorities of critical mineral strategies and to explain why different world regions responded differently to the global problem of securing stable supply of critical minerals. The policy styles are used as a sense making device, rather than the object of analysis. The object of analysis is the history of policy action around critical minerals in mineral producing and consuming countries and world regions. To our knowledge, there exists no other study which endeavours to explain the development trajectories of mineral policies in such detail.

3 The Concept of Criticality

The origins of the literature on supply risk date back to the late 1930s and gained salience when oil and cobalt crisis burst in the 1970s. In recent years, the debate has been revived and extended to non-energy minerals. The contemporary literature aims at developing methods to evaluate criticality of minerals on the one hand, and at examining the extent to which potential bottlenecks affect national economies, specific industries or technologies on the other. In particular, the aim is to provide industries and manufacturers with informed decisions in order to anticipate and mitigate the adverse effects the criticality of input raw materials might cause, and to provide directions for policy and industry makers in formulating mineral strategies.

Theoretical studies on supply risk can be classified into three broad categories based on the methodology they use to assess criticality: criticality matrices, criticality indices, and scenario or time series analysis (Erdmann and Graedel, 2011). The most relevant for evaluating mineral's criticality in a broader context are criticality matrices. The first to develop a comprehensive conceptual framework was the National Research Council (2008). Within their criticality matrix, minerals are evaluated based on their importance in use and on their supply risk, i.e. availability and reliability of the mineral supply. The degree of importance is evaluated from the perspective of minerals' chemical and physical properties and their substitutability within technologies. Mineral supply risk is influenced by geologic, technical, environmental and social, as well as political and economic factors in the long term. In the short to medium terms instead, supply risk translates into physical unavailability or higher prices, and is caused by increased demand and limitations to expand production in the short period of time. Within this framework, a critical mineral is one which is subject to supply risk and has high importance in use with little or no substitutes available. Authors also note that criticality is a dynamic concept and can change overtime with technology innovation, popularity of using the technology, as well as rise of regulatory and environmental issues. This framework was later extended by

Graedel et al. (2012) who added environmental implications as a third dimension to it. Consequently, they evaluate criticality of metals within a criticality space rather than within a matrix. They also add a temporal perspective to supply risk - short versus long term - and propose to evaluate vulnerability to supply restriction on three organisational levels: global, national and corporate. Achzet and Helbig (2013) review the most important empirical studies and find out that, while risks can be summarised in the broad categories of supply risk, vulnerability and ecological risk, there is a lack of consensus on appropriate indicators. They conclude that the most often used indicators are quantitative, such as country risk, country concentration, depletion time, by-product dependency, company concentration and demand growth. Contrary to this, qualitative indicators such as substitutability, risk of strategic use and climate change vulnerability are applied by very few studies only. Similarly, studies tend to understate the role of social, ecological and political (other than country risk) determinants of supply risk. In this light, Erdmann and Graedel (2011) state out that classification of materials as critical relates to the level of attention society pays to certain materials in terms of technological change and political vision.

In terms of the empirical literature, several countries have assessed the criticality of minerals for their respective economies. The list of critical materials varies from country to country, due to different scope and approaches adopted. For example the report by National Research Council (2008) considers a mineral to be critical *"if it performs an essential function for which few or no satisfactory substitutes exist"* and *"if an assessment also indicates a high probability that its supply may become restricted, leading either to physical unavailability or to significantly higher prices for that mineral in key applications"*. At the same time, the report by the EC, 2010a follows a relative concept of criticality, whereby raw material is labelled critical *"when the risks of supply shortage and their impact on the economy are higher than for most of the other raw materials"*. While both studies use criticality matrices for a short term assessment, the first sets out a more qualitative assessment of supply risk while the second uses mostly quantitative indicators. Despite the conceptual differences, both studies agree on the criticality of rare earth elements, due to their high import dependence, distorted primary supply, low recycling rates and lack of substitutability. The updated version of the European study examines separately the sub-groups of heavy and light rare earths, as well as scandium (EC, 2014f). While the level of economic importance is very similar for the two, supply risk is substantially higher for heavy rare earths due to their higher demand growth projections and to the entire global supply originating from China (dysprosium is part of this sub-group). Also Japan has labelled rare earths as critical, since they are essential for maintaining and increasing the country's industrial competitiveness and their potential supply disruption would negatively impact Japan's economy. Japan defines *"rare metals"* as those which are either scarce or economically or technologically difficult to extract in pure form and for which a substantial industrial demand exists both now and in future due to technological innovation (Advisory Committee on Energy and Natural Resources, 2009). In this sense, Japan adopts a more forward looking perspective to criticality. In contrast, Australia is the major exporter of minerals globally, yet it is a relatively a small consumer of both major and minor minerals. Due to this, its downstream sectors are not exposed to the issue of mineral criticality. As a producer rather than a user, Australia considers criticality as its own *"resource potential"* to tap into the global demand for these minerals, among others for rare earths (Skirrow et al., 2013). Last but not least China, which is the leading global producer but at the same time it also consumes most of its domestic production, is very protective about its raw materials. In fact, China has declared rare earths as *"protected and strategic materials"*, what allows it to take advantage of its domestic resources for own industrial upgrading (SCIO, 2012).

One of the commonalities in these studies is that they all define criticality in terms of supply risk and importance of raw materials for the economy. Another one concerns the fact that raw materials criticality seems to be more relevant from an economic and a geopolitical perspective, than from a physical constraint perspective. In fact, reserves for several critical minerals are abundant and their size can be further increased by mineral exploration and technology development. In the particular case of dysprosium and neodymium, limitations to increasing their production outside China exist in the short term and are exacerbated by potential shortages due to their rapid demand growth. Nonetheless, the major concern relates to political factors, such as concentration of supply and political risk associated with supplier countries' resource nationalism. The latter becomes even more pressing considering the high import dependence by consumer countries which strive to establish an undistorted access to critical raw materials. This rising relevance of economic and political dimensions of raw materials criticality has translated into a policy trend, whereby raw materials are considered a strategic matter. In line with this, developments on the minerals market are influenced by active government intervention in both resource-rich and resource-poor countries. Government mineral strategies however do not occur in a vacuum. They are shaped by national interests, resource endowment and countries' historical experience in tackling supply risk, as well as by national institutional context. Therefore, in order to understand the development of policy choices over time one needs to analyse the entire system in which these mineral strategies developed.

4 Strategies for Mitigating Mineral Criticality in the World

This section is not intended to provide a complete account of historical developments; rather it describes the major events which played a role in the formulation of countries' mineral strategies. For this purpose, a variety of countries affected in distinct ways by rare earth criticality has been selected. The analysis begins with resource-rich China which is currently the dominant producer but at the same time also the largest consumer of rare earths globally. Next, the United States and Australia, which represent the competitive fringe, are examined. Both countries possess economic deposits of rare earths, yet as opposed to the US, Australia's consumption is rather negligible. Finally, Japan and the European Union are both completely import dependent, however while the former uses them as intermediate goods, the EU sources rare earths mainly in form of finished products. Besides these countries, there exist other smaller players on the market, such as India and Russia which produce small quantities of rare earths, and numerous junior rare earth projects in various other countries which are currently under development. Yet it will take some years until these might actually start mining and production. On the demand side, South Korean manufacturing industry also relies on rare earth imports, yet the exposure to criticality seems much lower than in the case of Japan.

4.1 China

China entered the rare earth market in the 1950s when Baotou Iron and Steel Company started mining the iron deposits at Bayan Obo in Inner Mongolia, of which rare earths are co-products. Yet, it was not until the early 1970s when Xu Guangxian, also known as the father of Chinese rare earth chemistry, developed the new extraction method of rare earths what kicked off the large scale extraction of rare earths in China. Moreover, after the Cultural Revolution, the idea that natural resources processing and export might fuel Chinese economic growth was put forward by President Deng Xiaoping. To underlie the strategic importance of rare earths in this context, he stated out in 1992: *"There is oil in the Middle East; there is rare earth in China..."* (Baotou

Development Zone, 2015). At that time, a special industrial zone was set up in Baotou to attract foreign direct investment in rare earth facilities, with the view of bridging the technology gap between China and the developed world (Mancheri et al., 2013). After a transitory period in the 1980s, China took lead in the global rare earth production in the early 1990s, and was gradually increasing its monopoly position over the next two decades. With 98% of market share it reached the absolute monopoly in 2009, which has been slightly eroding ever since (USGS, 2015a). This success is often attributed to China's cheap labour force and lower regulatory costs, as well as to its favourable deposits of rare earths in terms of number, size and heavy rare earth content (Haxel et al., 2002). Lower prices of Chinese rare earth oxide contributed to the rest of the world losing their market shares by early 2000s, indeed. Yet, prices alone were not the only engine behind the remarkable success of the Chinese rare earth industry development.

The Chinese rare earth innovation system dates back to the 1960s when the first research institutes were established. The Baotou Research Institute of Rare Earths, which was established in 1963 under the former Ministry of Metallurgy Industry and in 1992 merged into Baotou Iron & Steel (Group) Company, is now the largest rare earth technological R&D institution specialized on rare earths in China. It has more than ten subsidiaries and employs altogether more than 700 employees, half of them engineering technicians (BRIRE, 2015). Its research focuses on industrial uses of rare earths such as metallurgy, environmental protection, new materials and application in traditional industry. Similarly, the General Research Institute for Nonferrous Metalsestablished in 1952, has been working on R&D of nonferrous metals and facilitating the development of the rare metals industry across China ever since. It was transformed from an R&D institute into a research company in 2000 and its main research aims are to develop resource-saving, highly efficient, environmentally friendly and internationally competitive technologies and to provide materials' solutions for new strategic industry development (GRINM, 2015). In the meantime, Xu Guangxian became the major protagonist of the rare earth industry development of China. He was chairing the National Natural Science Foundation of China, launched several rare earth research programs in the 1990s and also established other two laboratories carrying out research on rare earths (Hurst, 2010). The State Key Laboratory of Rare Earth Materials Chemistry and Applications is affiliated with the College of Chemistry and Molecular Engineering in Peking University, employs more than 60 faculty members, and deals with basic research on rare earth material chemistry, new rare earth materials and materials designs (RELAB, 2015). The CAS Key Laboratory of Rare Earth on Advanced Materials and Valuable Utilization of Resources is affiliated with ChangChun Institute of Applied Chemistry under the supervision of the Chinese Academy of Sciences, has 32 faculty members, and its main research directions include applied research on rare earth chemistry and physics, chemical biology of rare earths and their separation chemistry (CAS, 2015). Additionally, innovation and diffusion of knowledge take place through the Chinese Society of Rare Earths. This was established in 1979 as the first national society on rare earth science, technology and applications in the world. Its aim is to promote sustainable and sound development of the rare earth industry, gathering together more than 100'000 registered experts who engage in various aspects of rare earth R&D. The organization also publishes the only two peer-reviewed journals on rare earths in the world: Journal of Rare Earths (both in English and Chinese) and Chinese Rare Earths (in Chinese only), as well as the newsletter Chinese Rare Earth Information. It also maintains a comprehensive database of rare earth research, and hosts meetings and conferences, such as the International Conference on Rare Earth Development and Application (CSRE, 2015).

Ever since Guangxian's invention, China has been doing a lot of R&D in rare earths to achieve global leadership in the industry. In 1986 the National High Technology Research and Development Program (Program 863) was endorsed by President Deng Xiaoping. The objective of the Program is to boost innovation capacity in the high-tech sectors, as well as to achieve breakthroughs and to leapfrog development in key technical fields in which China enjoys relative advantages or in which it should take strategic positions to fulfil its strategic objectives (MOST, 2015a). The overall investment in the Program during the period 1986-2010 was 96.7 billion RMB (or approximately 14 billion EUR according to 2015 exchange rates) (ERAWATCH, 2015b). Since rare earths are recognized as one of the strategic resource for China and are contained in most of the technology fields covered by the Program, a lot of R&D initiatives were targeting these. Furthermore, the National Basic Research Program (Program 973), which targets China's basic research and promotes collaboration between research institutes, universities and industries, was established in 1997 (MOST, 2015b). The objectives of the Program are to strengthen original innovations and to address scientific issues concerning national, economic and social development so as to improve China's innovation capabilities. The program budget for the period 1998-2010 was 15.7 billion RMB (or approximately 2.3 billion EUR according to 2015 exchange rates) (ERAWATCH, 2015a). Moreover, the National Program for Long and Medium Term Scientific and Technological Development (2006-2020) lists rare earth-intensive technologies as key target of basic and frontier R&D (SCIO, 2012). To conclude with, not only the quantity but also the quality of research has increased over time. For example, paper contributions by Chinese researchers in rare earth chemistry and their quality have been constantly on the increase since the early 1990s, the pace of improvement having accelerated sharply after 2001. Increased research funding and the foundation of national rare earth research centres, as well as transfer of R&D bases to China, have made China to become the global centre of research for rare earth science and technology (Adachi et al., 2010).

In light of the recent changes in international manufacturing structure caused by the sluggish growth in most developed countries, a new ten year action plan - Made in China 2025 - has been presented by Premier Li Keqiang, endorsing the blueprint for the next generation of manufacturing in China. Its aim is to: *"...seek innovation-driven development, apply smart technologies, strengthen foundations, pursue green development and redouble [our] efforts to upgrade China from a manufacturer of quantity to one of quality."* (Hui, 2015). Among the ten sectors covered are also new materials, high energy vehicles and high-end robotics, which involved the use of rare earths. Increasing the competitiveness of Chinese manufacturing also entails Chinese firms moving up the value chain in production and innovation. In the particular case of rare earths, this idea has been put forward already in 1999 by President Jiang Zemin who stated: *"Improve the development and applications of rare earth, and change the resource advantage into economic superiority."* (Baotou Development Zone, 2015). Further to this, China has been pursuing various strategies to achieve its long term goal of manufacturing higher value added forms of rare earths. With regards to R&D, various initiatives allowed China to shift gradually from export of rare earth compounds and metals, towards export of intermediaries such as magnets and phosphors, and high-tech products like mobile phones, computers, batteries and electric motors (Bromby, 2015a). Another strategy was the technology transfer through foreign direct investment. An example of a successful technology transfer was the acquisition of Magnequench in the mid- 1990s by two Chinese companies with close ties to the Chinese Government. Magnequench was a subsidiary of General Motors, which commercialized the manufacturing of bonded permanent magnets and enjoyed a monopoly in supplying laser-guided smart bombs (Molycorp Inc, 2015b; Robison and Ratnam, 2010). Just a few years after this acquisition, its plant in Indiana was closed down and the operations along with the know-how were transferred to Tianjin in China, and later expanded to Singapore and Thailand. This move helped China to gain access to the neodymium-based permanent magnet technology, which previously was only available in the US and Japan. At present, China manufactures around 80% of global annual output, yet it does not hold any patents on neodymium-iron-boron magnets (Shen, 2015c). The rights on bonded and hot pressed magnets in the US are currently held by the newly refurbished Magnequench owned by Molycorp, while Hitachi in Japan holds patents on sintered magnets. At present, only nine companies in China are licensees of Hitachi. This leaves most of the Chinese manufacturers without the possibility of exporting their magnets globally. China has recently filed a complaint against Hitachi extending patent expirations for which the coverage ended in July 2014 (Hitachi Metals, 2013; Kosich, 2013). Should the legal dispute end in favour of Chinese manufacturers, this would extend the Chinese monopoly from rare earth extraction and processing to include also manufacturing of finished products.

To protect its own industrial upgrading and to hold back rare earths for its domestic purposes, China has declared rare earths as *"protected and strategic materials"* more than two decades ago (SCIO, 2012). In line with this, China prescribed protected exploitation of rare earth minerals and issued the National Plan for Mineral Resources (2008-2015). Further to these, it introduced the following industrial policies: foreign companies are banned from engaging in any part of the supply chain other than forming joint ventures with domestic companies; both domestic and joint venture companies are subjected to production and export quotas; state control is increased by merging several companies into one "megacompany", by banning new rare earth mining licenses, and by eliminating smuggling; it has been proposed to create a joint pricing platform and a national pricing system; to fight the overproduction and strengthen its pricing power, China supports benevolent production halts, ordered phasing out some of the production capacities and decided to set up large strategic stockpiles (MOFCOM, 2012a; MOFCOM, 2012h; MOFCOM, 2012i; MOFCOM, 2012f; MOFCOM, 2012d; MOFCOM, 2012e; MOFCOM, 2012c; MOFCOM, 2012b; MOFCOM, 2012g; MLR, 2013) (Shen, 2014). Taken together, these protectionist policies demonstrate a clear alignment of China's natural resource policies with its national interests of industrial upgrading and creating competitive advantage for its manufacturing. Yet China's main lines of argumentation behind these measures are environmental and social costs arising from excessive mining and polluting techniques employed to mining and processing of rare earths (SCIO, 2012). In 2014, further to the dispute settlement filed by the US, the EU and Japan against the Chinese trade restrictions, the World Trade Organisation (WTO) ruled that China violated the international trade rules (WTO, 2014). In 2015, China abolished the export tariffs and quotas, but introduced new industrial policy in form of resource tax and export licensing in order to prevent over-consumption and to boost industrial upgrading (MOFCOM, 2014a) Shen (2015b). Following the 12th Five-Year Plan, the Government continues consolidation and restructuring of the downstream side of the supply chain. By merging rare earth producers into six state-owned industrial groups it intends to regulate production volumes in order to keep the environmental damage under control and to stabilise prices, to minimise potential competition from emerging global players and to achieve full integration of rare earth industry (Lifton, 2015). This should further help to eliminate smuggling, which occurs under the protective umbrella of local governments, and which China has been unsuccessfully combating during the past decade (Shen, 2015a,d).

