U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

HEARING CHARTER

Rare Earth Minerals and 21st Century Industry

Tuesday, March 16, 2010
2:00 - 4:00 P.M.
2318 Rayburn House Office Building

Purpose

The United States, as part of its strategy to reduce emissions from electricity generation and transportation, is investing significant funds in renewable energy technologies such as wind power and hybrid vehicles. The American Recovery and Reinvestment Act provides $2.3 billion for advanced energy manufacturing facilities, including wind turbine manufacturing plants. The Act further makes available $2 billion "…for Advanced Battery Manufacturing grants to support the manufacturing of advanced vehicle batteries and components…" Yet these investments may fail to prompt the desired outcome – a buoyant industry producing renewable energy systems – for lack of rare earth minerals.[1]

The United States finds itself dependent on the People's Republic of China for a commodity without which it would be hard to compete in high-technology industries. With a near-monopoly in supplies of rare earths, the Chinese government threatens to limit exports and tries to induce manufacturing firms to locate their facilities in Inner Mongolia. The main American supplier is seeking funding to restart its mining operation, which closed in 2002, having suffered from low prices as China expanded into the market and from a late start on renewing its environmental permits in California. Support for research has diminished.

This hearing by the Subcommittee on Investigations and Oversight will examine these intertwined threads to determine ways of redressing the expected imbalance between available supplies of rare earths and the Nation's need for them. The hearing will also ask why the policy structure put in place thirty years ago precisely to identify and respond to situations like this before they became acute bottlenecks failed to do its job.

[1] These minerals were named "Rare Earths" at the time of their discovery as they were originally found in the form of oxides (bound together with oxygen; compounds were called "earths" by scientists in the late 18th Century). "Rare" reflected the fact that the Swedish scientists who originally separated the various compounds had not encountered them before. Today, the name is somewhat misleading in that "…even the two least abundant, thulium and lutetium, are nearly 200 times as abundant as gold…." Committee on Critical Mineral Impacts on the U.S. Economy, *Minerals, Critical Minerals and the U.S. Economy* (Washington: National Research Council, 2008); p. 133 (hereafter cited as *NRC Report*).

Witnesses

Dr. Stephen W. Freiman
President, Freiman Consulting, Inc.
Member, National Research Council Committee on
Critical Mineral Impacts on the U.S. Economy

Dr. Freiman will present the findings and recommendations of the most recent National Research Council study evaluating potential responses to fluctuations in the supply-demand balance for minerals and materials. The Council included rare earth minerals among the cases analyzed, concluding that there are sufficient supply risks for rare earths to be classified as a critical resource. Dr. Freiman, a materials scientist, served as Chief of the Ceramics Division and Director of the Materials Science and Engineering Laboratory during a career at the National Institute of Standards and Technology that spanned 28 years. A specialist in the fracture of brittle materials, he has published more than 150 scientific papers.

Dr. Steven Duclos
Chief Scientist and Manager, Material Sustainability
General Electric Global Research

Dr. Duclos will testify on the process underlying General Electric's Materials Sustainability Initiative, which assesses the company's businesses for risks posed by lack of raw materials. If a problem is identified, are there steps to reduce that risk by finding substitutes, reducing the need for the material or recycling? Terbium, one of the rare earths, was identified as a high risk for GE by the Initiative. Dr. Duclos managed the company's Optical Materials Laboratory, working with GE units to develop advanced materials. He came to GE from a post-doctorate position at the AT&T Bell Labs studying superconductivity in buckminsterfullerene, the form of carbon popularly known as "buckyballs."

Dr. Karl A Gschneidner, Jr.
Anson Marston Distinguished Professor
Department of Materials Science and Engineering
Iowa State University

Dr. Gschneidner's testimony will focus on current studies of rare earths and the processes needed to convert the ores into industrially-useful materials. He has also been asked for comments to recommend improvements in the existing U.S. research program. In addition to his professorship at Iowa State University, Dr. Gschneidner holds the position of Senior Metallurgist at the Ames National Laboratory of the Department of Energy. He has researched the properties of rare earth minerals, has served as the Senior Editor of the *Handbook of the Physics and Chemistry of Rare Earths* since 1976 and was for years Director of the Ames Laboratory Rare Earth Information Center. Dr. Gschneidner is currently funded by DOE to design a refrigerator using magnets to control temperatures. He was elected to the National Academy of Engineering in 2007.

