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COMMENTARY

Geopolitics of "Cleaner" Energy Series

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Competition for Strategic Materials[1]

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As clean energy technologies begin to account for a growing share of the international energy supply, it is inevitable that additional infrastructure and capital will be needed. Although clean energy technologies require, in general, little or no extracted natural resources for energy generation, the infrastructure and industrial processes that are required to build the physical technologies are often materials intensive. This commentary will explore rising concerns over the potential danger of transferring dependence on fossil fuels to dependence on input materials for machinery.

In the energy community, the term "resource nationalism" is being applied more broadly than ever. Traditionally used to refer to government policies toward conventional fossil fuels, it is becoming an accepted fact that there are other resources subject to such policies as well. As shown in the table below, there are a number of elements that are deemed "key" by the U.S. Department of Energy (DOE) with regard to the production of clean energy technologies. In 2010, Chinese policies regarding rare earth minerals, a group of 17 materials that are crucial to the production of clean energy and military and communication technologies, spurred a global debate about the efficacy of concentrating production of a critical natural resource in the hands of a single country.

In light of the recent debate over the availability of rare earth elements (REEs), which served to highlight concerns regarding future material supply, this discussion of critical materials will center on those elements. The tables below, however, should serve as an important reminder that REEs are not the only elements that will play a large role in the future of the clean energy economy. Of the elements in those tables, the REEs are dysprosium, europium, neodymium, terbium, yttrium, cerium, lanthanum, praseodymium, and samarium. In fact, as technologies continue to develop and new innovations emerge, there is no guarantee that new materials will not also be deemed critical, necessitating periodic criticality reassessments. After identifying the key materials found in table 1 below, DOE carried out a criticality study to determine the likelihood that a supply shortage could threaten clean energy industries based on factors such as price trends, resource availability, current production, and production potential. The study found five short- and medium-term[2] materials that were deemed critical (table 2), all of which are REEs.

[1] This commentary is the second in a series of commentaries that evaluate major trends shaping the shift toward or away from cleaner energy sources, as well as some of the emerging geopolitical dynamics arising as part of the push for cleaner energy. More information about this series can be found on the CSIS Energy and National Security Program website, https://csis.org/node/37613.

[2] The Department of Energy defines short term as the time between publication (December 2011) and 2015, roughly 3 years. The medium term refers to the subsequent 10 years (2015–2025). U.S. Department of Energy (DOE), *Critical Materials Strategy* (Washington, DC: DOE, December 2011), 9, http://energy.gov/sites/prod/files/DOE_CMS2011_FINAL_Full.pdf.

Table 1: Key Materials for Clean Energy Technologies

	Photovoltaic Films	Wind Turbines	Vehicles		Lighting
MATERIAL	Coatings	Magnets	Magnets	Batteries	Phosphors
Indium	●				
Gallium	●				
Tellurium	●				
Dysprosium		●	●		
Praesodymium		●	●	●	
Neodymium		●	●	●	
Lanthanum				●	●
Cobalt				●	
Manganese				●	
Nickel				●	
Lithium				●	
Cerium				●	●
Terbium					●
Europium					●
Yttrium					●

Source: U.S. Department of Energy (DOE), *Critical Materials Strategy* (Washington, DC: DOE, December 2011), 14, http://energy.gov/sites/prod/files/DOE_CMS2011_FINAL_Full.pdf.

Table 2: Key Materials by Criticality Classification

Short Term	Medium term
Critical	**Critical**
• Dysprosium • Europium • Neodymium • Terbium • Yttrium	• Dysprosium • Europium • Neodymium • Terbium • Yttrium
Near-Critical	**Near-Critical**
• Cerium • Indium • Lanthanum • Tellurium	• Lithium • Tellurium
Not Critical	**Not Critical**
• Cobalt • Gallium • Lithium • Manganese • Nickel • Praseodymium • Samarium	• Cerium • Cobalt • Gallium • Indium • Lanthanum • Manganese • Nickel • Praseodymium • Samarium

Source: DOE, *Critical Materials Strategy* (2011), 116.