Finally, China's strategy of manufacturing more high value added goods will put pressure on its domestic resources in the near future. In fact, China plans sourcing more than 40% and 70% of manufacturing components domestically by 2020 and 2025, respectively. It thus proves essential that China assures reliable access to raw materials, especially to heavy rare earths (Berry, 2015). China's concern about potential future resource bottlenecks has been addressed within its "go global" policy, one of the objectives of which is acquisition of strategic resources abroad (Humphries, 2015). In particular, the outbound direct investment in the mining sector is expected to achieve 390 billion USD over the next five years (344.7 billion EUR according to 2015 exchange rates). China also strives to diversify its rare earth supply sources internationally. In 2005 China National Offshore Oil Corp (CNOOC) made a bid for the American oil group UNOCAL, however the deal failed due to political opposition by the US Government. Though UNOCAL was primarily an oil and gas producer, it also owned the Mountain Pass mine Ű America's largest deposit of rare earths and currently one of the only two non-Chinese rare earth projects in operation (Chovanec, 2010). Some years later, Chinese companies successfully acquired a stake in the Australian Arafura, and also attempted to purchase a controlling stake in Lynas (The Sydney Morning Herald, 2009). There are also signs of China's interest in North Korean rare earths (Schearf, 2014). Recently, Chinese Sheng Kang Ning Mining Investment, a subsidiary of one of the six major Chinese rare earth producing companies, formed a joint venture with Canadian Pele Mountain Resources, which owns the only mine that has previously produced rare earth oxides in Canada (InvestorIntel, 2015). Besides taking equity positions in foreign companies, China also offers grants and loans to countries in exchange for access to their raw materials. Administered by the Department of Aid to Foreign Countries, almost half of China's economic development aid has been disbursed to resource-rich Africa (Hanauer and Morris, 2014). Regarding domestic measures for increasing availability of raw materials, China implemented the concept of circular economy as the new economic model of development. The latter is based on the "3R" principles, i.e. reduction, reuse and recycling activities conducted in the process of production, circulation and consumption (NPCSC, 2008). While no official information is available on the extent to which the concept of circular economy is implemented in the context of rare earths, the Central Government has been setting targets for more efficient resource use and waste management across various industries, part of which are also nonferrous metals (State Council, 2013).

4.2 The United States

The debate on secure supply of raw materials has a long tradition in the United States and is strongly related to military and security interests in US policymaking. The term critical material was first introduced in the late 1930s within the Strategic and Critical Materials Stock Piling Act (United States Public Laws, 1939). The National Defense Stockpile, considered as the cornerstone of the US minerals policy, was established some years later (United States Public Laws, 1939). This is administered by the Defense Logistics Agency (DLA) - Strategic Materials and is intended to support military and essential civilian needs at times of national emergency. Economic stockpiles instead, are intended to smooth temporary interruptions of minerals flows, and were first proposed by the National Commission on Supplies and Shortages, which was itself established two years prior by President Ford in 1976 (National Commission of Supplies and Shortages, 1976). In the early 1950s the President's Materials Policy Commission (Paley Commission) was appointed by President Truman in order to address the concerns of continued adequacy of post-World War II raw material supplies in the US (Mason, 1952). Within their report, the Commission made recommendations on increasing supply of raw materials by encouraging exploitation on public lands by private enterprises, by improving technology for commercial extraction, recycling, production of substitutes and redesign of equipment, as well as by more responsible stockpile procurement and establishing multilateral contracts, among others. The criticality of imported non-energy materials was further examined within the National Security Study Memorandum by the Nixon Administration (Council on International Economic Policy, 1974). The study also evaluated the US policy options to safeguard against supply and price manipulation and shortages, such as developing self-sufficiency, diversifying foreign sources of supply, developing economic stockpile and consumer-producer cooperation. In the late 1970s, the two oil price shocks and the interruption of Zairian cobalt production caused by political insurrection increased concerns about the US dependence on foreign minerals. Further to these, the report on strategic and non-energy minerals by the US CBO, 1983 analysed the US vulnerability to supply disruptions of eight major minerals. It concluded that the most important options for the short term were stockpiling and subsidising domestic production. Diversification of sources of supply, encouraging exploitation and production on public lands, intensification of R&D in the field of metals and materials, and using foreign policy initiatives were directed more towards long term US minerals security, instead.

National materials and minerals policies and goals to assure materials availability for national economic well-being, national defence and industrial production have been formulated within the National Materials and Minerals Policy, Research and Development Act of 1980 (United States Public Laws, 1980). These included: basic R&D for extraction, processing and recycling of materials and improved understanding of their performance and substitution in engineering designs; improved collection and dissemination of scientific material and data; establishing early warning system for supply issues; measures to promote industrial innovation in materials and material technologies; encouraging cooperative materials research across private corporations and federal and state institutions; assessing opportunities to promote multilateral agreements for materials development in foreign nations. The importance of materials research has been further acknowledged by the National Critical Materials Act (United States Public Laws, 1984) which provided for establishment the National Critical Materials Council. This was responsible for formulating and coordinating national materials policies and priorities of research activities of the entire government, as well as for monitoring needs for critical materials and advising the President on global trends and their implications for national economy and security. Due to its ample responsibilities, the Council was mandated to cooperate with various federal departments and agencies which have had instituted materials research programs within their agendas, such as the National Security Council, the Council of Environmental Quality, the Office of Management and Budget and the Committee on Materials within the Office of Science and Technology Policy.

For what concerns rare earths in particular, the well-established regulatory environment has contributed to the rare earth industry boom. The United States has been dominating the rare earth market in the second half of the 20th century until the 1980s. Production was located in Mountain Pass California's Mojave Desert. Originally the area was prospected for uranium and later mined for europium oxide which was used for colour TV screens. Over time, other light rare earths and at a later stage also some of the heavy rare earths were mined here, what ultimately led to large scale production between 1965 and 1995. During this period, Molycorp not only supplied rare earths for the US Government's stockpiles, it was also the major supplier of rare earths globally. In 1998, after a series of water leakages containing heavy metals and radioactive material, Molycorp temporarily suspended operations and continued only with extracting ores from stockpiles (Molycorp Inc, 2015c; Nystrom, 2003). Yet in 2002, the company's environmental problems and low prices of rare earths from China forced Molycorp completely out of the market. However, only a few years later Molycorp received a 30 year mining plan permit and in 2007 extraction of neodymium and praseodymium resumed. In 2010 the company managed to secure environmental permits to begin construction of the Phoenix project and restarted active mining on site. At present, Molycorp is producing only a small part of the global demand, especially of light rare earths. In 2012 it completed the acquisition of Neo Material Technologies what allowed it to start producing and developing neodymium-iron-boron magnetic powders used in the production of permanent magnets. To further strengthen its position as a mine-to-magnetics vertically integrated player with global supply chain, Molycorp formed joint ventures with Daido Steel and Mitsubishi Corporation to manufacture sintered neodymium-iron-boron permanent magnets in Japan (Molycorp Inc, 2014). Furthermore, Molycorp in collaboration with Siemens and Shin-Etsu, works on minimising the amount of dysprosium within magnets used for direct drive turbine generators (Molycorp Inc, 2015a). In spite of all these initiatives and of the favourable regulatory environment, increasing capital needs, delays in the Phoenix Project and low rare earth prices due to removal of Chinese export tariffs and the large illegal mining and trade, forced Molycorp and its North American subsidiaries to file for bankruptcy protection in 2015 (Shah, 2015). While its European and Asian separation facilities continue to operate, the suspension of Mountain Pass might disrupt rare earth production industry until the end of the decade, when the emerging junior projects are not expected to start producing.

Besides producing rare earths, the United States also manufactures various higher value-added products containing rare earths. In terms of permanent magnets, the search for innovative composition of magnets started with the cobalt crunch in the late 1970s. The fact that samarium-cobalt magnets were expensive and that supply of cobalt fluctuated turned out as an issue for General Motors which used these in the starter motors of their automobiles. Several research groups started to work on neodymium-iron-boron magnets in the United States, both at industry level and as collaboration between academic, industrial and state laboratories. In the end, two companies succeeded in fully developing and patenting the permanent magnet technology which was nearly cobalt free, contained neodymium and traces of dysprosium and had superior properties compared to any technology commercialized before: General Motors in the United States developed bonded magnets, while the Japanese Sumitomo Special Metals (now Hitachi Metals) developed sintered magnets in 1983 (Robinson, 1987). General Motors subsequently established a new division called Magnequench, which was manufacturing rare earth magnets during two decades. However, when Magnequench was acquired by a consortium of Chinese companies, its factories were closed down and production was outsourced to China (Robison and Ratnam, 2010). Some years later, what was left of Magnequench became part of Neo Material Technologies and was subsequently acquired by Molycorp.

Following the change in geopolitics in the late 1980s, such as the end of the Cold War and the stabilisation of the situation in supplier countries of South Africa, provoked a loss of strategic perception of non-energy minerals by the US (Humprheys, 1995). This trend has however been reversed two decades later, when China tightened its rare earth export quotas, Molycorp shut down the production and Magnequench production lines relocated overseas. In fact, the disruption in the industry revived the interest of both the Government and public in rare earths. Ultimately, concerns over the US losing domestic capacity to produce critical minerals and its implications for national security and industrial production led to the development of Critical Materials Strategy. The current Strategy was developed in 2010 by the US Department of Energy (DOE) and is based on three pillars (Bauer et al., 2010). The first one deals with diversifying supply chains in order to mitigate supply risk, by facilitating extraction, refining and manufacturing within the US and encouraging additional sources of supply globally. The second pillar is targeting R&D in material and technology substitutes, in order to meet material needs of the clean energy economy. The third pillar foresees research into recycling processes coupled with design of policies which would promote recycling, reuse and more efficient use of critical materials.

To start with diversification of supply, the importance of developing domestic rare earth supply has been highlighted in a statement by Senator Murkowski: *"rather than sit on our hands while China corners the market on these strategic elements, we can and should pursue timely production of the rare earth supplies that exist within our own borders"* (Ucore Rare Metals, 2013). In this respect, improving the permitting process for critical mineral mines, providing financial assistance for domestic production and processing, as well as education, information gathering and stockpiling are viewed as the most important policy directions. Some of these have also been reflected in the recent legislation proposals (Humphries, 2013). For example, the Critical Minerals Policy Act of 2013 aims at facilitating the re-establishment of domestic critical minerals industries by devising policies targeting environmentally responsible production, manufacturing and recycling of critical minerals (Murkowski, 2013). The Act would require establishing a list of critical minerals to the US economy, improve the permitting process, provide for worker training and associated grants to academic institutions related to critical minerals, and require the Secretary of Energy to conduct R&D program for producing rare earth elements from non-traditional sources. The National Strategic and Critical Minerals Production Act of 2015 instead, is directed towards the Secretary of the Interior and the Secretary of Agriculture and seeks to define critical and strategic minerals and to streamline the federal permitting process. The latter is to be achieved by establishing a lead agency responsible for issuing mine permits within minimal time limits, maximising domestic mineral resource development and mitigating environmental impacts (Amodei, 2015). The measures proposed within this legislation were supported by the United States Magnetic Materials Association, an organisation lobbying for securing a stable supply of rare earths, and other industry representatives (USMMA, 2012). Additionally, the Association for Rare Earth, an opinion leader for rare earth industry, along with other industry organizations, strongly urged the accession of the US to the United Nations Convention on the Law of the Sea (RARE, 2012). This should help securing the US sovereign rights to the Exclusive Economic Zones (EEZ) and thus to new sources of rare earths from the seabed floor. In terms of knowledge and capabilities, with the disruption of the rare earth industry, the US lost not only their primacy in rare earth production and magnet manufacturing, but also the know-how and the expertise in rare earth mining, processing, chemistry and manufacturing, which in turn slowed the R&D and innovation activities in the field. The lack of trained workforce was highlighted by Gschneidner Jr (2010) who claims that today there is more than 15 times less people employed in every aspect of rare earth industry than was before the disruption. He therefore called for establishing training programs in conjunction with a research centre with long tradition in critical materials research and in close collaboration with universities, governmental laboratories and non-profit research organisations. Such centre would, besides providing training, also promote networking and diffusion of knowledge, and coordinate activities with the Rare Earth Industry and Technology Association (REITA). For what concerns information gathering, the US Geological Survey (USGS) provides the most comprehensive domestic and international non-energy historical minerals data, among others mineral yearbooks and commodity summaries which contain data on domestic and international mining and production, consumption, technology uses and other market trends for rare earths (USGS, 2015b). Besides this, the DOE also engages with stakeholders through various technical workshops in order to gain better understanding on current trends in rare earths and other critical minerals. With regards to inter-agency collaboration, the Subcommittee on Critical and Strategic Mineral Supply Chains was established by the White House Office of Science and Technology Policy, the goal of which is to facilitate the effort across federal agencies in identifying and addressing policy implications of strategic minerals supply issues (DOE, 2015). Finally, several R&D initiatives, such as such as the Small Business Innovation Research and the Critical Materials Energy Innovation Hub, have been set up to provide funding for development of techniques which improve separation and decrease cost of processing rare earths (Bauer et al., 2011).

Securing foreign supply of rare earths relies mainly on resource diplomacy initiatives. According to the DOE, cooperation with other resource poor countries could help *"to optimize resources for research and accelerate research and development on key topics"* (Bauer et al., 2010). In line with this, the DOE is involved in international discussion and collaboration through the annual Trilateral US-EU-Japan Conference on Critical Materials for a Clean Energy Future, the US-Australia Joint Commission Steering Committee Meeting on Science and Technology, the

US-Japan Roundtable on Rare Earth Elements Research and Development for Clean Energy Technologies, and the Trans-Atlantic Workshop on Rare Earth Elements and Other Critical Materials for a Clean Energy Future (DOE, 2015). With regards to resource rich countries which tend to violate free trade agreements, the oversight of a rule-based global trading is the principal strategy of the US. In this respect, the United Steelworkers, North America's largest industrial union, filed a petition under Section 301 of the US trade laws about the WTO violations by China concerning the green technology sector (United Steelworkers, 2010). Furthermore, the Rare Earth Caucus, in a letter to President Obama in 2012, pointed to the need to address Chinese restrictions, quotas and embargoes in the rare earth market (U.S. House Rare Earth Caucus, 2012). In the same year, the US filed a complaint at WTO, jointly with Japan and Europe, against China's export restrictions. President Obama argued in his speech: *"We want our companies building those [high-tech] products right here in America. But to do that, American manufacturers need to have access to rare earth materials which China supplies. Now, if China would simply let the market work on its own, we'd have no objections."* (CNN Wire Staff, 2012). Besides the limited availability of rare earths, the US administration was concerned about their increasing prices for non-Chinese consumers, and ultimately about the latter moving their operations, jobs and technologies to China. Of particular concern are rare earths for military uses, such as missile guidance systems, drones and strike fighters. Indeed, the dependence of the US military on heavy rare earths from China has been acknowledged by the DOD, 2013. This recommended the US Administration to accumulate 120 million USD (103.9 million EUR according to 2015 exchange rates) worth of heavy rare earths, especially yttrium, dysprosium and erbium, as part of a 320 million USD (277 million EUR according to 2015 exchange rates) program to stockpile 23 critical materials. Despite, the warnings by the Strategic Materials Advisory Council (2013) against stockpiling being a risky mitigation strategy, the DLA Strategic Materials received authorisation to acquire six materials to mitigate their supply risk, including dysprosium metal and yttrium oxide (DOD, 2015).

R&D plays a central role across all three pillars of the Strategy, though it proves most important in developing substitutes and recycling. In terms of permanent magnets, several initiatives are in place on substitution, minimization and improvement of performance of rare earth-free magnets. The government-owned Ames Laboratory has the longest history in research in materials science, design and theory. It closely cooperates with the Iowa State University and has 745 employees and associates. Its Materials Preparation Center specialises in purification, preparation and characterisation of metals, alloys and compounds, including rare earths. Also since 2013, Ames Laboratory leads the Critical Materials Institute - a DOE Innovation Hub gathering researchers from national laboratories, academia and industry, with the aim of developing substitute materials and technologies, which are more resource efficient and eliminate the need for using raw materials under potential supply shortages, and transferring these to the market through technology lincense agreements (Ames Laboratory, 2015). Besides the Ames Laboratory, there are several other national laboratories which through their basic and applied research help reducing criticality of materials. Furthermore, the University of Delaware runs a research program on the next generation of permanent magnets (Bauer et al., 2011). In terms of financing, the Advanced Research Projects Agency (ARPA), established in 2009 by the DOE, provides funding for early-stage technology innovations which eliminate or minimize the use of rare earths through its Rare Earth Alternative in Critical Technologies (REACT) program. In 2010, ARPA together with the Office of Science and the Office of Energy Efficiency and Renewable Energy provided 50 million USD (44.4 million EUR according to 2015 exchange rates) funding for research on rare earths, materials substitutes in high-energy-density permanent magnets, rare earth-free battery technologies and alternative electric motor and wind turbine generator designs that do not use permanent magnets (Bauer et al., 2010).

Concerning recycling of rare earths in the United States, some initiatives are already in place. For example, the Center for Resource Recovery and Recycling, established using the National Science Foundation funding, groups together two American and one European universities in material engineering. It aims at advancing technologies that recover, recycle and reuse materials through manufacturing process (CR3, 2015). Moreover, the DOE's Critical Materials Institute developed recovery and separation technology for neodymium, dysprosium and praseodymium from electronic waste, which has now been licensed to a rare earth exploration junior company (Duchesne, 2015). From an industry perspective, Retriev Technologies is the major recycler in the United States. They recycle rechargeable nickel-metal-hydride (NiMH) batteries containing rare earths, though the process is currently only targeting recovery of cadmium (Retriev Technologies, 2014). Nonetheless, as opposed to Europe and Japan, the US lacks laws which would enforce recycling standards and encourage private sector to collect and recycle of end-of-life products. These are necessary in order to develop economically viable recycling processes in the country.

4.3 Europe

As opposed to the United States, the EU output of metallic minerals has been historically low and decreasing over time, representing today only 3% of the world production (EC, 2008). This is mainly caused by exhaustion of favourable domestic deposits, by decreased exploration and development of new deposits, by reduced access to mineral deposits due to lack of planning policies and restrictive environmental standards, as well as by insufficient development of new technologies for exploration, production and processing of raw materials (Tiess, 2010). These developments ultimately led to increasing import dependence of minerals on foreign imports, some of which currently exceed 80%, and ultimately make Europe more vulnerable to external developments.

The debate on security of raw material supply in Europe was initiated within The Community's Supplies of Raw Materials report (EC, 1975). This pointed out the necessity of maintaining access to sources of supply from developing countries in order to accommodate manufacturing needs and those for economic development of European countries. It identified the following supply problems: insufficient knowledge on present and future outlooks of minerals; relative and absolute shortages of minerals; insufficient diversification of supply; and political problems due to instability and monopoly position of supplier countries. In order to spread the risk, the report suggested developing European resources, exploitation of raw materials from sea bed and diversification of foreign sources of supply. Furthermore, recycling of waste, substitution by other materials and new manufacturing processes, as well as extension of product life were advocated as remedies for mineral shortages. Finally, it proposed to handle the risk of temporary bottlenecks and price fluctuations by long-term contracts, emergency stocks and international agreements. The latter should have been taken up in multilateral trade negotiations, and entailed observance of international rules relating to notification and consultation procedure of Article XI of the General Agreement on Tariffs and Trade (GATT). The report concluded by reiterating the need for common guidelines within the Community, arguing that the scale of security of supply was too big to be coped with on the individual member state level. It called for coordination of activities at different levels and for launching common initiatives.