Mr. Mark Smith
Chief Executive Officer
Molycorp Minerals, LLC

Mr. Smith's company is focused on restarting the mine in Mountain Pass, California, holding the primary source of rare earth minerals in the United States. The mine was previously owned by the mining subsidiary of the Chevron Corporation, which acquired it as part of its purchase of the Union Oil Company of California. Mr. Smith, who served as head of Chevron's mining subsidiary, left to become President and CEO of Molycorp in April 2006 and negotiated to buy the Mountain Pass mine from his old company in 2007. Operations at the mine were halted after accidental spills and failure to complete environmental permits required by the State of California. Mr. Smith has been asked to describe his plan for restoring mining operations and for expanding the company into the production of magnets for next-generation wind turbine generators.

Mr. Terence Stewart, Esq.
Managing Partner
Stewart and Stewart

Mr. Stewart has an extensive history in international trade and customs law. He is a leading expert on the World Trade Organization and has assisted industry and labor groups with trade issues. Given China's outsized role in the rare earths market and its efforts to increase its influence in high-technology industries, Mr. Stewart has been invited to present his insights into China's policies and actions on resource issues and into their ramifications for U.S. industry and the economy.

Background

In November 2009, the Australian Broadcasting Corporation summarized the rare earths issues quite succinctly:

> The rare earth metals story is one lens through which we can view changing world economics, the ways and the pitfalls of how China integrates with the capitalist world, and global trade. China provides more than 90% of the world's supply of rare earths. The business media in particular is full of stories of how if the Chinese hold back on their supply of rare earths, your iPhone won't work. And more, much more. Climate change comes into it, too, because the green technologies are very dependent on rare earths.[2]

The current issues relating to rare earths supply and demand represent the latest instance of a continuing story in which what was an obscure, commodity mineral or material suddenly assumes outsized importance. Industry finds new uses that strain supplies, and American firms find that there are no domestic suppliers. In 1985, the Office of Technology Assessment (OTA) published *Strategic Materials: Technologies to Reduce U.S. Import Vulnerability* in response to concerns that

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[2] Stan Correy. "Background Briefing: Rare Earths and China." Australian Broadcasting Corporation transcript, November 15, 2009. Accessed at http://www.abc.net.au/rn/backgroundbriefing/stories/2009/2738774.htm, January 28, 2010.

> Three nations, South Africa, Zaire, and the U.S.S.R., account for over half of the world's production of chromium, cobalt, manganese, and platinum group metals. These metals are essential in the production of high-temperature alloys, steel and stainless steel, industrial and automotive catalysts, electronics, and other applications that are critical to the U.S. economy and the national defense….[3]

At that time, OTA identified the following as options for the Federal Government to pursue: increase exploration for domestic sources, find new overseas suppliers, find substitutes or reduce the need. Many of these same options apply to the case of rare earth minerals – although the unique properties that make these elements valuable may not be found in any substitute materials or minerals.[4]

The Global Rare Earths Playing Field

The United States Geological Survey's Minerals Information Team annually publishes *Mineral Commodity Summaries*, collecting information on supply, demand and market activity on some 90 minerals and materials, among them the rare earths. In January 2010, the most recent summary for the rare earths was issued, with data current to 2008.[5] USGS reported there that the United States was completely dependent on imports: between 2005 and 2008, 91% of its consumption came from China, 3% from France, 3% from Japan, 1% from Russia and 2% from other sources. The estimated cost of processed ore suitable for extracting rare earths rose from $6.61 to $8.82 per kilogram between 2007 and 2008, then dropped back to $5.73 during 2009.[6]

USGS issued the following assessment of global rare earths supply:[7]

World Mine Production and Reserves: Reserves data for Australia, China, and India were updated based on data from the respective countries.