Heightened use of quotas to control the supply of REEs by China, the world's largest producer of REEs, in recent years spurred concerns about the availability of these materials in the rest of the world, and resulted in the reevaluation of material sustainability standards by a number of corporations. Of great concern to clean technology companies is the fear that focusing solely on solving the problem of REE availability will leave the industry in a position where high demand for the technologies or materials developed as solutions or alternatives to REEs will result in new shortages and resource disputes. Solving the problem of materials sustainability with an eye to the long term will result in greater overall stability.

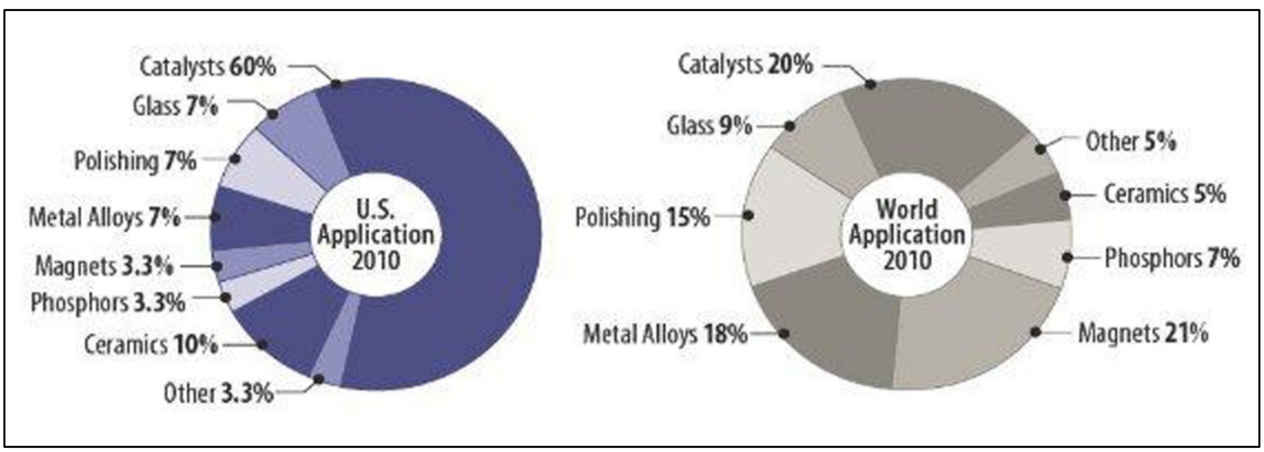
Text Box 1: A Rare Earths Primer

In order to fully understand this debate, several facts about REEs must be established. First, they are not rare. The term "rare earth elements" refers to a group of elements on the periodic table, specifically Scandium, Yttrium, and the 15 lanthanoids, which are elements 57 to 71. These elements are found in varying concentrations throughout the earth's crust, commonly associated with elements such as thorium. If anything is rare about REEs, it is finding them in concentrations that are commercially feasible in terms of large-scale production. Currently REE production is concentrated in China, although Brazil, India, and Malaysia produce small amounts, and previously mined stocks in the United States and the Commonwealth of Independent States (CIS) are processed and sold. Of the recognized untapped deposits, the most feasible ones for commercial extraction are located in China, the United States, Canada, Australia, Brazil, India, and Russia. Small deposits have also been recognized in Greenland, Vietnam, and South Africa, though it is likely that more will be recognized with time.

As alluded to in table 1, REEs are used in a broad spectrum of technologies, including wind turbines, electric vehicles, and color television sets (rare earth permanent magnets), crude oil refining cracking catalysts (lanthanum and cerium, lightweight aluminum alloys [scandium], lasers for targeting systems on military applications [yttrium, gadolinium, neodymium], and advanced batteries for vehicles, cell phones, and more. Figure 1 below shows the share of REEs used per application in 2010, with the overwhelming share being used in rare earth magnets, which are used in a wide variety of applications including wind turbines and electric vehicle motors, and catalysts for autos and petroleum refining.