Despite the fact that minerals used to play a central role for Europe, as reflected by the European Coal and Steel Community, common political priorities in securing non-energy minerals supply have been missing from the European policy agendas until recently, what led to uncoordinated policy actions across Europe. This stands in a sharp contrast energy minerals, such as oil and gas, where rising energy costs and high dependence of the EU on energy imports have been at the centre of political attention ever since the 1970s. While all Member States were found to have established by now government funded institutions which coordinate geological and geophysical surveys providing data on the location and the nature of mineral reserves, there tend to be substantial differences within countries' Minerals Planning Policy. These are mainly related to land use planning legislative structures and policies, as well as to permitting procedures for exploration and mineral extraction, and to the Environmental Impact Assessment required within the authorization process (Wagner et al., 2004). Also in terms of securing raw materials supplies, European countries formulated different strategies in line with their respective domestic situations. For example, besides promoting domestic exploration, extraction and reprocessing of raw materials and foreign investment in mining projects, the German strategy focuses on R&D for substitution, resource intensity and recycling, in which it already has an established track record. It also intends to increase education and information diffusion by empowering faculties that deal with topics of geoscience, raw materials and mining. As an example of establishing partnerships with resource-rich countries, the German Government has signed an intergovernmental agreement for resources, industry and technology partnership with Mongolia, to secure access to rare earths and coal, in exchange for machines to extract resources (DEFRA, 2012). France's Strategic Metals Plan aims at understanding industrial needs with respect to critical metals, identifying the most critical resources and updating the mining inventory. This is in line with the existence of abundant gold and polymetallic nodule deposits in the French EEZ, as well in former colonies of French Guyana and New Caledonia. Furthermore, France intends to accelerate implementation of recycling projects and increasing R&D in substitution. In terms of international cooperation, the French Geological Survey signed an agreement with the Kazakh national uranium miner to help developing Kazakhstan's rare earth metal deposits (DEFRA, 2012). Contrary to these, Finland as a resource-rich country, places focus on its own minerals sector, which is comprised of exploration, mining and processing, as well as of production and supply of machinery, technology and services for these operations. Its strategy is linked to promoting exploration and efficient use of resources, by using tax incentives, reducing permit processing times, enhancing availability and distribution of geoscientific and environmental data on the one hand, and to reducing the environmental impact of the industry and increasing its productivity by establishing research programmes for developing innovative solutions, improving material and energy efficiency of processing technologies and creating incentives for recycling and reuse of waste on the other (Ministry of Employment and the Economy, 2010). Similarly, Sweden which is the leading mining nation within the European Union has developed a comprehensive minerals strategy. The minerals and mining industry is targeted through eleven action areas, among which are achieving greater resource efficiency through analysis of extraction and recycling potential, establishing a more effective regulatory framework by shortening permitting lead-times, fuelling infrastructure investments, promoting research and innovation to create competitiveness of the minerals industry, increasing skill supply that meets the needs of the industry and promoting investment (Ministry of Enterprise Energy and Communications, 2013). Both Finland and Sweden have important economic deposits of rare earths. Yet, while these countries have an established track record in raw materials policy making, mineral strategies in others are still in their infancy.

The need for an integrated approach was brought back to the political agenda by the request of Council of the European Union (2007) to *"develop a coherent political approach with regard to raw materials supplies for industry, including all relevant areas of policy (foreign affairs, trade, environmental, development and research and innovation policy) and to identify appropriate measures for cost-effective, reliable and environmentally friendly access to and exploitation of natural resources, secondary raw materials and recyclable waste, especially concerning third-country markets"*. The High

Level Group on Competitiveness Energy and the Environment (2007) has further called for the development of a raw materials policy based, among others, on international multilateral and bilateral agreements, streamlining access to domestic raw materials and improving resource efficiency through better use of resources embedded in waste. Finally, the urgency for a common policy response to ensure that the EU industry has sufficient access to raw materials at undistorted prices has been expressed by Günter Verheugen, the European Commission Vice President: *"European industries need predictability in the flow of raw materials and stable prices to remain competitive. We are committed to improve the conditions of access to raw materials, be it within Europe or by creating a level playing field in accessing such materials from abroad."* (EC, 2007a). The European Union subsequently launched a public consultation on the Commission Raw Materials Initiative (EC, 2007b). The Initiative itself was formulated in 2008 and revised in 2011 (EC, 2008; EC, 2011). It is currently coordinated by the Directorate General Internal Market, Industry, Entrepreneurship and SMEs, though the Initiative is a collaborative effort of other Directorates, such as Trade, Environment, Research and Innovation, and International Cooperation and Development. It should help the European Union to form a coherent strategy on long term sustainable supply of non-energy raw materials in the context of the EU industrial policy: *"Securing reliable and undistorted access to raw materials is increasingly becoming an important factor for the EU's competitiveness and, hence, crucial to the success of the Lisbon Partnership for growth and jobs."*. The Raw Materials Initiative is implemented primarily through the European Innovation Partnership (EIP) on Raw Materials. This stakeholder platform was endorsed in 2013 and brings together representatives from industry, public services, academia and NGOs with the aim of providing guidance on challenges related to non-energy non-agricultural raw materials (EC, 2015b). Besides contributing to the 2020 objectives of the EU Industrial policy, it also plays an important role in meeting the objectives of the Innovation Union, and the Resource Efficient Europe initiatives of the European Commission.

The Raw Material Initiative itself is built on three pillars. The first one represents access to raw materials on world markets at undistorted conditions. This foresees active raw materials diplomacy and involves managing external policies and dialogues with developing resource-rich countries. An example of such a policy dialogue on access to raw materials and natural resources management is the Joint Africa Ű EU Strategy implemented in 2007 (EC, 2007c). This is based on mutual interest from Europe's development policies aimed at strengthening states, promoting sound investment climate and sustainable management of raw materials in developing countries, and its own need for undistorted access to raw materials. This has been first put forward within the report on Community's Supplies of Raw Materials (EC, 1975) and implemented a year later when the First Lomé Convention was established between the EU and African-Caribbean-Pacific States (Tiess, 2010). Its aim was securing preferential mineral imports into the European Community in exchange for financial aid and investment in the participating countries. The convention has been abandoned after it was found incompatible with the WTO rules and has now been replaced by the Cotonou Partnership Agreement. The latter is based on development, political, economic and trade cooperation, especially in countries which are committed to implementing reforms that focus on improved transparency and governance in extractive industries (EC, 2015c). The EU has supported further initiatives to promote transparency and accountability in the extractive industry in developing countries within the framework of the Extractive Industries Transparency Initiative EITI, 2015 and the Kimberly Process Certification Scheme (Kimberly Process, 2015). On the other hand, the European Union also strives to remove measures introduced by some resource-rich countries which distort competition and increase global prices of raw materials. With regards to filing the joint WTO complaint against Chinese restrictions on rare earths, the EU Trade Commissioner Karel De Gucht stated out: *"These measures hurt our producers and consumers in the EU and across the world, including manufacturers of pioneering hi-tech and 'green' business appli-*

cations." (EC, 2012b). Finally, the European Union also manages strategic partnerships with other resource-dependent countries. The Trilateral Critical Materials Initiative is taking form of annual meetings with stakeholders from Japan and the US and with participation of Australia, Canada and South Africa, and aims at identifying common interests and positions in the international context of securing raw materials supply by improving extraction, finding substitutes, improving efficiency and encouraging recycling (EC, 2013; NEDO, 2012; DOE, 2011).

The second pillar of the Initiative aims at setting framework conditions within the European Union to foster sustainable supply of raw materials from European sources. Among the most pressing issues are access to land, streamlining the mining permitting process across Member States and public funding of exploration. In terms of rare earths, currently there exist only two advanced projects in Europe, one in Sweden and the other in Greenland, owned by a Canadian and an Australian company, respectively. Both have a potential to secure rare earth supply for Europe and are very attractive due to their deposits of heavy rare earth-rich minerals. Yet, the actual start of their production will depend on environmental permitting and finances available for further development (ERECON, 2015). For what concerns stockpiling instead, this is not part of the European mineral strategy. Though some EU countries do have experience with publicly stockpiling critical raw materials, none of them currently accumulates inventories of rare earths (RPA, 2012). Contrary to this, establishing the knowledge base on mineral deposits and networking between national geological surveys proves important to determine the domestic sources of minerals supply. In fact, one of the hurdles that hinder the implementation of the Raw Materials Initiative is the lack of EU-wide comprehensive minerals statistics. Separate databases are available on country level, yet these only cover country relevant data. To date only the British Geological Survey produces some of the statistics covering the whole European Union. As a response to this, the Minerals4EU project is currently under development and has the task of putting in place an EU mineral knowledge base and intelligence network (EC, 2015d). Moreover, the EU aims at promoting research projects focusing on extraction and processing of raw materials. One such project is the European Technology Platform on Sustainable Mineral Resources (ETP SMR, 2015). This is an international association grouping various stakeholders across the value chain since in 2005, and is committed to providing a coordination function for raw materials related technological research, development and education activities in order to enable exploration and inventory of resources, mineral extraction from land and sea bed deposits, mineral processing, metallurgy and recycling. Finally, in terms of skills shortage, the European Union is encouraging generation of new high skills in various aspects of minerals through its Erasmus Mundus Minerals and Environmental Programme. The latter is coordinated by the Federation of European Mineral Programs (FEMP, 2015) and provides a strong link between industry and participating universities. In the particular context of rare earths, the EURARE (2015) project was established in 2013 to set basis for development of the European rare earth industry by evaluating resources in Europe, developing technologies for efficient exploitation of resources, establishing critical mass of scientist and engineers, and developing integrated knowledge management system. This project brings together academia, industry and geological surveys. Also, the European Union has established a multi-stakeholder European Rare Earths Competency Network (ERECON) (EC, 2015e) to improve the rare earth supply security of Europe. One of the working groups is mandated to explore options for primary production of rare earths in the EU. The other one explores options for more efficient use, potential substitution and end-of-life recycling of rare earths in the EU, and is thus linked to the third pillar of Raw Materials Initiative.

The third pillar of the Raw Materials Initiative aims at reducing primary consumption of raw materials through resource efficiency, recycling, substitution and increased use of renewable raw materials. In terms of improving resource efficiency, the EU has introduced the Ecodesign

Directive which sets mandatory ecological requirements for energy-using and energy-related products and also includes provisions for the design of resource-efficient products (EC, 2015f). For what concerns recycling, this has a long tradition in Europe. The EU's waste management policy has evolved over the past three decades through various environmental action plans and framework legislation. The Thematic Strategy on the Prevention and Recycling of Waste was adopted in 2005 as part of the 6th Environment Action Plan. The Waste Framework Directive of 2008 is the cornerstone of EU's waste policy and treats the management of waste disposal, hazardous waste and oil waste. It establishes a five step waste hierarchy and its development today takes place within the context of the Raw Materials Initiative, as well as within the 7th Environment Action Programme and the Resource Efficiency Roadmap (EC, 2010b). Waste shipments are controlled for by the regulation on shipments of waste, while the End of Life Vehicles Directive restricts the use of hazardous materials used in vehicles and sets reuse, recovery and recycling targets. The Waste Electronic and Electrical Equipment Directive (WEEE) lays down collection, recycling and recovery targets for electric goods, while the Directive Restricting the use of Hazardous Substances (RoHS) restricts the use of hazardous substances in the former. Additionally, the Batteries Directive has been set up to regulate collection, recycling and recovery targets for batteries (EC, 2010c). The latter directives prove especially relevant for the recovery of rare earths, since they make rare earth intensive end-of-life products a fast growing segment for recycling. In Europe, Umicore - a materials technology and recycling group, claims to be the first to have built a facility to recycle various battery technologies, including NiMH batteries from electric vehicles (Umicore, 2014). In terms of recycling magnetic material, Solvay - a chemicals company, announced plans to recover rare earths from light bulbs and permanent magnets (Solvay, 2012). Yet, no large scale permanent magnet recycling has been commercialised in Europe so far. While magnets from wind turbines and electric vehicles are suitable for reuse, they are not available for recycling due to their low penetration and long service lives. Similarly, material recovery from urban mines, such as hard disc drives, cell phones and air conditioners is not a set up practice in Europe yet, mainly due to lack of processes in place for disassembling end-of-life-products. In 2013, the EU set up the European Rare Earth (Magnet) Recycling Network of academia and industry which should train young chemists and engineers in recycling of rare earths. Besides this, the Belgium Katholieke Universiteit Leuven is funding a knowledge platform (RARE3) focusing on advanced recycling and reuse of rare earths and other critical minerals, and participates in the Center for Resource Recovery and Recycling in the US (KU Leuven, 2015).

Besides recycling, also improvements in manufacturing processes and substitution can help decreasing import dependence on raw materials. The joint scientific research and technological development policy in Europe dates back to the 1960s, when the Working Party on Scientific and Technical Research Policy (PREST) was created. This was later superseded by the Scientific and Technical Research Committee (CREST) which was commissioned to coordinate national policies and to define objectives of interest to the Community in the field of science and technology. Specifically, its subcommittee on raw materials research and development was set up to provide a forum for cooperation in R&D in mining or and in new techniques for processing ores and their recycling, among others (EC, 1975). At present, the critical mass for research and innovation on European level is built through public-private partnerships, such as the EIP on Raw Materials. Being a multi-stakeholder group which supports innovation activities along the entire value chain, it helps meeting the objectives of the Europe 2020 Innovation Union initiative for creating an innovation friendly environment. Similarly, the European Institute of Innovation and Technology (EIT) Raw Materials established in 2014 as a knowledge and innovation community (KIC), shall help boosting competitiveness, growth and attractiveness of the European raw materials sector via innovation and entrepreneurship (EIT, 2015). Bringing together education institutions, research labs and industry, it covers activities from mining through processing, recycling and substitution. Furthermore, the Network on Industrial Handling of Raw Materials for European Industries (ERA-MIN) has been established in 2011 within the ERA-NET scheme in order to promote coordinated research across the entire value chain, by networking European stakeholders, road mapping research priorities and implementing joint actions (ERA-MIN, 2015). One of its working groups covers issues related to substitution of critical minerals. While a comprehensive policy framework to support substitution of critical materials in applications is currently being set up, at this stage there is a lack of practical projects on finding substitutes for rare earths on European level. This may be due to the fact that historically the downstream side of the rare earth value chain was not developed extensively in Europe (the only exceptions are Vacuumschmelze and Magnetfabrik Schramberg in Germany, which both produce rare earth permanent magnets and are licensees of the Japanese Hitachi Metals). Nonetheless, there is one project which resulted from the EU 7th Framework Program (FP7) and has the objective of developing high-performing rare earth free magnetic materials (NANOPYME, 2015). Another initiative funded by FP7 is the Critical Raw Materials Innovation Network which has been established to map out critical raw material substitution initiatives at the EU and Member States levels, to identify opportunities for developments in the field of substitution of critical raw materials, to propose a roadmap for the substitution of critical materials in five key applications, and to provide a platform for the stakeholder community (CRM_Innonet, 2015).

4.4 Japan

Japan, similarly to the EU, has been historically a resource-poor country dependent on imports of oil, gas and various minerals from overseas. Yet, while Europe's dependence on imports of rare earths is mainly in terms of manufacturing end use technologies such as wind turbines and alternative technology vehicles, Japan's economy is significantly dependent on refining rare earths into metals and alloys, as well as on manufacturing and exports of component parts and high value added products which use rare earths as input materials. In fact, Japan is the largest consumer of dysprosium which is used as doping agent in permanent magnets in high-tech products such as cell phones and hard disk drives, as well as in home appliances, in robotics and in electric motors of hybrid and electric vehicles (Kawamoto, 2008). The stable supply of rare earths is thus detrimental for maintaining the international competitiveness of Japan's automotive and electronics industries, in which Japan is the global leader. In 2008, Japan was 100% dependent on rare earth imports and sourced 90% of them from China (Shen, 2015e). Besides the economic dependence, there is also a geopolitical perspective to importing raw materials from China. While China's assertive actions are not uncommon in the disputed waters (The Economist, 2013), Japan has seen itself directly involved in a maritime incident when a Chinese fishing trawler collided with Japanese coast guard vessels. The detention of the Chinese captain resulted in a diplomatic dispute between the two countries, the ultimate consequence of which was China halting the exports of rare earths to Japan for a period of two months (Bradsher, 2010). It was this incident that made both the Government and the private sector aware of the Japanese vulnerability to political risk tied to import dependence of critical metals from China. For example, the Toyota Motor Corp spokesman stated out right after the incident: *"There are many risks in depending on one nation."* (Hosaka, 2010). Similarly, according to Akihiro Ohata, Japan's Minister of Economy, Trade and Industry: *"the situation reminded us of the need to craft a long-term strategy to procure rare earths"* (MarketWatch, 2010). As a response to this threat, the Japanese Government allocated additional 101.2 billion Yen (730 million EUR according to 2015 exchange rates) from the supplementary budget for 2010 for securing rare earths and other natural resources in the context of promoting green innovation (MOF, 2010). Finally, Nippon Keidanren (Japan Business Federation) in its proposal for Japan's

Trade Strategy, called for restoring the discipline against restrictive measures affecting exports of rare earths under the WTO agreements (Nippon Keidanren, 2011).

The Japanese mineral strategy in itself dates back to the economic warfare against Japan during the WWII. During this time, the majority of Japan's merchant vessels were sunk by the Allies and Japan was forced to withdraw its troops from its strongholds in South-East Asia and Pacific islands. Moreover, the American embargo on pig-iron and oil increased Japan's import dependence on iron ore from China and Korea and forced it to use up its enormous raw material stockpiles. This gradually led to shortages of steel, oil and coal, which were detrimental for manufacturing Japan's armaments, and thus adversely impacted its ability to sustain military operations (Milward, 1977). Further to this incident, the Japanese Government set the stability of supply of imported resources as the main aim of its energy policy, in view of sustaining its economic security. In 2006 the Japanese Ministry of Economy, Trade and Industry (METI) deliberated over the New National Energy Strategy, one of the aims of which was to strengthen resource diplomacy and energy and environmental cooperation, through strategic utilization of official development assistance (ODA) and promotion of mutual investment, as well as through overseas resource development and diversification of supply (METI, 2006). The government's role of supporting exploration and development of projects, by assisting negotiation of Japanese exploration companies with foreign state-run companies in resource producing countries as well as by overseeing that resource producing countries are not introducing distorting measures, was laid down within the Guidelines for Securing Natural Resources (METI, 2008). Furthermore, the Strategic Energy Plan of 2007, which was later revised in 2010 and 2014, put forward recycling and stockpiling of rare metals, as well as seabed exploration (METI, 2014). METI also set a goal for improving resource security by increasing self-sufficiency to 80% for base metals and to 50% for rare metals by 2030 (Japan Metal Bulletin, 2010). Based on the above, and in the context of green innovation inducing economic growth, METI spelled out its comprehensive strategy to assure stable supply of resources and energy within its 100 Actions to Launch Japan's New Growth Strategy (METI, 2010a).