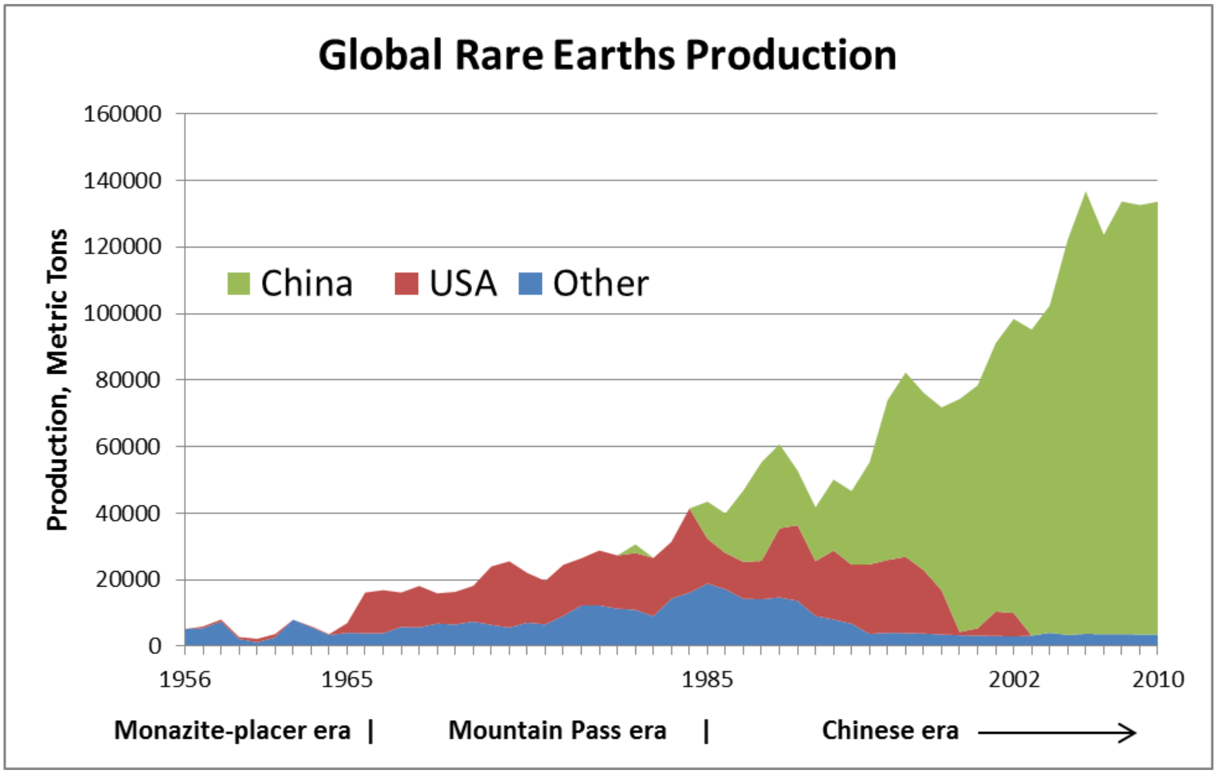
The Global Dynamics of Rare Earths

Figure 1: Use of REEs by application, 2010 estimates



Source: Marc Humphries, "Rare Earth Elements: The Global Supply Chain," Congressional Research Service, June 8, 2012, p. 5, http://www.fas.org/sgp/crs/natsec/R41347.pdf.

Figure 2: Global Production of REE



Sources: Pui Kwan-Tse, *China's Rare Earth Industry* (Reston, VA: U.S. Geological Survey, 2011), 3, http://pubs.usgs.gov/of/2011/1042/of2011-1042.pdf; and analysis of additional USGS data by CSIS.