Over time, Japan developed a truly comprehensive strategy to guide and coordinate policy on securing raw materials supplies. This can be summarized by the quote by the Trade Minister Yukio Edano: *"We want to further diversify sources of suppliers, secure our interests and support domestic technological development to cut the amount used and promote recycling."* (Kaneko, 2012). The Japanese Strategy for Ensuring Stable Supplies of Rare Metals is coordinated by METI and is built on four pillars with the main objective of sustaining economic security (Advisory Committee on Energy and Natural Resources, 2009). The first pillar targets diversifying supply sources through strategic resource diplomacy. Government's main tasks in this respect are facilitating technology transfer, infrastructure development and energy cooperation through bilateral and multilateral trade agreements, which would serve the development objectives of resource-rich countries and at the same time assure access to raw materials for Japan. This strategy is closely linked to establishing joint exploration initiatives with resource-rich countries and their financing. In Japan such initiatives take form of public-private partnerships whereby public institutions, such as the Japan Oil, Gas and Metals National Corporation (JOGMEC), carry out overseas field surveys and provide financial assistance to high risk mine development projects. JOGMEC was established in 2004 by merging together the Metal Mining Agency of Japan (MMAJ), which was itself created in 1963 as the Metallic Minerals Exploration Financing Agency of Japan with the purpose of ensuring stable and inexpensive supply of metals and strengthening the competitiveness of Japanese mining industry by providing loans for metals exploration, and the Japan National Oil Corporation (JNOC) which was established in 1967 as Japan Petroleum Development Corporation and served for promoting exploration and development of overseas oil and gas resources (JOGMEC, 2015a). Nowadays, JOGMEC's tasks lie within promoting exploration and development for oil, natural gas, non-ferrous metals and minerals by providing loan guarantees and financial assistance, domestic and overseas mining related information and cutting-edge technological tools for exploration, processing and recycling, as well as within national stockpiling and technical assistance for dealing with mine pollution. In particular, JOGMEC in joint cooperation with Sojitz, a general trading company with a track record of 40 years in rare earth trading (Sojitz, 2013), assisted setting up long term supply agreements, joint ventures and strategic alliances with producers in various countries, such as Vietnam (Vinacomin, 2012), Kazakhstan (Paxton, 2012), Australia (Sojitz, 2013), India (Shah, 2014) and Mongolia (Tanquintic-Misa, 2015), in exchange for exploration technology, know-how transfer and project financing. The overseas business operations by Japanese companies are furthermore supported by: the Japan Bank for International Co-operation (JBIC) which conducts lending, investment and guarantee operations to the private sector; the Nippon Export and Investment Insurance (NEXI) which conducts trade and investment insurance business operations; and the Japan International Cooperation Agency (JICA) which coordinates Japan's official development assistance. Overall, the supply diversification strategy contributed to successfully decreasing Japan's dependence on Chinese imports of rare earths down to 60% in 2014 (Shen, 2015e). Besides the initiatives targeting resource-rich countries, Japan also cooperates with resource-poor countries through the Trilateral Conference on Critical Materials where common strategy for tackling security of supply or rare earths is discussed. Finally, Japan is also pioneering exploration for heavy rare earths on seabed deposits within Japan's EEZ (Evans-Pritchard, 2013). Public-private partnerships in seabed exploration for mineral resources in Japan date back to the 1980s (DORD, 2015), yet the basic framework for promotion of ocean based strategies, such as enhancement of scientific knowledge on oceans, as well as development of ocean industries and strengthening international competitiveness, has only been established in 2007 with the promulgation of the Basic Plan on Ocean Policy (Terashima, 2009).

Recycling of scrap and end-of-life products constitutes the second pillar of the Japanese minerals strategy and calls for improved utilization of existing recycling processes and promoting R&D in recycling technology Advisory Committee on Energy and Natural Resources (2009). Japan's legislation dates back to the 1970s and covers systematically the topic of reducing waste and promoting recycling by recycling-related laws. Recycling guidelines were first established in 1990 by METI and aim at promoting voluntary initiatives by businesses across various sectors. Several other policies were drafted since then, such as the Law for Promotion of Effective Utilisation of Resources (1991), the Basic Law for Promoting the Creation of a Recycling-Oriented Society (2000) and the Home Appliances Recycling Law (2001), all of which contributed to the successful establishment of the recycling-oriented society in Japan. For example, the Home Appliances Recycling Law started to regulate collection and recycling of home appliances and gave thus rise to urban mining in Japan - the systematic collection of end-of-life products for establishing a secondary supply of raw materials. Collecting these appliances made it in turn possible for companies to develop recycling processes for the recovery of steel, copper, aluminium, and other materials. With the financial assistance of METI, these processes were later extended to recycling of rare earths, mainly dysprosium and neodymium. One such initiative was the development of automatic dismantling equipment to recover rare earths from air conditioners by Mitsubishi Electric in close cooperation with magnet and appliances manufacturers (Mitsubishi Electric, 2012). Similarly, Hitachi has developed recycling technologies to separate and collect rare earth magnets from hard disk drive motors, air conditioners and other compressors (Hitachi Ltd, 2010). In terms of NiMH batteries, both Honda and JOGMEC's Metals Mining Technology Group have developed technologies to recover rare earths and reuse them for production of new batteries (Honda, 2013; JOGMEC, 2015b). Besides initiatives on recycling, METI and other government agencies are promoting the "3Rs" policy (reduce, reuse, recycle) in order to create *"a sustainable economic system that pursues environmental protection as well as economic growth."* (METI, 2010b). The idea of expanding from single R (recycling of products and materials) to incorporating reduction of waste generation and reuse of parts and products has been put forward by the Waste Prevention and Recycling Subcommittee of the Industrial Structure Council in 1999. What is more, Japan is currently proposing to extend this policy to a regional level and create a "sustainable Asia based on 3Rs" (METI, 2004).

Besides striving to increase primary and secondary supply, Japan also aims at promoting the use of alternative materials in order to maintain its competitiveness and to develop new industries. In the context of rare earths, the initiatives are mainly targeted towards lowering the usage of rare earths in permanent magnets. Their production dates back to early 1970s when Japan began producing samarium-cobalt magnets. In 1982 Sumitomo Special Metals (now merged with Hitachi Metals) patented the Neomax sintered neodymium permanent magnets, and to-date still holds 615 patents licensed to 14 companies globally (Hitachi, 2015; Hitachi Metals, 2013). Permanent magnets are used within electric motors of electric and hybrid vehicles, in the production of which Japan is the world leader. In this respect, Japan's aim is to strengthen industry-university-government linkages as well as collaboration across up- and downstream sides of the supply chain (Advisory Committee on Energy and Natural Resources, 2009). Such efforts are carried out under the auspices of METI and the Ministry of Education, Culture, Sports, Science and Technology (MEXT), and are financed through funding agencies: the New Energy and Industrial Technology Development Organization (NEDO); and the Japan Science and Technology Agency (JST) along with the Japan Society for the Promotion of Science (JSPS), respectively. While METI is promoting applied research through the National Institute of Advanced Industrial Science and Technology (AIST) as well as industry related projects, MEXT is advocating basic research at universities and strategic research by the National Institute for Materials Science (NIMS) and by the Riken research organization (NIMS, 2011). NIMS in particular, is the national research and development agency specializing in materials science. It has a long tradition of research, being established in 2001 by merging the National Research Institute for Metals (NRIM) and the National Institute for Research in Inorganic Materials (NIRIM), which were established under the auspices of the former Science and Technology Agency in 1956 and 1966, respectively. NIMS currently employs over 1500 researchers and its mission is to carry out fundamental and basic research, to share advanced research equipment and to develop and apply cutting-edge nanotechnology. For example, in the context of rare earths in magnets, NIMS set up the Elements Strategy Initiative Center for Magnetic Materials (ESICMM) dedicated to R&D of novel high performance permanent magnets free of critical elements. NIMS also provides training and education through its International Center for Young Scientists and through various joint graduate school and internship programs. Finally, it also maintains external collaboration through centres of excellence (for example with Toyota, Honda and LG) and joint research centres with universities (NIMS, 2015). The most important examples of such industry-university-government collaborative projects are the Rare Metal Substitute Materials Development Project coordinated by METI and the Elements Science and Technology Project by MEXT (NIMS, 2015). The respective rare earth project themes aim at developing a new category of permanent magnets with reduced amounts of dysprosium and neodymium by minimization (nanotechnology), by substitution for other metals, or by improving performance of rare earth-free magnets, while achieving comparable magnet properties to neodymium-iron-boron permanent magnets. Furthermore, magnet saving motor developments by small motor makers are financed through METI, which in 2012 alone provided a subsidy of 5 billion yen (36.2 million EUR according to 2015 exchange rates) expecting a 30% decrease in domestic dysprosium consumption within two years (Japan Metal Bulletin, 2012). Examples of such initiatives are the NEDO - Hitachi Industrial Equipment Systems collaboration and the NEDO - Hokkaido University collaboration which both resulted in developing rare earth electric motor technologies (Hitachi Ltd, 2012; Japan for Sustainability, 2011).

The last pillar of the Japanese mineral strategy relates to stockpiling of strategic materials in order to hedge against short-term supply risk, as a complement to the medium and long term strategies covered by the previous three pillars. The idea of stockpiling dates back to the WWII when energy materials such as oil were stockpiled in order to mitigate adverse consequences of import restrictions from abroad. Further to the oil crisis, the national stockpiling scheme for rare metals was established in 1983 (JOGMEC, 2015c). According to the scheme, rare metals are stockpiled in response to Japan's degree of import dependence, to the unavailability of substitutes within Japan's manufacturing industry and to the high geological concentration of their global production. While the exact list of stockpiled metals is confidential, at the end of 2010 Japan had stockpiles of chromium, cobalt, gallium, indium, manganese, molybdenum, nickel tungsten and vanadium (RPA, 2012). At present, the Japanese stockpiles serve both economic and military purposes and are managed by JOGMEC based on market trends. There is no official information on Japan's public stockpile of rare earths, yet their demand and supply situation is monitored by JOGMEC. There is however evidence of private stockpiling activities ongoing due to currently low rare earth prices (Shen, 2015a).

4.5 Australia

Australia is yet another relevant stakeholder within the discussion on mineral strategies. Nevertheless, not from the perspective of a consumer country, but as one of the major exporters globally. Australia's mineral exports account for approximately 60% of value of goods and services, and 10% of country's GDP (Skirrow et al., 2013). While the country is known for being a leader in extracting iron ore, nickel, aluminium, gold and coal, rare earth exploration has been historically much less significant. In fact, deposits of rare earths were mainly discovered as a result of uranium and thorium prospecting. Australia has been a historical exporter of monazite since 1950s, which was used for extraction of rare earths and thorium in overseas processing plants. Until the mid-1990s, France was one of the major importers of Australian monazite. Yet when the debate on toxic waste disposal intensified in France, its monazite processing plant was closed down, what lead to complete disruption of the monazite mining industry in Australia (Hoatson et al., 2011). Moreover, since the beginning of the 20th century there were several attempts to establish small scale commercial rare earth production industry in Australia, but the projects were not successful due to lack of capital, environmental concerns, low grades and low tonnage (Geoscience Australia, 2010). However, the increases in metal prices in the early years of the new millennium have revived exploration interests for rare earths. The first major mining project was established in 2007 at Mount Weld deposit, which is also one of the world's richest deposits of rare earths with low thorium contamination, and is one of the only two non-Chinese producers of rare earths globally. The mine is currently managed by Lynas Corporation. The first stage of mining activities was completed in 2008. The ore produced is concentrated in the concentration plant on-site and shipped to the Lamp Advanced Materials Plant (LAMP) in Malaysia for further refining (Lynas, 2015). LAMP is the world's largest refinery of rare earths and the first one to be constructed outside of China during the past decades. However, the construction of the plant faced opposition from Malaysian community lobby groups and local inhabitants due to concerns that radioactive waste from the rare earth production would have adverse environmental and health impacts (Stop Lynas, 2015). The locational choice for the processing plant was motivated by strategic reasons of lower capital and operating costs as compared to an Australian location, by a tax exemption granted by the Malaysian Government, and possibly by the country's lax environmental regulations on toxic waste disposal (Bradsher, 2011). The intention to dispose of the radioactive waste in Malaysia sparked controversy against both Lynas and the Australian Government. As a response to this, the latter issued a statement on the Australian laws prohibiting the import of radioactive waste into the country: *"National legislation stipulates that Australia will not accept responsibility for any waste product produced from offshore processing of resources purchased in Australia such as iron ore, mineral sands and the rare earth produced by Lynas Corporation"* (Sta Maria, 2012). Despite the opposition, the Malaysia's Atomic Energy Licensing Board has initially granted a temporary operating licence, which was in 2014 extended to a two year full operating stage licence.

From the Australian perspective, rare earths have been determined as critical minerals with high resource potential (based on availability and costs of production and estimates of world demand). In fact, according to the assessment by Geoscience Australia, rare earths rank within "category 1" of resource potential, based on their level of criticality from the global perspective, on Australia's current resources and potential for new discoveries, as well as on the rare earth market size and growth outlook (Skirrow et al., 2013). Indeed, Australia has large potential for mining rare earths and other critical minerals. Besides Mount Weld, there are several junior projects in the advanced stage of development, some of which contain high percentage of heavy rare earths. In particular, of all global projects outside China, the Dubbo Zirconia deposit is the richest deposit with up to 60% of heavy rare earth oxide content (Hoatson et al., 2011). Once this project turns operational, it might become a swing producer of heavy rare earths globally. Hence, as opposed to China, Japan, the United States and Europe, Australia sees its resources as a source of future income from exports, rather than as input materials for its weak manufacturing industry (Bromby, 2015b). Hence criticality itself is not an issue for the country, in that it is a relatively small consumer of minerals. Therefore, also its policies are directed towards the upstream parts of supply chain, such as mining and production. From the institutional perspective, mineral and energy policies are concentrated in the hands of the Department of Industry and Science, while previously this function was assumed by the Department of Resources, Energy and Tourism (Department of Industry and Science, 2015e). The overarching aim of the minerals policy is to expand Australia's resource base and to increase the international competitiveness and sustainability of resources sector. Australia as a mineral producer is characterized by large commodity endowment, political stability, supportive policy settings, long term stability of mining industry and data availability for prospective mining (Barnicoat, 2013). This gives it a significant advantage in providing secure supply of rare earths, as compared to other prospective producer countries such as Brazil, South Africa, Vietnam and Kazakhstan. Increasing the investor confidence in Australia's resources sector has been achieved through various resource programs. To start with, Australia undertook a domestic pilot to test how applying the EITI rules and principles could be suited to country's conditions. The results of the test confirmed the strength of Australia's governance frameworks in extractive industries and recommended the implementation of an adapted EITI model, claiming that transparency and information management practices are important for inducing investment into and development of the extractive sector (Department of Industry and Science, 2015b). In terms of sustainability of mining, the Government launched the Leading Practice Sustainable Development Program for the Mining Industry (LPSDP) which provides information on sustainable mining practices to mine managers, communities and regulators through various workshops and a series of handbooks (Department of Industry and Science, 2015c). Another initiative is the Working in Partnership (WIP) which promotes long term effective partnerships between the stakeholders of the mining industry and communities, with particular focus on building indigenous business capacity (Department of Industry and Science, 2015f). In addition to this, the National Mine Safety Framework (NMSF) initiative was developed by a multi-stakeholder steering group with the aim of assuring safety of workers in the mining industry (Department of Industry and Science, 2015d). Finally, besides participating in key international forums through which it seeks to maximise its export opportunities and to enhance its energy security, Australia also engages in bilateral minerals and energy consultations with its main trading partners in order to identify and facilitate two-way commercial opportunities within resources sector. For example, during the 34th Meeting of the Australia-Japan High Level Group on Energy and Minerals Consultations, the opportunities for investing in Australian rare earths were discussed, among others (Department of Industry and Science, 2011).

Though exploration constitutes only a minor part of the Australian economy, it proves significant in discovering commercially valuable resources for further extraction. Yet the exploration sector has now reached a ten year low, facing rising costs and decreased productivity, with the quality and the quantity of new discovered sites decreasing over time. It is for this reason that the Australian Government mandated the Productivity Commission to undertake an inquiry into the non-financial barriers to mineral and energy exploration (Productivity Commission, 2013). The latter has in turn issued a list of recommendations on reducing green and red tape from regulatory burdens. In line with this, within the proposed 2015 energy market reforms agenda, the Government prioritizes the improvement of geoscience information in order to attract commercial exploration, eradication of duplicative survey and data collection efforts to reduce cost for businesses and improve public understanding of the sector, the streamlining of regulation for mineral and energy resources development, and the establishment of policy framework to support new mineral and energy resources development, especially less common minerals and rare earths (Department of Industry and Science, 2015a). Particular value is laid on implementing the "one-stop shop" for environmental approvals which should decrease the time and cost of the permitting process. Similarly, the provision of pre-competitive geoscientific information, as provided by Australian geological survey organizations shall encourage exploration activities (Geoscience Australia, 2015). In terms of financial incentives instead, the Government introduced the Exploration Development Incentive which provides economic incentives to invest in small exploration companies. The latter raise capital from private sector investors through exploration credits, paid as a refundable tax offset to Australian resident shareholders (ATO, 2015). Furthermore, the R&D tax incentive designed to encourage companies to engage in R&D activities applies to mining companies of various sizes and contributes to funding of drilling and exploration activities (Edwards, 2015).