The REE industry has shifted dramatically over the past 50 years. As shown in figure 2, production was initially small and located primarily in the former USSR (Monazite-placer era). It then grew and shifted to the United States (known as the Mountain Pass era), followed by a dramatic drop off of U.S. production and a massive increase in Chinese production. In the late 1980s and early 1990s, global REE production shifted to China as a result of low prices and increasingly strict environmental regulations in Western nations. While some analyses have painted this shift as a plot by the Chinese to overtake the industry, it is more likely that the Chinese recognized that they had an intrinsic cost and resource advantage in producing these elements. Although the Chinese have benefitted from their apparent dominance of the REE production industry, they have also suffered significant environmental and political consequences. As will be discussed below, some Chinese REE policies have been undermined by inconsistent oversight and unsuccessful limitations on the activities of small illegal mining companies. This has, in turn, resulted in damage to the environment and limited effectiveness of the quota system. In 2010, global REE demand was estimated at 136,100 tons, with more than 90 percent of that demand concentrated in China, Japan and Northeast Asia, and the United States, all of which are home to significant levels of high-tech production.

A Rare Earths Crisis?

In late 2010, Chinese REE policies began to take on what appeared to be an increasingly political bent, eventually resulting in uneasiness in the REE industry and governments, most notably in Japan and the United States. For a number of years China had utilized export quotas to restrict the sale of REEs, as illustrated in table 5. In 2010, however, the Chinese government began to lower quotas sharply, catching the attention of the importing nations, especially Japan, which has long been sensitive to its reliance on China. A precipitous fall in quotas for the second half of 2010 resulted in 40 percent less total exports for 2010 than 2009. As technology companies, mining companies with REE prospects, and their supporting governments calculated the anticipated impact of these quota changes, they also began to consider their options for impact mitigation, contemplating everything from REE stockpiles, such as those already existing in Japan and South Korea, to expanded production outside China.

Table 3: Quotas on Chinese Rare Earth Exports (in tons)[3]

Year	2006	2007	2008	2009			2010			2011		
				First	Second	Total	First	Second	Total	First	Second	Total
Export Quotas	61,560	60,173	47,449	21,728	28,417	50,145	22,283	7,976	30,259	14,446	15,738	30,184

-40% -35%

Sources: Jane Nakano, "Rare Earth Trade Challenges and Japan-Sino Relations: A Rise of Resource Nationalism," in *Asia's Rising Energy and Resource Nationalism: Implications for the United States, China, and the Asia-Pacific Region*, ed. Mikkal Herberg (Seattle, WA: National Bureau of Asian Research, September 2011), 59; and Jason Scott and Jennifer M. Freedman, "EU Says China Is Tightening Rare-Earth Access Even as Sale Quotas Increase," Bloomberg.com, July 15, 2011, http://www.bloomberg.com/news/2011-07-14/china-almost-doubles-rare-earth-export-quota-in-second-half-after-wto-move.html.

In early autumn 2010, tension erupted between Japan and China following the arrest of the captain of a Chinese ship that collided with Japanese Coast Guard vessels on September 7. Political rhetoric between the two countries escalated quickly, as Chinese officials insisted that the Japanese government release the skipper, whom it had arrested on suspicion that the collision had been intentional. It was later that month that Japanese industries announced that rare earth shipments were not reaching them, fueling speculation that the cutoff of exports was both deliberate and political. Those claims were supported by industry-wide surveys conducted by the Japanese Ministry of Economy, Trade and Industry (METI), which found holdups in export license applications, pricing agreements, customs clearances, and/or shipment processes.[4] Although the Chinese government argued that the delays were not the result of an organized government policy, at one point even suggesting that there had been a "spontaneous and simultaneous decision by the country's 32 authorized rare earth exporters not to make shipments,"[5] tensions between China and Japan, and to some extent the United States, increased dramatically. Japan, the United States, Australia, South Korea, the European Union, the Netherlands, and Canada all reacted by significantly increasing their search for alternative sources for REE supplies and other strategies to prevent future market disruption by China.[6] The dispute over shipments to Japan officially ended in late November 2010, when METI announced that shipments of REEs from China to Japan had resumed.[7]