In addition to the initiatives described above, Australia has also launched the Industry Innovation and Competitiveness Agenda, as part of Government's Economic Action Strategy in 2014. It concerns reforms to boost competitiveness and is centred on four goals: lower cost and business friendly environment; more skilled labour force; better economic infrastructure; and industry policy which fosters innovation and entrepreneurship. One of the key initiatives to achieve the fourth goal is establishing non-profit Industry Growth Centers (Australian Government, 2014). The government intends to invest 188.5 million AUD (or approximately 119 million EUR according to 2015 exchange rates) over a period of 4 years within sectors with high competitive strength. Among those selected are also the mining equipment, technology and services sector, and the oil, gas and energy resources sector. The role of the Centers will be to develop roadmaps of priority actions with view of increasing the competitiveness of respective sectors, to help improving regulatory environment and to facilitate industry-university-government partnerships in order to develop innovative products and services. Furthermore, the Agenda intends to place science at the centre of industry policy, bringing together universities, R&D corporations, industry initiatives and publicly funded research agencies (Department of Industry and Science, 2014). One such agency is the Commonwealth Scientific and

Industrial Research Organisation (CSIRO), Australia's leading multidisciplinary research organization. It was established in 1926 as the Council for Scientific and Industrial Research with the purpose of carrying out scientific research on topics of Australia's farming, mining and manufacturing industries. These were later expanded across all fields of primary, secondary and tertiary industries. For example, the CSIRO Minerals Down Under Flagship initiative was set up in order to promote industry-university-community linkages and thus to further technology and innovation solutions for more efficient development of country's mineral resource across the entire value chain (CSIRO, 2013). For rare earths in particular, CSIRO is currently developing methods for better and less energy intensive ways to extract rare earths from the ore body (Treadgold, 2015). Similarly, the Australian Nuclear Science and Technology Organisation (ANSTO) Minerals branch has been involved in developing various processing options for rare earths from minerals of different grades for more than two decades (ANSTO Minerals, 2015). This international mining consultancy is the world leader in uranium and rare earth processing, radioactivity control and fundamental research applied to industrial problems.

However Australia also brings resource nationalism perspectives into its mineral strategies. For example, the recent foreign acquisitions of Australian mining companies have sparked concerns among politicians and the public about the possibility of losing grip over country's resources. As a response to these, the Australian regulators blocked several bids by foreign companies for Australian mineral producers. Such was the case of the unsuccessful attempt of Chinalco to increase its stake in Rio Tinto's iron ore, copper, and aluminium assets, as well as the bid by China Minmetals Corp for OZ Minerals which owns and operates copper-gold mines, and the proposed takeover of a controlling stake in Lynas by China Non-Ferrous Metal Mining Company which were both halted by Australia's Foreign Investment Review Board (Macalister, 2009; Scott, 2009). Analogously, the Australian policymakers strive to ensure that country's natural resources are not only benefiting international mining companies, but also the Australian population. This idea has been reflected within the Review of Australia's Future Tax System (also known as the Henry Tax Review) (MCA, 2008), which has later become basis for the mining taxation overhaul. The Australian Government developed a package of tax reforms *"to harness the super profits of our mining boom and redirect them to the vital task of national economic reform... We will ensure Australia gets a fair share of our resource wealth, directing the proceeds towards sustainable economic growth right across the economy."* (Australian Government, 2010). The roots of this decision go back to more than half a century of persistently high current account deficits caused by Australia's narrow export base and large imports of capital goods (The Australian Business Journal, 2010). The Government first announced its intention to introduce a Resource Super Profits Tax (RSPT) in 2010, which would tax mining projects on profits, rather than on production. The introduction of such a tax would have implied levying 40% rate on excess profits of all extractive industries. While the proposal for this tax received support from several renowned economists (Argy et al., 2010), there was a controversy among the largest explorer companies grouped under the umbrella of the Minerals Council of Australia (The Australian Business Journal, 2010). This has ultimately resulted in an "advertising war" against the new tax measure and lasted until the resignation of the Prime Minister in summer 2010 (Davis, 2011). Subsequently, his successor abolished the RSPT and replaced it by Mineral Resource Rent Tax (MRRT), the design of which was a compromise between the industrial lobby led by BHP Billiton, Xstrata and Rio Tinto, and the Government (AAP, 2012). As a second best option, this new tax policy was implemented in 2012 and levied a 30% tax on excess profits generated from the extraction of coal and iron ore or anything produced by in-situ consumption of coal or iron ore. Yet, its design and implementation were criticized by economists (The Economist, 2012) as well as by some mining lobby groups and the federal opposition who claimed that the policy would not raise the expected revenues and would drive investment and jobs outside of Australia instead (Mercer, 2011). After winning the elections the Coalition repealed the tax in 2014, aiming to restore the industry confidence (ATO, 2014; MCA, 2013).

4.6 Summary

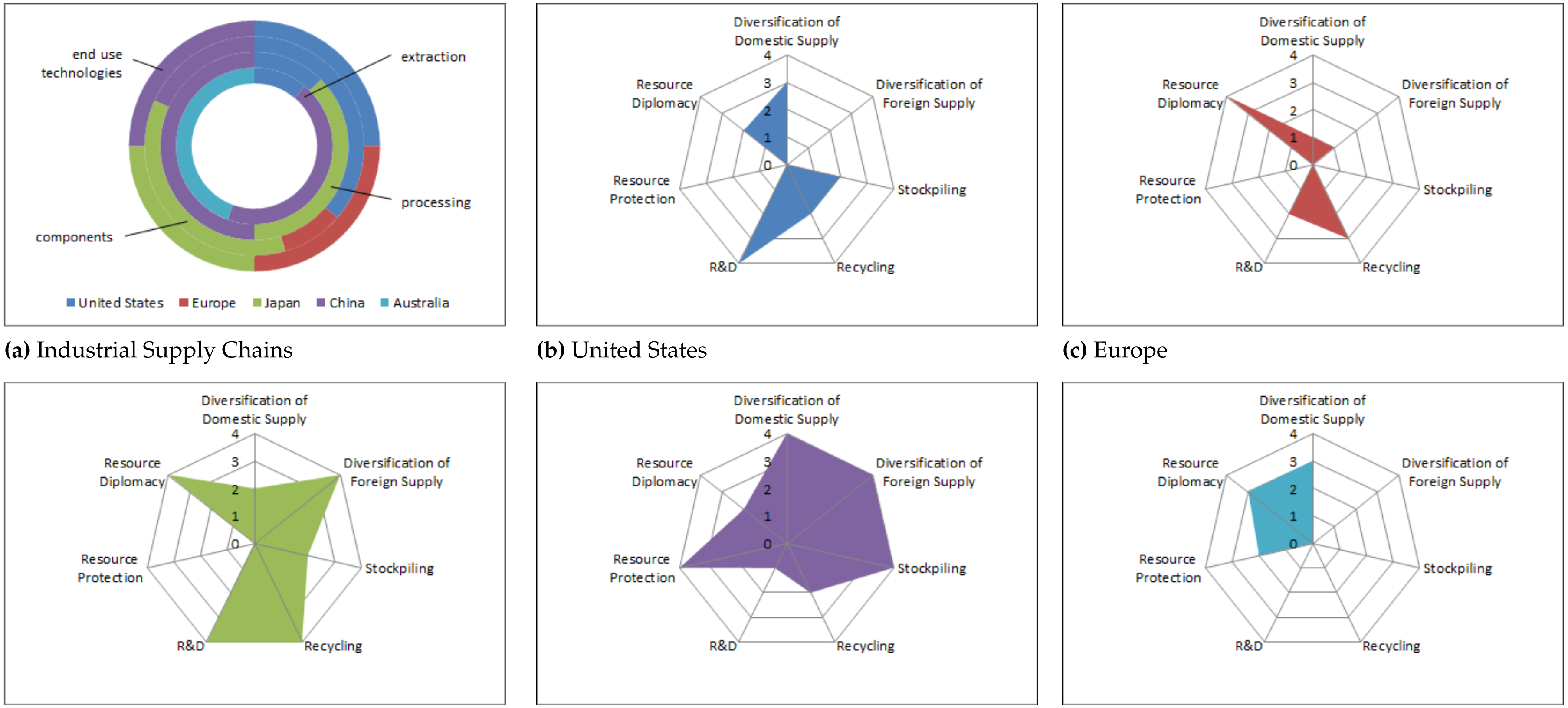
This final subsection highlights the most important points raised within the above historical account. The static interpretation of results is summarised within Table 1 and also illustrated graphically within Figure 1. Though these constitute merely a subjective attempt to translate the richness of the qualitative analysis into numbers, the aim of such assessment is to help understanding the different policy directions taken by individual stakeholders in response to the common problem of security of supply. In particular, rare earth industrial supply chains are evaluated within the generic supply chain framework across four main processes: extraction of oxides from the earth's crust; processing through separation and refining into metals, alloys and powders; manufacturing of component parts such as magnets, motors and generators; and assembling these into end use low carbon technologies such as wind turbines and alternative technology vehicles (Bauer et al., 2010). The general observation is that China appears to be the only country with a vertically integrated rare earth supply chain. In fact, while downstream parts of supply chains tend to be well established across all major stakeholders (with the exception of Australia), currently on China disposes of well integrated activities on the upstream side of the supply chain (with Australia outsourcing processing to Malaysia, Japan lacking primary supply and the United States having shut down Molycorp). Regarding rare earth mineral strategies instead, these are evaluated across seven elements which were identified as common across the countries analysed and largely correspond with categories considered by other studies (Bauer et al., 2010): domestic and foreign diversification of supply, resource diplomacy, stockpiling, recycling, R&D and resource protection. The scores assigned within Figure 1 illustrate the diversity of policy directions taken by individual stakeholders, ranging from policy diplomacy by Europe, through a more hands-on approach in R&D in Japan and the United States, to policies targeting diversification of domestic supply and resource nationalism by Australia and China. These results, along with the analysis of policy styles, form the basis for the comparative political economy discussion in Section 5.

Table 1: Summary Table on Rare Earth Industrial Supply Chains and Strategies Across World Regions

	Industrial Supply Chain		**Diversification of Supply**		**Resource Diplomacy** (policy dialogue, i.e. excl. financing: oversight of free trade issues, development aid, international collaboration)	**Stockpiling** (private, public: defence vs. economic)	**Recycling** (established recycling processes, waste management policies, training programmes)	**R&D** (substitution, minimisation, improvement of performance, industry-university-government linkages, training programmes)	**Resource Protection** (export and production restrictions, consolidation of industry, investment restrictions)
	Upstream (extraction, processing into metals, alloys and powders)	**Downstream** (manufacturing of components, e.g. magnets, motors, generators, and end use technologies, e.g. wind turbines, alternative technology vehicles)	**Domestic** (mining regulation, data and information gathering, exploration, permitting, skilled workforce, R&D)	**Foreign** (financing of projects abroad)					
United States	+	++	++	o	+	+	+	++	o
Europe	o	+	+	+*	++	o	++	+	o
Japan	+	++	+	++	++	+	++	++	o
China	++	++	++	++	+	++	+	+	++
Australia	++	o	++	o	++	o	o	o	+

This table summarises the results of the qualitative analysis. Scores have been assigned based on the status quo of respective rare earth-to-low carbon technology supply chains (first two columns) and of national policies (rest of the table) as follows: o = not applicable; + work in progress (weak); ++ established (strong).
Note that all strategy elements are evaluated within the specific context of rare earths, with the exception of the development aid component in resource diplomacy.
* No integrated European approach, only single country initiatives.

Figure 1: Assessment of Rare Earth Industrial Supply Chains and Strategies Across World Regions.



(a) Industrial Supply Chains

(b) United States

(c) Europe

(d) Japan

(e) China

(f) Australia

The diagrams are a subjective attempt to translate the richness of the qualitative analysis into numbers. Scores have been assigned based on the status quo of respective rare earth-to-low carbon technology supply chains (Figure 1a) and of national policies (Figures 1b to 1f) in the range from 0 to 4 indicating: 0 = not established; 1 = weakly established; 2 = partially established; 3 = well established but incomplete; 4 = strongly established in every aspect. Note that all strategy elements are evaluated within the specific context of rare earths, with the exception of the development aid component in resource diplomacy.

5 Discussion

The information presented in the previous section serves as basis for explaining why different world regions responded differently to the global problem of securing stable supply of critical materials. This is done in the present section, by examining the influence of national interests, resource endowment, countries' historical experience in tackling supply risk and their respective national policy styles on the development of critical material policy choices within a comparative political economy framework.

To start with China, its well-established policies targeting the rare earths industry are rooted in China's étatist, activist, comprehensive and legalist policy style. China treating rare earths as "protected and strategic materials" reflects its preference for policy solutions through state regulation. In fact, its industrial policies prescribe protected exploitation of rare earth minerals, and at the same time limit the access of foreigners to the Chinese market, regulate domestic production and stockpiling, and explicitly increase the state control within the industry. The issue of industry influence is complicated. On the one hand, the tight control of production quotas and phasing out domestic production capacities illustrates the lack of institutional channels for industry associations to intervene in the policymaking process. On the other hand, the informal authority structure makes the enforcement rather difficult. In fact, the central government has been unsuccessfully fighting over-production and smuggling which occur under the protective umbrella of local governments. This is in line with findings by Hung Lo et al. (2000) who describe China's policy style as active, legalistic and adhering to procedural formalities, but at the same time shaped by informal political activity. However, in addition its national policy style, Chinese industrial policies have also been shaped by the influence of transnational organisations. In fact, the ruling of the WTO against China violating international trade rules led to abolishing tariffs and quotas and to introducing resource tax and export licensing. Furthermore, the radical and innovative nature of China's policy style is reflected in its early efforts to establish the rare earths innovation system. Policies targeting rare earths are embedded within comprehensive R&D programmes and within the new action plan for industrial upgrading. Such comprehensive policymaking with long term vision is rooted in the stability of the one-party regime and the centralisation of the political power. However, China is a developmental state, what makes it difficult to compare it with the remainder of developed countries analysed in this paper. In fact, its state policies, focusing on growth and industrialisation, have placed national interests in the forefront and neglected the environmental consequences. This has also been reflected in the rare earths industry, where excessive mining and polluting techniques led to large environmental and social costs. What is more, the lack of environmental concerns in policy making has been worsened by the missing public participation in policymaking. Furthermore, the fact that China is a resource abundant country explains some of its policy priorities. Because of its large primary supply, China does not have policies in place targeting secondary supply in form of recycling. Similarly, despite the existence of extensive R&D programs, China does not seem to focus on R&D in substitution and minimisation of rare earths in applications, neither does it seem to target improvement of performance linked to rare earth-free designs. Yet, China seems to be aware of the pressure on its domestic resources and in line with this orients its resource diplomacy along the "go global" policy. This targets acquisition of strategic resources abroad and technology transfer through foreign direct investment and is another example of the rational planning of Chinese policy makers.

In contrast to the Chinese policy style, the American style is liberal-pluralist, less comprehensive, somewhat activist but also adversarial and legalist. This has significantly shaped the critical mineral policy priorities in terms of diversification of domestic supply, R&D initiatives, and partially strategic stockpiling and resource diplomacy. The debate on security of raw material supply is rooted in a historical legalist tradition, whereby the term critical material was first introduced within the Strategic and Critical Materials Stock Piling Act of 1939 and continues ever since to reappear in other legislations. This has laid the basis for a well-established regulatory environment, which in turn facilitated the rare earth industry development in the United States during the second half of the 20th century. Yet, its continuous success was inhibited by the adversarial and fragmented policy by the Government. For example, as Molycorp, the only American rare earth producer, faced criminal investigations due to wastewater breaches, it was forced to suspend and later to completely shut down its operations. The fragmented policy style can clearly be seen from the United States abandoning its strong interest in security of supply in the 1980s. This also interfered with its activist approach in terms of R&D. In fact, the United States has a long tradition of national laboratories engaging in research on different aspects of metals, which was also the main driving force behind the search for innovative composition of permanent magnets in the 1970s. After a temporary loss of strategic perception of non-energy minerals due to a change in geopolitics, the revival of American attention in rare earths two decades later was driven by the disruption of the domestic industry and by limitations in the international trade. The prominence of R&D became eventually even stronger, reflected in the creation of new laboratories focusing specifically on critical materials research, in the establishment of research programs at universities and of comprehensive financing of projects. Nowadays, R&D is firmly established across all three pillars of the Critical Materials Strategy and is mainly seen to drive substitution and minimisation of rare earths and improvement of performance of rare earth-free designs. Besides this, the United States also has a strong military tradition, the implications of which can be seen in minerals policymaking. In fact, in order to decrease the current dependence of the US military on China, the Department of Defense authorised the National Defense Stockpile to stockpile heavy rare earths. Finally, the American industrial associations also tend to have a significant influence on critical minerals policymaking, lobbying for industry interests and addressing their concerns directly to the Congress. An example of such intervention is the initiative by the largest US industrial union which ultimately played a significant role in the US filing a complaint to WTO against China's export restrictions. The participation by interest associations, organisations and unions in the policymaking process is one of the main differences between the United States and China, and is clearly facilitated by the liberal-pluralist policy style in the former. Similarly, as opposed to China, the US policymaking in the context of critical minerals can be characterised by highly formalised interagency collaboration facilitating the policymaking effort across federal agencies.

Concerning Europe, one cannot speak of a single regulatory style since the Europe Union was formally established only in 1993, though it existed previously as European Community since 1967. The more so, since the EU is composed of nations which, through their different development trajectories, developed different institutional contexts. The étatist, activist and paternalist policy style of France, contrast strongly with the policy style of the United Kingdom which is liberal-pluralist, pragmatic and reactive, while Germany and Sweden are corporatist but rank between comprehensive and fragmented, and active and reactive regulatory styles (Van Waarden, 1995). The lack of a harmonised policy style within the EU also makes the discussion of institutional determinants of policymaking more complex. Additionally, until recently the non-energy minerals policy has been largely uncoordinated across the EU. The differences in countries' Mineral Planning Policies may potentially be attributed to their distinct regulatory styles. Yet they might also be a simple reflection of countries' distinct national interests in raw materials. Nonetheless, the regulatory style differences explain at least part of the countries' engagement in securing raw material supplies. For example, the more active involvement of the state in France and Germany led to establishing partnerships with Mongolia and Kazakhstan in rare earth exploration and mining. Also, within the French étatist context critical mineral policies seem to be less intensive than those in the corporatist Germany, where interest groups play an active role in policy formulation and implementation. The active policy approaches in Finland and Sweden, the two European countries with important economic deposits of rare earths, are reflected in the strong focus on their domestic mineral sectors. Yet, mineral strategies of other countries are still in their infancy, what is ultimately reflected in the weakly developed European policies related to the domestic supply diversification. All in all, the European policy style can be considered as fragmented and diverse. This is due to its short history of existence but also to the variety of national interests it represents. This ultimately led to a missing integrated approach within the EU. While the need for launching common initiatives was spelled out already in the late 1970s this has only been brought back to the political agenda some 30 years later, based on the request by supranational institutions. This approach is largely in line with Europe's pragmatic yet reactive style without preference for radical solutions. Nonetheless, it has resulted in the Raw Materials Initiative, the formulation of which has been influenced by Europe's consensual style which created a platform for wide public consultation. The formulation and the implementation of raw material policies remain a collaborative effort across various Directorate Generals of the European Commission and often happen in public-private partnerships, stakeholder platforms and multi-stakeholder initiatives where the process is guided jointly by industry, public services, academia and NGOs. Furthermore, Europe's historical dependence on foreign imports of metallic minerals explains the importance of resource diplomacy focus within its critical mineral strategy. The path dependence in Europe using its external relations to ensure stable supply of resources through liaising with developing countries dates back to the 1970s when the Fist Lomé Convention was established. Over time, external policy dialogues took various forms, and are to-date firmly established as the first pillar of the European Raw Material Initiative. Recently, resource diplomacy has also been extended to cooperation with resource-poor countries. Similarly, the importance of rare earth recycling is embedded within the European tradition for waste management. This gave rise to various directives which also relate to the recovery of rare earths from batteries and electronic and electrical equipment, and served as a basis for establishing new initiatives in form of rare earth recycling networks and knowledge platforms. Finally, there is a lack of practical projects on finding substitutes for rare earths on the European level. This might be a result of the fact that the downstream side of rare earth supply chain has been historically underdeveloped across Europe.