[3] Although the quotas for 2011 were set at 30,184, in December 2011 Chinese officials announced that only 14,750 tons had been exported in the first 11 months of 2011, raising questions about the impact and importance of the quotas in light of slightly lower quotas for the first half of 2012. Chuin-Wei Yap, "China Revamps Rare Earth Exports," *Wall Street Journal*, December 28, 2011, http://online.wsj.com/article/SB10001424052970204296804577124343176436540.html.

[4] Jane Nakano, "Rare Earth Trade Challenges and Japan-Sino Relations: A Rise of Resource Nationalism," in *Asia's Rising Energy and Resource Nationalism: Implications for the United States, China, and the Asia-Pacific Region*, ed. Mikkal Herberg (Seattle, WA: National Bureau of Asian Research, September 2011), 61.

[5] Keith Bradsher, "China Is Said to Resume Shipping Rare Earth Minerals," *New York Times,* October 28, 2010, http://www.nytimes.com/2010/10/29/business/energy-environment/29rare.html?pagewanted=all.

[6] DOE, *Critical Materials Strategy* (2011), 61–62. For more explicit details on plans and strategies to combat rare earth dependencies by countries other than the United States, see DOE, *Critical Materials Strategy* (Washington, DC: DOE, December 2010), Chapter 6, http://energy.gov/sites/prod/files/piprod/documents/cms_dec_17_full_web.pdf.

[7] Jae Hur, "China Resumes Rare Earth Exports to Japan, METI Says," Bloomberg.com, November 24, 2010, http://www.bloomberg.com/news/2010-11-24/china-resumes-rare-earths-shipments-to-japan-trade-minister-ohata-says.html.

Without changing tack, China announced that the quota for the second half of 2011 would bring the annual total to nearly that of 2010. This move came on the heels of the World Trade Organization (WTO) ruling on July 5, 2011, which announced that similar restrictions on raw materials trade constitutes a violation of international trade rules in a case brought against the Chinese by the European Union, Mexico, and the United States.[8] This case referred to numerous materials, from steel to nonferrous metals, of which REEs were not included, although most observers argued that the implications of the ruling for the REE industry were strong. In short, the ruling was a blow to China's claims that it had been restricting exports in an attempt to improve environmental conditions, as significant and parallel restrictions on overall production were not found, and indicated that the policies were instead of a protectionist nature and thereby not permitted. In August 2011, China appealed the decision, arguing that the nation's policies were not in violation of WTO rules because they were primarily intended to protect the environment, as well as arguing against the premise that the ruling was not applicable to China's REE policies.[9] In January 2012, China lost its appeal, as WTO upheld the original decision.[10] The EU trade commissioner released a statement asserting that, although pleased with the outcome, the European Union remains concerned with Chinese REE policies.[11] At the time of this writing, the United States, the European Union, and Japan have taken the first step to file a WTO complaint against China's export restrictions on REEs.[12]

It would seem that there is an impetus to consider how best to control, oversee, and regulate REE (and other key raw material) production and markets. As evidenced by the WTO case brought against China by the Office of the U.S. Trade Representative (USTR), raw materials have been held to the standards of WTO, a ruling that has strong implications for future market stability. Encouraging further acceptance of WTO and other international standards would help bring stability to the REE market and provide an environment in which companies and the mining industry would find it easier to make informed decisions.

Moving Forward: Options for Industry, Tech Companies, and Government

In the wake of the market activities and tremors in 2010, interest in the REE industry has increased multifold. To claim, however, that the activities that occurred in the second half of 2010 and beyond are solely responsible for the actions being taken now is to unfairly discount the ability of markets and industries to react to a changing resource landscape. Indeed, even before quotas were sharply curtailed, technology industries, mining companies, and governments were beginning to recognize that a new form of resource dependency was taking shape, and they were reacting accordingly.[13] The notion that REE products are so far down a company's supply chain that a market failure would take them by surprise is particularly misleading, as the majority of companies map out mineral criticality for all products. Similarly, government agencies with heavy reliance on REEs, such as the U.S. Department of Defense, have also recognized the potential shortfall.[14]

The options for limiting resource dependency are numerous, and differ greatly depending on the organization looking to implement them and its timeline for doing so. In general, however, these options fall into a few categories, which

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[8] Erik Wasson, "US scores major trade case victory over China," *The Hill*, June 5, 2011, http://thehill.com/blogs/on-the-money/1005-trade/169599-us-scores-major-wto-win-over-china.
[9] "China to appeal WTO rare earths ruling," *People's Daily*, August 25, 2011, http://english.peopledaily.com.cn/90778/7579296.html.
[10] Tom Barkley, "China Loses Trade Appeal Over Its Curbs on Exports," *Wall Street Journal*, January 31, 2012, http://online.wsj.com/article/SB10001424052970204652904577193131423685816.html.
[11] "China loses WTO appeal over raw materials exports," BBC, January 30, 2012, http://www.bbc.co.uk/news/business-16803072.
[12] Barack Obama, "Remarks on Fair Trade" (remarks presented at The White House, Washington DC, March 13, 2012), http://www.whitehouse.gov/photos-and-video/video/2012/03/13/president-obama-speaks-enforcing-trade-rights-china#transcript.
[13] As early as October 2008, Japan was in the process of developing a strategy to ensure adequate supplies of critical metals. Ministry of Economy, Trade and Industry, "Announcement of 'Strategy for Ensuring Stable Supplies of Rare Metals,'" news release, July 28, 2009, http://www.meti.go.jp/english/press/data/20090728_01.html.
[14] Following H.R. 6523: Ike Skelton National Defense Authorization Act for Fiscal Year 2011, Congress mandated that the Department of Defense (DOD), under the Office of the Secretary of Defense, undertake an analysis of critical minerals. No DOD report was ever released, but the Congressional Research Service did release an initial report on the issue in June 2011. See Valerie Bailey Grasso, "Rare Earth Elements in National Defense: Background, Oversight Issues, and Options for Congress," Congressional Research Service, June 2011, https://www.fas.org/sgp/crs/natsec/R41744.pdf.

include sourcing and supply diversification, technology modifications, alternatives, and recycling/reuse. In many ways, the broad spectrum of these options has already been taken under consideration by a variety of organizations, including the U.S. Department of Energy in its *Critical Materials Strategy*, released in December 2010 and updated in 2011.

The broad spectrum of policy options include:

- *Sourcing and Supply Diversification:* This is a broad category of strategies, which can include strategic inventory reserves, global sourcing, hedging in the market, large volume purchases, and development of new mines to truly diversify supply. Some companies already have private strategic reserves of REEs (particularly in Japan and South Korea); China is developing a national reserve;[15] and calls for reserves in the United States and the European Union, particularly in military-related organizations and trade associations, are strong. Similarly, South Korea has been particularly active, moving forward with plans to establish a national stockpile of REEs and to invest in new sources of REEs worldwide.[16] The development of new mines is being undertaken in Australia, Canada, and the United States, along with newer projects under consideration in places as diverse as Kazakhstan, South Africa, Greenland, Malawi, and Sweden, and, as in the case of Molycorp's Mountain Pass mine in California, old mines are being reopened.[17] Parties with interest in mines and sufficient supply of REEs (including mining and technology companies) have placed great pressure on governments in those countries to support these projects politically and financially (loan guarantees, etc.).
- *Technology Modifications:* Efforts are being undertaken to develop versions of REE-dependent technologies that would require considerably smaller amounts of REEs while providing the same benefits.[18] Even a small reduction in the quantities of REEs required to produce a battery or permanent magnet may have the effect of significantly changing the footprint of REE dependency for a company when that reduction is repeated throughout the supply chain. Government may be able to play a role in this process in terms of supporting R&D for advanced technologies.
- *Alternatives:* Developing alternatives for REEs, ideally materials that can be used as substitutes, is an emerging mid- and long-term strategy, as this is still a relatively new area of interest. Research undertaken at the university, national laboratory, corporate, and government-agency levels can provide much needed advancements in the realm of basic knowledge. Similarly, system substitution toward new technologies may be an option, such as utilizing REE-free organic polymer solar cells (vs. copper indium diselenide or other materials systems that incorporate REEs), or even making full systems substitutions, such as the development of advanced REE-free battery and transmission technologies for vehicles as an alternative to the current transportation system, which is dependent on REEs for batteries, transmissions, and fluid cracking catalysts. Focusing solely on solving the problem of rare earths, however, could result in companies developing new and equally unsustainable dependencies, and rigorous criticality and supply analyses should be undertaken if this is the path chosen.