As opposed to other countries, Japan's urge for diversifying domestic and foreign supply has been largely influenced by geopolitical developments in East Asia. Industry associations, business federations as well as single large manufacturers affected by the diplomatic dispute between China and Japan which disrupted rare earths trade, have raised their concerns to the Government and demanded restoring international trade discipline under WTO agreements. As a response, the Japanese Government has allocated supplementary budget for securing rare earth supplies and filed a joint complaint against China at WTO. These developments clearly reflect the liberal-pluralist, consensual and pragmatic regulatory style of Japan. Furthermore, Japan's preference for active style can be identified in its radical and innovative policies targeting new sources of rare earths, through strategic utilisation of ODA, long term supply agreements with rare earth producing countries, overseas resource development and domestic seabed exploration. These were facilitated by well-functioning institutions and public-private partnerships. In the meantime, supply diversification has become one of the main pillars of Japan's comprehensive Strategy for Ensuring Stable Supplies of Rare Metals. Another prominent pillar of the Japanese strategy is recycling. Similar to the European case, this resulted from Japan's long history of legislation on reducing waste and promoting recycling. But as opposed to the European directives which tend to be more legalistic, Japanese recycling guidelines established in the early 1990s were promoting voluntary initiatives by businesses. This characteristic is in line with findings of Kagan (2000) that Japan has a strong preference for more informal and less legalistic regulation which tends to be implemented through informal administrative guidance and voluntary plans by companies. Additionally, its more recent legislation focusing on collection and recycling of home appliances, along with the active role of the State providing financial assistance for developing recycling processes and technologies, contributed to establishing urban mining in Japan. Similarly, concerning basic and applied research initiatives, these have emerged from the long history of rare earth permanent magnet research and production in Japan. Analogous with the US experience, Japan's active style of policy making, in terms of coordination and financing, has been the main driver behind establishing extensive R&D programs and industry-university-government linkages collaborating on lowering the usage of rare earths in permanent magnets. Finally, the current policies targeting stockpiling of "rare metals" are rooted in Japan's historical experience with managing import dependence. The economic warfare in early 1940s motivated the establishment of stockpiles in Japan and also set stability of supply of imported resources at the centre of its energy policy.

Last but not least, the weakly established policies on critical minerals in Australia can be largely explained by the fact that rather than being a consumer, Australia is an exporter of minerals. In line with this, downstream side of the supply chain remained underdeveloped in Australia, what explains the complete lack of policies on diversification of foreign supply, stockpiling, recycling and R&D. In contrast, similar to China, Australia has established some resource protectionist policies. These reflect concerns of the wider public about losing the grip over country's resources. Yet, Australia has a large potential for rare earths mining, thus most of its critical mineral related policies focus on the upstream part of the supply chain, namely on mining and production. In fact, various policies are devised to increase the international competitiveness and the sustainability of the resource sector, both in terms of financial and non-financial incentives, by establishing Industry Growth Centers to foster innovation, and through bilateral mineral consultations with main trading partners. The stability of the mining sector is reflected in the comprehensive and active policy style of the Government, which is at the same time pragmatic in that it provides information on sustainable mining practices in an informal fashion. Also, unlike in Europe, the US and Japan where mineral policymaking is decentralised, in Australia this is concentrated in the hands of the Department of Industry and Science. One can conclude that Australian style of policymaking is corporatist, where industrial associations and the government have a rather balanced relationship. This is largely in line with the findings by O'Neill (2000) who concludes that hazardous waste trading policies are characterised by high levels of government control in Australia. Similarly, her findings on the open system of regulation, accommodating the involvement by electorate and environmental groups are also reflected in the case of critical mineral policies. Yet, as illustrated by the example of the large opposition against the mining taxation overhaul which was supposed to redistribute the proceeds from super profit tax to minimise the gap within Australia's two speed economy, the involvement of industry in policymaking can also fundamentally alter the policy design. In fact, due to the large controversy among the explorer companies, the original tax proposal was replaced by a new tax which was designed based on the compromise between the industrial lobby and the Government, and was later completely repealed further to the federal opposition. Such findings are also in line with the results of previous empirical literature on Australia's environmental regulation.

6 Conclusions

This paper has attempted to describe how different world regions responded to the common problem of security of supply of raw materials for the case of rare earths, which due to their special properties of ferromagnetism, superconductivity and luminescence are key technology components in many high-tech and low carbon technologies and at the same time their supply is adversely affected by small and concentrated markets and by resource nationalism of producing countries. With the help of comparative political economy analysis the paper seeks to explain why different world regions adopted different critical mineral policies. This paper concludes that despite their similar objectives, the foci of country strategies differ. This is caused by the policymaking being a path dependent process influenced by countries' national interests and resource abundance, by their historical experience in dealing with supply risk, but also by their respective regulatory styles and the influence of transnational organisations on national policymaking. Clearly, resource abundant countries are more prone to devise policies with a strong focus on development of the domestic mineral sectors and on resource protection, than are resource poor countries. The extent to which they do so depends on whether they are consumers of these resources, such as China, or only exporters, such as Australia. Yet, the Chinese strongly established industrial policies with long term targets for rare earth industry development are also rooted in its étatist, activist and comprehensive style of regulation. In contrast, the European critical mineral policies are rather weak, what results from the regulatory styles of European countries having had different development trajectories. Yet, the recent European Raw Material Initiative evolved from the consensual style of European policy making, facilitating the multi-stakeholder involvement and guidance, what has been missing in raw materials policymaking in China. Instead, the strength of European policy on resource diplomacy and recycling are rooted in the path dependence and the long tradition of waste management. The more hands-on approach by Japan evolved from its active, liberal-pluralist, consensual and pragmatic regulatory style. Japan successfully established extensive R&D programs for lowering rare earth contents in permanent magnets. Concerning recycling, while both European and Japanese rare earth recycling policies emerged from their respective historical tradition for waste management, the activist and informal administrative guidance by Japanese seemed to have resulted in better established policies on urban mining compared to those which emerged under the legalist reactive European regulatory approach. The prominence of R&D programs in the United States lies within its long tradition of national laboratories engaging in research on different aspects of metals and within it activist regulatory style. In contrast to China, the American policymaking is characterised by highly formalised inter-agency collaboration as well as by participation of the general public. Yet, its adversarial and fragmented policy style was also one of the main drivers behind the disruption of the American rare earths industry in the late 1990s.

To conclude with, the regulatory styles to critical minerals policymaking discovered in the paper broadly correspond with those identified for environmental regulation. Another interesting finding of this paper is that both Japan and China have been able to build up strong policies, whilst having diametrically opposed regulatory styles. This points to the fact that policy styles alone do not explain the differences in policymaking. Nonetheless, based on the above discussion it is possible to generalise that countries with active, comprehensive and radical policy styles tend to devise stronger policies than countries with preference for reactive, fragmented and less radical solutions. Yet, it is not possible to conclude on one-size-fits all policy style, since policy choices are heavily shaped by the ups and downs of the mining industries as well as by the path dependent processes embedded in countries' national interests, resource endowment and their historical experience in tackling supply risk. These should therefore not be disregarded in comparative political analysis of regulation. Events (rooted in economic and political circumstances) as well as persistent traditions of policy making and implementation, captured in the notion of policy style, were found to play an important role.

References

Achzet, B. and Helbig, C. (2013). How to evaluate raw material supply risks - An overview. *Resources Policy*, 38(4):435–447.

Adachi, G.-y., Imanaka, N., and Tamura, S. (2010). Research trends in rare earths: A preliminary analysis. *Journal of Rare Earths*, 28(6):843–846.

Advisory Committee on Energy and Natural Resources (2009). Strategy to secure rare metals (draft). Technical report, Ministry of Economy, Trade and Industry. Available in Japanese only from http://www.meti.go.jp/committee/materials2/downloadfiles/g90603a07j.pdf.

Alonso, E., Sherman, A., Wallington, T., Everson, M., Field, F., Roth, R., and Kirchain, R. (2012). Evaluating rare earth element availability: A case with revolutionary demand from clean technologies. *Environmental Science & Technology*, 46(6):3406–3414.

Ames Laboratory (2015). About Ames Lab. Available from https://www.ameslab.gov/about. Accessed: 07-07-2015.

Amodei, M. (2015). H.R. 1937: National Strategic and Critical Minerals Production Act of 2015. Available from https://www.govtrack.us/congress/bills/114/hr1937. Accessed: 09-09-2015.

Argy, F., Borland, J., Cobb-Clark, D., Coelli, T., Denniss, R., Fels, A., Freebairn, J., Grafton, Q., Gruen, N., Guest, R., Hamilton, C., Keating, M., Langmore, J., Mangan, J., Menezes, F., O'Donnell, C., Pannell, D., Quiggin, J., Rao, P., Rolfe, J., Smith, B., and Throsby, D. (2010). Economists statement. Available from http://www.scribd.com/doc/31959942/Economists-Statement. Accessed: 07-07-2015.

Association for Rare Earth, (2012). Coalition letter in support of the "Law of the Sea Treaty". Available from http://www.rareearthassociation.org/120613_Coalition_LOSTRatification_Kerry_Lugar.pdf. Accessed: 30-06-2015.

Australian Associated Press (2012). Mining tax faces one more hurdle. Available from http://www.brisbanetimes.com.au//breaking-news-national/mining-tax-faces-one-more-hurdle-20120206-1r1r3.html. Accessed: 26-08-2015.

Australian Government (2010). Stronger, fairer, simpler - A tax plan for our future. Technical report, Australian Government. Available from http://www.taxwatch.org.au/ssl/CMS/files_cms/Glossy%20B5_final.pdf.

Australian Government (2014). Industry Innovation and Competitiveness Agenda - An action plan for a stronger australia. Technical report, Australian Government. Available from http://www.industry.gov.au/industry/Documents/Industry-Innovation-and-Competitiveness-Agenda.pdf.

Australian Nuclear Science and Technology Organisation - Minerals (2015). Rare earth processing. Available from http://www.ansto.gov.au/BusinessServices/ANSTOMinerals/Capabilities/RareEarthProcessing/. Accessed: 26-08-2015.

Australian Taxation Office (2014). Minerals resource rent tax (MRRT). Available from https://www.ato.gov.au/Business/Minerals-resource-rent-tax/. Accessed: 09-09-2015.

Australian Taxation Office (2015). Exploration Development Incentive. Available from https://www.ato.gov.au/General/New-legislation/In-detail/Direct-taxes/Income-tax-for-businesses/Exploration-Development-Incentive/. Accessed: 09-09-2015.

Baotou National Rare Earth Hi-Tech Industrial Development Zone (2015). Rare earth: An introduction. Available from http://www.rev.cn/en/int.htm. Accessed: 05-07-2015.

Baotou Research Institute of Rare Earths (2015). Baotou research institute of rare earths - About us. Available from http://www.brire.com/english/english.htm. Accessed: 04-07-2015.

Barnicoat, A. (2013). Australia's critical commodities: Uncovering the potential. Presented during the Annual Research Workshop 2013.

Bauer, D., Diamond, D., Li, J., McKittrick, M., Sandalow, D., Telleen, P., and Wanner, B. (2011). US Department of Energy Critical Materials Strategy. Technical report, US Department of Energy. Available from http://energy.gov/sites/prod/files/DOE_CMS2011_FINAL_Full.pdf.

Bauer, D., Diamond, D., Li, J., Sandalow, D., Telleen, P., and Wanner, B. (2010). US Department of Energy Critical Materials Strategy. Technical report, US Department of Energy. Available from http://energy.gov/sites/prod/files/edg/news/documents/criticalmaterialsstrategy.pdf.

Berry, C. (2015). China, minor metals, and supply chains over the next five years. Available from http://www.discoveryinvesting.com/blog/2015/6/24/china-minor-metals-and-supply-chains-over-the-next-five-years. Accessed: 09-09-2015.

Bradsher, K. (2010). Amid tension, China blocks vital exports to Japan. Available from http://www.nytimes.com/2010/09/23/business/global/23rare.html?pagewanted=all&_r=1&. Accessed: 16-11-2013.

Bradsher, K. (2011). Taking a risk for rare earths. Available from http://www.nytimes.com/2011/03/09/business/energy-environment/09rare.html?pagewanted=2&_r=0. Accessed: 26-08-2015.

Bromby, R. (2015a). China's rare earth situation: Rampant illegal production, inadequate quotas, imperfect tax system (but great market expansion!). Available from http://investorintel.com/cleantech-intel/chinas-rare-earth-record-rampant-illegal-production-inadequate-quotas-imperfect-tax-system-but-great-market-expansion/. Accessed: 20-08-2015.

Bromby, R. (2015b). Critical metals: The West is sleepwalking to its economic decline. Available from http://investorintel.com/technology-metals-intel/critical-metals-the-west-is-sleepwalking-to-its-economic-decline/. Accessed: 26-08-2015.

Center for Resource Recovery and Recycling (2015). About. Available from http://wp.wpi.edu/cr3/about/. Accessed: 30-07-2015.

ChangChun Institute of Applied Chemistry (2015). CAS key laboratory of rare earth chemistry and physics. Available from http://english.ciac.cas.cn/rh/rd/200907/t20090710_22709.html. Accessed: 04-07-2015.

Chovanec, P. (2010). The politics of rare earth. Available from http://www.forbes.com/sites/china/2010/10/04/the-politics-of-rare-earth/. Accessed: 09-09-2015.

CNN Wire Staff (2012). Obama announces WTO case against China over rare earths. Available from http://edition.cnn.com/2012/03/13/world/asia/china-rare-earths-case/. Accessed: 05-04-2015.

Commonwealth Scientific and Industrial Research Organisation (2013). Program 1: National Research Flagships. Available from http://www.csiro.au/en/About/Reports/Annual-reports/13-14-annual-report/Part2/Performance-portfolio/Flagships. Accessed: 09-09-2015.

Congressional Budget Office (1983). Strategic and critical nonfuel minerals: Problems and policy alternatives. Technical report, Congress of the United States. Available from https://www.cbo.gov/sites/default/files/doc15-entire.pdf.

Council of the European Union (2007). Competitiveness (Internal Market, Industry and Research). Technical report, Press Office - General Secretariat of the Council. Available from https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/intm/94184.pdf.

Council on International Economic Policy (1974). National security study memorandum - NSSM 197 critical imported commodities. Available from http://www.nixonlibrary.gov/virtuallibrary/documents/nationalsecuritystudymemoranda.php. Accessed: 06-07-2015.

Critical Raw Materials Innovation Network (2015). CRM_InnoNet - Substitution of critical raw materials. Available from http://www.criticalrawmaterials.eu/project-summary/. Accessed: 30-07-2015.

Davis, M. (2011). A snip at $22m to get rid of PM. Available from http://www.smh.com.au/business/a-snip-at-22m-to-get-rid-of-pm-20110201-1acgj.html. Accessed: 26-08-2015.

Deep Ocean Resources Development (2015). About dord. Available from http://www.dord.co.jp/english/corporate/index.html. Accessed: 22-08-2015.

Department of Environment Food and Rural Affairs (2012). A review of national resource strategies and research. Technical report, United Kingdom Government. Available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69526/pb13722-national-resource-strategies-review.pdf.

Department of Industry and Science (2011). Bilateral minerals and energy cooperation with japan. Available from http://www.industry.gov.au/resource/Enhancing/bmec/Pages/bmecJapan.aspx. Accessed: 27-08-2015.

Department of Industry and Science (2014). Industry Growth Centres Initiative. Technical report, Australian Government. Available from http://www.business.gov.au/advice-and-support/IndustryGrowthCentres/Documents/IndustryGrowthCentresInitiative.pdf.

Department of Industry and Science (2015a). 2015 Energy White Paper. Technical report, Australian Government. Available from http://ewp.industry.gov.au/sites/prod.ewp/files/EnergyWhitePaper.pdf.

Department of Industry and Science (2015b). Extractive Industries Transparency Initiative - Multi-stakeholder group report to the Government. Technical report, Australian Government. Available from http://www.industry.gov.au/resource/Programs/ExtractiveIndustriesTransparencyInitiative/Documents/EITI_MSG_ReportToGovt.pdf.

Department of Industry and Science (2015c). Leading Practice Sustainable Development Program for the Mining Industry. Available from http://www.industry.gov.au/resource/Programs/LPSD/Pages/default.aspx. Accessed: 26-08-2015.

Department of Industry and Science (2015d). National Mine Safety Framework. Available from http://www.industry.gov.au/resource/Mining/NationalMineSafetyFramework/Pages/default.aspx. Accessed: 26-08-2015.

Department of Industry and Science (2015e). Resources. Available from http://www.industry.gov.au/resource/Pages/default.aspx. Accessed: 26-08-2015.

Department of Industry and Science (2015f). Working in Partnership. Available from http://www.industry.gov.au/resource/Programs/WorkinginPartnershipinitiative/Pages/default.aspx. Accessed: 26-08-2015.

Duchesne, L. (2015). MSX technology to break the cost barrier of rare earth industry. Available from http://investorintel.com/technology-metals-intel/membrane-assisted-solvent-extraction-technology-to-break-the-cost-barrier-of-rare-earth-industry/. Accessed: 21-08-2015.

Edwards, J. (2015). R&d Tax Incentive âĂŞ r&d in the mining industry. Available from http://www.kpmg.com/au/en/issuesandinsights/articlespublications/tax-insights/pages/r-d-tax-incentive-mining-industry-24-june-2013.aspx. Accessed: 09-09-2015.

ERAWATCH (2015a). National basic research development programme (973 Programme). Available from http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/country_pages/cn/supportmeasure/support_mig_0004. Accessed: 04-07-2015.

ERAWATCH (2015b). National high technology R&D programme (863 Programme). Available from http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/country_pages/cn/supportmeasure/support_mig_0009. Accessed: 04-07-2015.

Erdmann, L. and Graedel, T. E. (2011). Criticality of non-fuel minerals: A review of major approaches and analyses. *Environmental Science & Technology*, 45(18):7620–7630.

EURARE (2015). About EURARE. Available from http://www.eurare.eu/about.html. Accessed: 30-07-2015.

European Commission (1975). The Community's supplies of raw materials. Technical report, Communication from the Commission to the Council. European Commission. Available from http://aei.pitt.edu/1481/1/raw_materials_COM_75_50.pdf.

European Commission (2007a). The Africa-EU Strategic Partnership - A Joint Africa-EU Strategy. Technical report, European Commission. Available from http://www.africa-eu-partnership.org/sites/default/files/documents/eas2007_joint_strategy_en.pdf.

European Commission (2007b). Public consultation on Commission Raw Materials Initiative - Background paper. Technical report, European Commission. Available from http://ec.europa.eu/enterprise/newsroom/cf/_getdocument.cfm?doc_id=633.

European Commission (2007c). VP Verheugen: Securing raw material supply for EU industries. Available from http://europa.eu/rapid/press-release_IP-07-767_en.htm?locale=en. Accessed: 30-07-2015.

European Commission (2008). The raw materials initiative–meeting our critical needs for growth and jobs in Europe. Available from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0699:FIN:en:PDF. Accessed: 09-11-2013.

European Commission (2010a). Being wise with waste: The EU's approach to waste management. Technical report, European Commission - Environment. Available from http://ec.europa.eu/environment/waste/pdf/WASTE%20BROCHURE.pdf.

European Commission (2010b). Commission staff working document accompanying the communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions on the thematic strategy on the prevention and recycling of waste. Technical report, European Commission. Available from http://ec.europa.eu/environment/waste/pdf/Commission%20Working%20Doc.pdf.

European Commission (2010c). Critical raw materials for the EU. Technical report, Report of the Ad-hoc Working Group on Defining Critical Raw Materials. Brussels: European Commission. Enterprise and Industry. Available from http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report-b_en.pdf.

European Commission (2011). Tackling the challenges in commodity markets and on raw materials. Technical report, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Available from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0025:FIN:en:PDF.

European Commission (2012). EU challenges China's rare earth export restrictions. Available from http://europa.eu/rapid/press-release_IP-12-239_en.htm. Accessed: 09-09-2015.

European Commission (2014). Report on critical raw materials for the EU. Technical report, Report of the Ad-hoc Working Group on Defining Critical Raw Materials. Brussels: European Commission. Enterprise and Industry. Available from http://www.amg-nv.com/files/Report-on-Critical-Raw-Materials-for-the-EU-2014.pdf.

European Commission (2015a). ACP - The Cotonou Agreement. Available from https://ec.europa.eu/europeaid/regions/african-caribbean-and-pacific-acp-region/cotonou-agreement_en. Accessed: 30-07-2015.

European Commission (2015b). Ecodesign. Available from http://ec.europa.eu/growth/industry/sustainability/ecodesign/index_en.htm. Accessed: 07-07-2015.

European Commission (2015c). The European Innovation Partnership (EIP) on Raw Materials. Available from http://ec.europa.eu/eip/raw-materials/en. Accessed: 30-07-2015.

European Commission (2015d). European Rare Earths Competency Network. Available from http://ec.europa.eu/enterprise/policies/raw-materials/erecon/faqs/index_en.htm. Accessed: 30-07-2015.

European Commission (2015e). Minerals Intelligence Network for Europe. Available from http://www.minerals4eu.eu/index.php/about. Accessed: 07-07-2015.

European Commission - Research & Innovation (2013). Third EU-Japan-U.S. Trilateral Conference on Critical Materials - Towards new models in efficient management of critical materials. Available from http://ec.europa.eu/research/industrial_technologies/event-13_en.html. Accessed: 12-11-2013.

European Institute of Innovation and Technology (2015). Eit Raw Materials. Available from http://eitrawmaterials.eu/strategy.php. Accessed: 30-07-2015.

European Rare Earths Competency Network (2015). Strengthening the European rare earths supply-chain: Challenges and policy options. Technical report, European Rare Earths Competency Network. Available from http://ec.europa.eu/DocsRoom/documents/10882/attachments/1/translations/en/renditions/native.

European Technology Platform on Sustainable Mineral Resources (2015). About us. Available from http://www.etpsmr.org/?page_id=6. Accessed: 30-07-2015.

Evans-Pritchard, A. (2013). Japan breaks China's stranglehold on rare metals with sea-mud bonanza. Available from http://www.telegraph.co.uk/finance/comment/ambroseevans_pritchard/9951299/Japan-breaks-Chinas-stranglehold-on-rare-metals-with-sea-mud-bonanza.html. Accessed: 17-08-2015.

Extractive Industries Transparency Initiative (2015). What is the EITI? Available from http://eiti.org/eiti. Accessed: 30-07-2015.

Federation of European Mineral Programs (2015). Federation of European Mineral programs - Home. Available from http://www.femp.org/. Accessed: 30-07-2015.

Feick, J. (1992). Comparing comparative policy studies - a path towards integration? *Journal of Public Policy*, 12(03):257–285.

General Research Institute for Nonferrous Metals (2015). General research institute for non-ferrous metals - Brief introduction. Available from http://www.grinm.com/Page/1112/language/zh-CN/default.aspx. Accessed: 04-07-2015.

Geoscience Australia (2010). Australia's identified mineral resources. Technical report, Geoscience Australia. Available from http://www.ga.gov.au/corporate_data/71584/71584.pdf.

Geoscience Australia (2015). Geoscience Australia - Our partners. Available from http://www.ga.gov.au/about/who-we-are/partners. Accessed: 25-08-2015.

Graedel, T. E., Barr, R., Chandler, C., Chase, T., Choi, J., Christoffersen, L., Friedlander, E., Henly, C., Jun, C., Nassar, N. T., et al. (2012). Methodology of metal criticality determination. *Environmental Science & Technology*, 46(2):1063–1070.

Gschneidner Jr, K. (2010). The rare earth crisis - The lack of an intellectual infrastructure. Available from https://www.ameslab.gov/files/RE_Crisis_Intell_Infrastruc_12.9.10.pdf. Accessed: 22-03-2014.

Hanauer, L. and Morris, L. J. (2014). Chinese engagement in Africa: Drivers, reactions, and implications for U.S. policy. Technical report, Rand National Security Research Division. Available from http://www.rand.org/content/dam/rand/pubs/research_reports/RR500/RR521/RAND_RR521.pdf.

Haxel, G. B., Hedrick, J. B., and Orris, G. J. (2002). Rare earth elements - Critical resources for high technology. Available from http://pubs.usgs.gov/fs/2002/fs087-02/fs087-02.pdf. Accessed: 30-03-2014.

High Level Group on Competitiveness Energy and the Environment (2007). Fourth report of the high level group on competitiveness, energy and the environment - contributing to an integrated approach on competitiveness, energy and the environment policies. Technical report, European Commission. Available from http://ec.europa.eu/enterprise/policies/sustainable-business/files/environment/hlg/june_07/fourth_report_11_06_2007_en.pdf.

Hitachi (2015). NEOMAX neodymium rare earth permanent magnet. Available from http://www.hitachi.com/environment/showcase/solution/materials/neomax.html. Accessed: 17-08-2015.

Hitachi Ltd (2010). Hitachi develops recycling technologies for rare earth metals. Available from http://www.hitachi.com/New/cnews/101206.html. Accessed: 01-03-2014.

Hitachi Ltd (2012). Highly efficient industrial 11kW permanent magnet synchronous motor without rare-earth metals. Available from http://www.hitachi.com/New/cnews/120411.html. Accessed: 13-03-2014.

Hitachi Metals (2013). Sintered Nd-Fe-B magnets. Available from http://www.hitachi-metals.co.jp/pdf/pi20131202ec.pdf. Accessed: 22-08-2015.

Hoatson, D. M., Jaireth, S., and Miezitis, Y. (2011). The major rare-earth-element deposits of Australia: Geological setting, exploration, and resources. Technical report, Geoscience Australia. Available from http://www.ga.gov.au/corporate_data/71820/Complete_Report.pdf.

Honda Motor Co. Ltd (2013). Honda established world's first process to reuse rare earth metals extracted from nickel-metal hydride batteries for hybrid vehicles. Available from http://www.hondanews.info/news/en/corporate/c130303eng. Accessed: 04-03-2014.

Hosaka, T. A. (2010). Nations wary of dependence on China's rare earths. Available from http://www.washingtontimes.com/news/2010/oct/4/nations-wary-of-dependence-on-chinas-rare-earths/?page=all. Accessed: 10-08-2015.

Hui, L. (2015). Made in China 2025: How Beijing is revamping its manufacturing sector. Available from http://www.scmp.com/tech/innovation/article/1818381/made-china-2025-how-beijing-revamping-its-manufacturing-sector. Accessed: 09-09-2015.

Humphries, M. (2013). Rare earth elements: The global supply chain. Technical report, Congressional Research Service. Available from https://fas.org/sgp/crs/natsec/R41347.pdf.

Humphries, M. (2015). China's mineral industry and U.S. access to strategic and critical minerals: Issues for Congress. Technical report, Congressional Research Service. Available from http://www.fas.org/sgp/crs/row/R43864.pdf.

Humprheys, D. (1995). Whatever happened to security of supply? minerals policy in the post-cold war world. *Resources Policy*, 21(2):91–97.

Hung Lo, C. W., To Yip, P. K., and Cheung, K. C. (2000). The regulatory style of environmental governance in China: The case of EIA regulation in Shanghai. *Public Administration and Development*, 20(4):305–318.

Hurst, C. (2010). China's rare earth elements industry: What can the West learn? Technical report, Institute for the Analysis of Global Security. Available from http://fmso.leavenworth.army.mil/documents/rareearth.pdf.

Information Office of the State Council - People's Republic of China (2012). Situation and policies of China's rare earth industry. *Foreign Languages Press*.

InvestorIntel (2015). China is looking everywhere for rare earths outside of China? Available from http://investorintel.com/technology-metals-intel/china-is-looking-everywhere-for-rare-earths-outside-of-china/. Accessed: 30-07-2015.

Japan for Sustainability (2011). Japanese agency and university co-develop rare earth-free motor for HEVs. Available from http://www.japanfs.org/en/news/archives/news_id030546.html. Accessed: 09-09-2015.

Japan Metal Bulletin (2010). METI launches new metal resource policy. Available from http://www.japanmetalbulletin.com/?p=5575. Accessed: 17-08-2015.

Japan Metal Bulletin (2012). METI to support rare earth, rare metal saving projects. Available from http://www.japanmetalbulletin.com/?p=19728. Accessed: 17-08-2015.

Japan Oil Gas and Metals National Corporation (2015a). Japan Oil, Gas and Metals National Corporation - About Us - History. Available from http://www.jogmec.go.jp/english/about/about003.html. Accessed: 17-08-2015.

Japan Oil Gas and Metals National Corporation (2015b). Metal recycling project from Ni-H batteries for hybrid electric vehicles and slag. Available from http://www.jogmec.go.jp/english/metal/technology_016.html. Accessed: 17-08-2015.

Japan Oil Gas and Metals National Corporation (2015c). Rare metals stockpiling program. Available from http://www.jogmec.go.jp/english/stockpiling/stockpiling_015.html. Accessed: 17-08-2015.

Kagan, R. (2000). Introduction: Comparing national styles of regulation in Japan and the United States. *Law & Policy*, 22(3-4):225–244.

Kaneko, K. (2012). Japan aims for half of rare earth supplies from outside China. Available from http://www.reuters.com/article/2012/11/12/japan-india-idUSL3E8MC1QL20121112. Accessed: 17-08-2015.

Katholieke Universiteit Leuven (2015). The Rare3 Platform. Available from http://www.kuleuven.rare3.eu/about/. Accessed: 04-07-2015.

Kawamoto, H. (2008). Japan's policies to be adopted on rare metal resources. *Quarterly Review*, 27:57–76.

Kimberly Process (2015). About. Available from http://www.kimberleyprocess.com/en/about. Accessed: 30-07-2015.

Kosich, D. (2013). Patent fight could impact half of global rare earth metal supply. Available from http://www.mineweb.com/mineweb/content/en/mineweb-industrial-metals-minerals-old?oid=200793&sn=Detail. Accessed: 28-03-2014.

Lifton, J. (2015). Investing in rare earth supply security, now or never? Available from http://investorintel.com/technology-metals-intel/investing-in-rare-earth-supply-security-now-or-never/. Accessed: 09-09-2015.

Löfstedt, R. E., Vogel, D., Renn, O., Slater, D., and Rogers, M. D. (2001). The changing character of regulation: A comparison of Europe and the United States. *Risk Analysis*, 21(3):399–416.

Lynas Corporation (2015). Foundations for the future. Available from https://www.lynascorp.com/Pages/about-lynas.aspx. Accessed: 26-08-2015.

Lynas Corporation Ltd (2010). What are rare earths? Available from http://www.lynascorp.com/Pages/What-Are-Rare-Earths.aspx. Accessed: 06-11-2013.

Macalister, T. (2009). Rio's deal with Chinalco collapses. Available from http://www.theguardian.com/business/2009/jun/04/rio-tinto-chinalco-investment. Accessed: 26-08-2015.

Mancheri, N., Sundaresan, L., and Chandrashekar, S. (2013). Dominating the world: China and the rare earth industry. Technical report, National Institute of Advanced Studies. Available from http://threeconsulting.com/pdfs/China-rare-earth-strategyin-wHighlights-.pdf.

MarketWatch (2010). Japan considers moves to secure rare earths. Available from http://www.marketwatch.com/story/japan-considers-moves-to-secure-rare-earths-2010-10-01. Accessed: 10-08-2015.

Mason, E. S. (1952). An american view of raw materials problems: The report of the president's materials policy commission. *The Journal of Industrial Economics*, 1(1):1–20.

Mercer, P. (2011). Can Australia's new mining tax achieve its objective? Available from http://www.bbc.com/news/business-15850019. Accessed: 26-08-2015.

Milward, A. S. (1977). *War, Economy, and Society, 1939-1945*, volume 5. Allen Lane.

Minerals Council of Australia (2008). Henry Tax Review. Technical report, Australian Government. Available from http://taxreview.treasury.gov.au/content/submissions/pre_14_november_2008/Minerals_Council_Australia.pdf.

Minerals Council of Australia (2013). Submission to Treasury: Minerals Resource Rent Tax Repeal and Other Measures Bill 2013. Available from http://www.minerals.org.au/news/submission_to_treasury_minerals_resource_rent_tax_repeal_and_other_measures. Accessed: 09-09-2015.

Ministry of Commerce of the People's Republic of China (2012a). Catalogue for the guidance of foreign investment industries (amended in 2011). Available from http://english.mofcom.gov.cn/article/policyrelease/domesticpolicy/201203/20120308027837.shtml. Accessed: 24-11-2013.

Ministry of Commerce of the People's Republic of China (2012b). China "building up rare earth reserves". Available from http://english.mofcom.gov.cn/article/counselorsreport/asiareport/201207/20120708233202.shtml. Accessed: 24-11-2013.

Ministry of Commerce of the People's Republic of China (2012c). China launches rare earth trading platform. Available from http://english.mofcom.gov.cn/article/counselorsreport/asiareport/201208/20120808275052.shtml. Accessed: 24-11-2013.

Ministry of Commerce of the People's Republic of China (2012d). China to continue rare earth protection: Official. Available from http://english.mofcom.gov.cn/article/counselorsreport/europereport/201207/20120708251407.shtml. Accessed: 24-11-2013.

Ministry of Commerce of the People's Republic of China (2012e). China to tighten standard for rare-earth mining, cut number of license. Available from http://english.mofcom.gov.cn/article/counselorsreport/asiareport/201207/20120708235128.shtml. Accessed: 24-11-2013.

Ministry of Commerce of the People's Republic of China (2012f). China's rare earths giant continues production halt. Available from http://english.mofcom.gov.cn/article/newsrelease/counselorsoffice/westernasiaandafricareport/201212/20121208505487.shtml. Accessed: 24-11-2013.

Ministry of Commerce of the People's Republic of China (2012g). Chinese rare earth firm to form megacompany. Available from http://english.mofcom.gov.cn/article/newsrelease/counselorsoffice/westernasiaandafricareport/201212/20121208508083.shtml. Accessed: 24-11-2013.

Ministry of Commerce of the People's Republic of China (2012h). Ministry of Commerce notice no. 86 of 2012 on the 2013 rare earth export quota reporting conditions and reporting procedures of the announcement. Available from http://wms.mofcom.gov.cn/article/zt_gypck/ysjsh/201211/20121108458854.shtml. Accessed: 23-11-2013.

Ministry of Commerce of the People's Republic of China (2012i). System to price rare earths. Available from http://english.mofcom.gov.cn/article/newsrelease/counselorsoffice/westernasiaandafricareport/201208/20120808277446.shtml. Accessed: 24-11-2013.

Ministry of Commerce of the People's Republic of China (2014). Announcement no. 97 of 2014 announced the "2015 classification of goods export license management certification directory". Available from http://www.mofcom.gov.cn/article/b/e/201412/20141200854927.shtml. Accessed: 11-01-2015.

Ministry of Economy Trade and Industry (2004). Toward a Sustainable Asia Based on the 3Rs. Technical report, Working Group on Enhancing International Recycling, Waste Prevention and Recycling Sub-committee, Industrial Structure Council. Available from http://www.meti.go.jp/policy/recycle/main/english/council/reports/report_sutainableasia_en.pdf.

Ministry of Economy Trade and Industry (2006). New National Energy Strategy. Technical report, Ministry of Economy, Trade and Industry. Available from http://www.meti.go.jp/english/information/downloadfiles/PressRelease/NewEnergyStrategy.pdf.