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[15] James T. Areddy, "China Moves to Strengthen Grip over Supply of Rare-Earth Metals," *Wall Street Journal*, February 7, 2011, http://online.wsj.com/article/SB10001424052748704124504576117511251161274.html.
[16] Sungwoo Park, "South Korea boosts rare-earth stockpile target as prices gain," Bloomberg.com, August 12, 2011, http://www.bloomberg.com/news/2011-08-12/s-korea-to-boost-rare-earth-stockpiles-explore-local-deposits.html.
[17] DOE, *Critical Materials Strategy* (2010), 72.
[18] Ibid., 101.

Figure 3: Current and Projected Projects Outside of China

(1) Molycorp, (2) Lynas, (3) Indian Rare Earths/Toyota Tsusho/Shin-Etsu, (4) Kazatomprom/Sumitomo, (5) Great Western Minerals, (6) Vietnamese Govt/Toyota Tsusho/Sojitz, (7) Stans Energy, (8) Alkane Resources, (9) Arafura Resources, (10) Greenland Minerals and Energy, (11) Great Western Minerals, (12) Avalon Rare Metals, (13) Rare Element Resources, (14) Pele Mountain Resources, (15) Quest Rare Minerals, (16) Ucore Uranium, (17) US Rare Earths, (18) Matamec Explorations, (19) Tasman Metals, (20) Montero Mining/Korea Resources, (21) Namibia Rare Earths, (22) Frontier Resources/Korea Resources, (23) Hudson Resources, (24) AMR Resources, (25) Neo Material Technologies

Source: DOE, *Critical Materials Strategy* (2011), 83.

- *Recycling and Reuse:* The potential for recycling or reusing REEs is challenging due to cost concerns and the anticipated difficulty of the undertaking. In general, rare earths are used in small quantities, meaning that recycling products with relatively high replacement rates (such as cellphones or their component pieces, which are frequently replaced every two years, as opposed to wind turbines, which are expected to last at least 10 times as long) may not contain enough REEs to make a recycling and reuse program cost effective. In the event that other materials can be simultaneously extracted and recycled, or REE prices rise considerably, then the cost effectiveness may be reconsidered. In spite of the relative unattractiveness of recycling REEs in terms of cost, there are advanced recycling companies, such as Umicore in Belgium, which have been developing recycling technologies and techniques for other products, such as dump sites and used electric appliance recycling, which could be applied to REEs. In the event that recycling and reuse becomes a viable option, there would be roles for government, clean tech companies, and the recycling industry to take part in the promotion of such projects.

While there are certainly concrete reasons for industry to be interested in, and even concerned with, the availability of REEs and other strategic minerals in the short run, there are numerous strategies that should prove capable of alleviating these concerns in the long run. The implementation of prudent government policies and forward-looking corporate strategies will help to minimize the danger of future resource disputes, in turn providing stability and predictability, which would benefit the development of clean energy and technology industries.

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