Ministry of Economy Trade and Industry (2008). Guidelines for Securing Natural Resources (provisional translation). Technical report, Ministry of Economy, Trade and Industry. Available from http://www.meti.go.jp/english/newtopics/data/pdf/080328Guidelines.pdf.

Ministry of Economy Trade and Industry (2010a). 100 Actions to Launch Japan's New Growth Strategy. Technical report, Ministry of Economy, Trade and Industry. Available from http://www.meti.go.jp/english/aboutmeti/policy/2011policies.pdf.

Ministry of Economy Trade and Industry (2010b). 3R Policies (Reduce Reuse Recycle). Available from http://www.meti.go.jp/policy/recycle/main/english/3r_policy/overview.html. Accessed: 17-08-2015.

Ministry of Economy Trade and Industry (2014). Strategic Energy Plan. Technical report, Ministry of Economy, Trade and Industry. Available from http://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/4th_strategic_energy_plan.pdf.

Ministry of Employment and the Economy (2010). Finland's minerals strategy. Technical report, United Kingdom Government. Available from http://projects.gtk.fi/export/sites/projects/minerals_strategy/documents/FinlandsMineralsStrategy_2.pdf.

Ministry of Enterprise Energy and Communications (2013). Sweden's minerals strategy - for sustainable use of Sweden's mineral resources that creates growth throughout the country. Technical report, Government Offices of Sweden. Available from http://www.government.se/contentassets/78bb6c6324bf43158d7c153ebf2a4611/swedens-minerals-strategy.-for-sustainable-use-of-swedens-mineral-resources-that-creates-growth-throughout-the-country-complete-version.

Ministry of Finance Japan (2010). The supplementary budget for FY2010. Technical report, Ministry of Finance Japan. Available from http://www.mof.go.jp/english/budget/budget/fy2010/10sb01.pdf.

Ministry of Land and Resources of the People's Republic of China (2013). Land and Resources issued the notice on the 2013 annual total rare earth tungsten ore, antimony ore mining control targets. Available from http://www.mlr.gov.cn/zwgk/zytz/201309/t20130906_1267679.htm. Accessed: 24-11-2013.

Ministry of Science and Technology of the People's Republic of China (2015a). National basic research program of china (973 Program). Available from http://www.973.gov.cn/English/Index.aspx. Accessed: 04-07-2015.

Ministry of Science and Technology of the People's Republic of China (2015b). National high-tech R&D program (863 Program). Available from http://www.most.gov.cn/eng/programmes1/200610/t20061009_36225.htm. Accessed: 04-07-2015.

Mitsubishi Electric (2012). Newly developed automatic dismantling equipment removes and recovers rare earth magnets in just 30 seconds. Available from http://www.mitsubishielectric.com/company/environment/ecotopics/rareearth/how/index.html. Accessed: 17-08-2015.

Molycorp Inc (2014). Annual report / Year in review: 2013. Technical report, Molycorp Inc. Available from http://www.molycorp.com/wp-content/uploads/Molycorp_AR2013_WEB.pdf.

Molycorp Inc (2015a). Molycorp chosen to supply rare earths for use in high-efficiency Siemens wind turbine generators. Available from http://www.molycorp.com/molycorp-chosen-to-supply-rare-earths-for-use-in-high-efficiency-siemens-wind-turbine-generators/. Accessed: 07-07-2015.

Molycorp Inc (2015b). Molycorp Magnequench timeline. Available from http://www.molycorp.com/about-us/our-facilities/molycorp-magnequench/history/. Accessed: 05-07-2015.

Molycorp Inc (2015c). Molycorp Mountain Pass. Available from http://www.molycorp.com/about-us/our-facilities/molycorp-mountain-pass/. Accessed: 05-07-2015.

Murkowski, L. (2013). Critical Minerals Policy Act of 2013. Available from https://www.congress.gov/113/bills/s1600/BILLS-113s1600is.xml. Accessed: 06-07-2015.

NANOPYME (2015). Goals of the project. Available from http://nanopyme-project.eu/background.php?fNumSecc=4. Accessed: 09-09-2015.

National Commission of Supplies and Shortages (1976). The commodity shortages of 1973-1974 - Case studies. Technical report, Department of Defense. Available from http://babel.hathitrust.org/cgi/pt?id=mdp.39015035071110;view=1up;seq=13.

National Institute for Materials Science (2011). Research trends on rare earth and critical elements in Japan. Available from http://energy.gov/sites/prod/files/Session_A7_Hono_NIMS.pdf. Accessed: 13-03-2014.

National Institute for Materials Science (2015). Our history from NRIM and NIRIM to NIMS. Available from http://www.nims.go.jp/eng/nims/history.html. Accessed: 17-08-2015.

National Research Council (2008). *Minerals, Critical Minerals, and the US Economy*. National Academies Press.

Network on Industrial Handling of Raw Materials for European Industries (2015). ERA-MIN Objectives. Available from http://www.era-min-eu.org/about/objectives. Accessed: 09-09-2015.

New Energy and Industrial Technology Development Organization (2012). The Second Trilateral EU-Japan-U.S. Conference on Critical Materials - Seminar on the strategic implications of global shortages in critical materials. Available from http://www.nedo.go.jp/content/100483482.pdf. Accessed: 12-11-2013.

Nippon Keidanren (2011). Proposals for Japan's trade strategy. Available from http://www.keidanren.or.jp/en/policy/2011/030proposal.html. Accessed: 27-08-2015.

Nystrom, E. C. (2003). From neglected space to protected place: An administrative history of Mojave National Preserve. Available from http://www.nps.gov/history/history/online_books/moja/adhi/adhi8a.htm. Accessed: 01-03-2014.

Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (2013). Strategic and critical materials 2013 report on stockpile requirements. Technical report, Department of Defense. Available from http://mineralsmakelife.org/assets/images/content/resources/Strategic_and_Critical_Materials_2013_Report_on_Stockpile_Requirements.pdf.

Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (2015). Strategic and critical materials 2015 report on stockpile requirements. Technical report, Department of Defense. Available from https://www.hsdl.org/?view&did=764766.

O'Neill, K. (2000). *Waste Trading Among Rich Nations: Building a New Theory of Environmental Regulation*. MIT Press Cambridge, MA.

Paxton, R. (2012). Kazakh nuclear firm and Japan's Sumitomo launch rare earth plant. Available from http://www.reuters.com/article/2012/11/02/rareearths-kazakhstan-japan-idUSL5E8M25UR20121102. Accessed: 17-08-2015.

Productivity Commission (2013). Mineral and energy resource exploration - Productivity Commission Inquiry Report. Technical report, Australian Government. Available from http://www.pc.gov.au/inquiries/completed/resource-exploration/report/resource-exploration.pdf.

Retriev Technologies (2014). Recycling technology - NiCad & NiMH. Available from http://www.retrievtech.com/recycling/nicad-and-nimh. Accessed: 04-03-2014.

Richardson, J., Gustafsson, G., and Jordan, G. (1982). The concept of policy style. In Richardson, J., editor, *Policy Styles in Western Europe*, pages 1–16. Allen & Unwin.

Risk & Policy Analysis Limited (2012). Stockpiling of non-energy raw materials. Technical report, European Commission - DG Enterprise and Industry. Available from http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/stockpiling-report_en.pdf.

Robinson, A. L. (1987). Powerful new magnet material found. In Gschneidner, K. A. and Capellen, J., editors, *Two Hundred Years of Rare Earths*, pages 119–149. Rare-Earth Information Center, Iowa State University, Ames, Iowa, USA.

Robison, P. and Ratnam, G. (2010). Pentagon losing control of bombs to China's monopoly. Available from http://www.bloomberg.com/news/articles/2010-09-29/pentagon-losing-control-of-afghanistan-bombs-to-china-s-neodymium-monopoly. Accessed: 20-08-2015.

Schearf, D. (2014). North Korea's rare earths could be game changer. Available from http://www.voanews.com/content/north-korea-rare-earths-game-changer/1832018.html. Accessed: 21-05-2014.

Scott, J. (2009). China Non-Ferrous barred from taking control of Lynas (update3). Available from http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aqHyQn1kkeOo. Accessed: 26-08-2015.

Shah, R. (2014). Japan to import rare earth from India âĂŞ Nikkei. Available from http://investorintel.com/technology-metals-press/japan-import-rare-earth-india-nikkei/. Accessed: 17-08-2015.

Shah, R. (2015). Molycorp, Inc. signs restructuring support agreement with key creditors; agreement covers more than 70% of 10% secured noteholders. Available from http://investorintel.com/technology-metals-news/molycorp-inc-signs-restructuring-support-agreement-with-key-creditors-agreement-covers-more-than-70-of-10-secured-noteholders/. Accessed: 30-07-2015.

Shen, H. (2014). China to close a total of 103,710 tons of rare earth (oxide) capacities. Available from http://investorintel.com/technology-metals-intel/china-orders-shutter-100000-tons-rare-earth-capacities-year/. Accessed: 31-07-2015.

Shen, H. (2015a). China increasing pressure on illegal rare earth activities. Available from http://investorintel.com/technology-metals-intel/china-increasing-pressure-illegal-rare-earth-activities/. Accessed: 31-07-2015.

Shen, H. (2015b). China to levy new resource tax on rare earths may 1st. Available from http://www.mofcom.gov.cn/article/b/e/201412/20141200854927.shtml. Accessed: 31-07-2015.

Shen, H. (2015c). China's most buzzworthy exports for july âĂŞ dysprosium and terbium. Available from http://investorintel.com/technology-metals-intel/chinas-most-buzzworthy-exports-for-july-dysprosium-and-terbium/. Accessed: 09-09-2015.

Shen, H. (2015d). China's new rare earth policies are all about control of pricing, supply and competitive r&d. Available from http://investorintel.com/technology-metals-intel/chinas-new-rare-earth-policies-control-pricing-supply/. Accessed: 31-07-2015.

Shen, H. (2015e). A turning of Japan's heavy dependence on Chinese rare earths. Available from http://investorintel.com/technology-metals-intel/a-turning-of-japans-heavy-dependence-on-chinese-rare-earths/. Accessed: 17-08-2015.

Skirrow, R. G., Huston, D. L., Mernagh, T. P., Thorne, J. P., Dulfer, H., and Senior, A. (2013). Critical commodities for aÂăhigh-techÂăworld: Australia's potential to supply global demand. Technical report, Geoscience Australia. Available from http://www.ga.gov.au/corporate_data/76526/76526.pdf.

Sojitz (2013). Rare earth development & production in australia & malaysia. Available from http://www.sojitz.com/en/special/project/post-9.php. Accessed: 17-08-2015.

Solvay (2012). Solvay launches its rare earth recycling activity in France. Available from http://www.solvay.com/en/media/press_releases/20120927-coleopterre.html. Accessed: 05-07-2015.

Sta Maria, S. (2012). Australia says it again: No to Lynas waste. Available from http://www.freemalaysiatoday.com/category/nation/2012/02/21/australia-says-it-again-no-to-lynas-waste/. Accessed: 26-08-2015.

Standing Committee of the National People's Congress (2008). Circular Economy Promotion Law of the People's Republic of China. Available from http://www.lawinfochina.com/display.aspx?id=7025&lib=law. Accessed: 06-10-2015.

State Council (2013). Circular Economy Development Strategies and Action Plan. Available from http://chinawaterrisk.org/resources/analysis-reviews/8-game-changing-policy-paths/. Accessed: 09-11-2015.

State Key Laboratory of Rare Earth Materials Chemistry and Applications (2015). State key laboratory of rare earth materials chemistry and applications - General survey. Available from http://relab.pku.edu.cn/index-en.php/about. Accessed: 04-07-2015.

Stop Lynas (2015). Opposition in Malaysia. Available from http://stoplynas.org/opposition-in-malaysia/. Accessed: 26-08-2015.

Strategic Materials Advisory Council (2013). US lobby group warns against rare earth stockpile plan. Available from http://www.strategicmaterials.org/2013/03/28/us-lobby-group-warns-against-rare-earth-stockpile-plan/. Accessed: 30-06-2015.

Tanquintic-Misa, E. (2015). Japan gets access to Mongolia rare earths in FTA. Available from http://www.ibtimes.com.au/japan-gets-access-mongolia-rare-earths-fta-1420723. Accessed: 17-08-2015.

Tasman Metals Ltd (2010). Principal uses of rare elements. Available from http://www.tasmanmetals.com/s/PrincipalUses.asp. Accessed: 06-11-2013.

Terashima, H. (2009). Ocean Governance and the Japanese Basic Act on Ocean Policy. Presented during The United Nations âĂŞ Nippon Foundation Fellowship Programme Inaugural Asia âĂŞ Pacific Alumni Meeting. Available from http://www.un.org/Depts/los/nippon/unnff_programme_home/alumni/tokyo_alumni_presents_files/alum_tokyo_terashima.pdf.

The Australian Business Journal (2010). Is the RSPT the breaking point for Australian tax reform? Available from http://www.australianbusinessjournal.com.au/is-the-rspt-the-breaking-point-for-australian-tax-reform/. Accessed: 26-08-2015.

The Chinese Society of Rare Earths (2015). Introduction of the Chinese society of rare earths (CSRE). Available from http://www.cs-re.org.cn/rareearth/english/aboutcsre/. Accessed: 04-07-2015.

The Economist (2012). Australia's new mining tax - laying 22 economists end to end. Available from http://www.brisbanetimes.com.au//breaking-news-national/mining-tax-faces-one-more-hurdle-20120206-1r1r3.html. Accessed: 26-08-2015.

The Economist (2013). China, Japan and America - Face-off. Available from http://www.economist.com/news/leaders/21590930-chinas-new-air-defence-zone-suggests-worrying-new-approach-region-face. Accessed: 17-08-2015.

The Sydney Morning Herald (2009). Concerns raised over china's 'rare earth' dominance. Available from http://www.smh.com.au/business/concerns-raised-over-chinas-rare-earth-dominance-20090901-f6xw.html. Accessed: 26-08-2015.

Tiess, G. (2010). Minerals policy in europe: Some recent developments. *Resources Policy*, 35(3):190–198.

Treadgold, T. (2015). The rare earth challenge. Available from http://www.csiro.au/en/Research/MRF/Areas/Resourceful-magazine/Issue-07/Rare-earth-challenge. Accessed: 26-08-2015.

Ucore Rare Metals (2013). Ucore comments on House Armed Services Committee dysprosium stockpile. Available from http://ucore.com/ucore-comments-on-house-armed-services-committee-dysprosium-stockpile-initiative. Accessed: 09-09-2015.

Umicore (2014). Umicore battery recycling. Available from http://www.batteryrecycling.umicore.com/UBR/. Accessed: 04-03-2014.

United States Public Laws (1939). Strategic and Critical Materials Stock Piling Act. Chapter 190, enacted june 7, 1939. Text from https://legcounsel.house.gov/Comps/Strategic%20And%20Critical%20Materials%20Stock%20Piling%20Act.pdf. Accessed: 30-06-2015.

United States Public Laws (1980). National Materials and Minerals Policy, Research and Development Act of 1980. Text from http://legcounsel.house.gov/comps/nmmprd90.pdf. Accessed: 06-07-2015.

United States Public Laws (1984). Public Law 98-373: National Critical Materials Act of 1984. Text from http://uscode.house.gov/statutes/pl/98/373.pdf. Accessed: 06-07-2015.

United Steelworkers (2010). United Steelworkers' Section 301 Petition demonstrates China's green technology practices violate WTO rules. Available from http://www.usw.org/news/pdfs/Sect301_Summary-of-Submission_USW_09-09-10PDF.pdf. Accessed: 09-09-2015.

US Department of Energy (2011). Trilateral EU-Japan-U.S. Conference on Critical Materials for a Clean Energy Future. Available from http://energy.gov/sites/prod/files/2013/05/f0/TRILATERAL_CRITICAL_MATERIALS_WORKSHOP_SummaryReportfinal%2020111129.pdf. Accessed: 12-11-2013.

US Department of Energy (2015). The department of energy's critical materials strategy. Available from http://energy.gov/epsa/initiatives/department-energy-s-critical-materials-strategy. Accessed: 07-07-2015.

U.S. Department of Interior - U.S. Geological Survey (2014). Mineral Commodity Summaries - Rare earths: 1988-2014. Available from http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/#pubs. Accessed: 23-11-2013.

U.S. Department of Interior - U.S. Geological Survey (2015a). Mineral commodity summaries - rare earths, 2015. Available from http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/mcs-2015-raree.pdf. Accessed: 04-07-2015.

U.S. Department of Interior - U.S. Geological Survey (2015b). Publications and data products. Available from http://minerals.usgs.gov/minerals/pubs/index.html. Accessed: 06-07-2015.

U.S. House Rare Earth Caucus (2012). Letter to President Obama from the Rare Earth Caucus. Available from http://www.rareearthassociation.org/2-2-12toPOTUSonREandWTO.pdf. Accessed: 30-06-2015.

US Magnetic Materials Association (2012). United States Magnetic Materials Association urges U.S. House of Representatives to vote "Yes" on H.R. 4402. Available from http://www.usmagneticmaterials.com/news/071212.htm. Accessed: 30-06-2015.

Van Waarden, F. (1995). Persistence of national policy styles: A study of their institutional foundations. In Unger, B. and Van Waarden, F., editors, *Convergence or Diversity: Internationalization and Economic Policy Response*, pages 333–372. Avebury.

Vinacomin (2012). Vinacomin & Japanese firm to exploit and process rare earth in Lai Chau. Available from http://www.vinacomin.vn/en/news/News-of-Vinacomin/Vinacomin-Japanese-firm-to-exploit-and-process-rare-earth-in-Lai-Chau-278.html. Accessed: 17-08-2015.

Vogel, D. (1986). *National Styles of Regulation: Environmental Policy in Great Britain and the United States*. Cornell University Press Ithaca, NY.

Wagner, H., Tiess, G., Nielsen, K., Solar, S., Hamor, T., Ike, P., Vervoort, A., Espi, J. A., Agioutantis, Z., Koziol, W., and Bauer, V. (2004). Minerals planning policies and supply practices in Europe. Technical report, European Commission, DG Enterprise. Available from http://ec.europa.eu/eip/raw-materials/en/system/files/ged/14%20leoben_2004_en.pdf.

World Trade Organization (2014). China - Measures related to the exportation of rare earths, tungsten, and molybdenum. Technical report, World Trade Organization. Available from https://www.wto.org/english/tratop_e/dispu_e/431_432_433r_e.pdf.

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