	Mine production[e]		Reserves[6]
	2008	2009	
United States	—	—	13,000,000
Australia	—	—	5,400,000
Brazil	650	650	48,000
China	120,000	120,000	36,000,000
Commonwealth of Independent States	NA	NA	19,000,000
India	2,700	2,700	3,100,000
Malaysia	380	380	30,000
Other countries	NA	NA	22,000,000
World total (rounded)	124,000	124,000	99,000,000

[e] Estimated

[6] **Reserves.** -That part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus, terms such as "extractable reserves" and "recoverable reserves" are redundant and are not a part of this classification system.

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[3] *Strategic Materials: Technologies to Reduce U.S. Import Vulnerability* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-ITE-248, May 1985); p.3.
[4] *NRC Report*, p. 131.
[5] James B. Hedrick, "Rare Earths," in *Mineral Commodity Summaries 2009* (Reston, VA: United States Geological Survey; January 2010); pp. 128-129.
[6] *Ibid.*, p. 128.
[7] *Ibid.*, p. 129.

Actions by the Chinese government (see the next section) and growing world investment in renewable energy equipment have reinvigorated efforts to identify new sources for rare earths. Molycorp restarted its separation plant in 2007 and is processing residual materials from its mine tailings. Australia has begun production at its Mt. Weld deposit. Evaluation of the economic viability of producing in Canada and Malawi is underway.[8] An Australian mining company is also studying a deposit in Greenland that could satisfy some 25% of world needs over the next fifty years.[9] Still, as Mr. Smith of Molycorp notes, it takes significant funding and time to bring new mines into production, and volatility in a commodity market can upset even well-laid plans.

China and the Global Market

Indications that China intended to reduce exports of the rare earth materials is a major reason that this issue has recently gained prominence. Reports last year indicated that the Ministry of Industry and Information Technology had submitted the draft of a six-year plan to the State Council of China that contemplated deepening existing cuts in shipments of minerals like dysprosium.[10] The ministry stated that it was concerned that China lacked enough of the minerals to meet its own needs.[11] The Japanese Ministry of Economy, Trade and Industry had earlier developed a "Strategy for Ensuring Stable Supplies of Rare Metals" after the threat that China might limit supplies came to the attention of the Cabinet in Tokyo.[12]

The rare earths issue showcases two major elements of China's strategy for economic development:

- the targeting of critical industries that are to be kept under government control; and
- the use of subsidies and other incentives to attract foreign investment that will result in moving China's production up the value chain, bringing advanced technology into the country, and generating sophisticated exports.

Non-ferrous metals, the category into which rare earths fall, represent one of six industries that the Chinese government considers most central to economic performance and growth. The other five of these "Heavyweight Industries" are machinery; automobiles; information technology; construction; and iron and steel. Plans to keep the

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[8] *Ibid*.

[9] Leo Lewis, "Greenland Challenge to Chinese Over Rare Earth Minerals," London *Times*, October 5, 2009; p. 39.

[10] Keith Bradsher, "China Tightens Grip on Rare Minerals," New York *Times*, September 1, 2009; p. B1. See also Ambrose Evans-Pritchard, "World Faces Hi-Tech Crunch as China Eyes Ban on Rare Metal Exports," Telegraph.co.uk on August 24, 2009 at 5:58 PM BST. Accessed at http://www.telegraph.co.uk/finance/comment/ambroseevans_pritchard/6082464/World-faces-hi-tech-crunch-as-China-eyes-ban-on-rare-metal-exports.html, October 15, 2009.

[11] Feiwen Rong and Xiao Yu, "Shortage of Rare Earths Used in Hybrids, TVs May Loom in China," Bloomberg News on September 3, 2009 at 4:54 AM EDT. Accessed at http://www.bloomberg.com/apps/news?pid=20601080&sid=afn.hOk6pEHg, October 17, 2009.

[12] Ministry of Economy, Trade and Industry, "Announcement of 'Strategy for Ensuring Stable Supplies of Rare Metals," July 28, 2009. Accessed at http://www.meti.go.jp/english/press/data/20090728_01.html, October 15, 2009.

nation's economy under control call for state ownership of the three largest firms in each industry.[13]

China's government has long been aware of its rare earths deposits' potential value and thought of them in strategic terms. An official publication quotes a 1992 statement by then-Paramount Leader Deng Xiaoping that "there is oil in the Middle East; there is rare earth in China." In conjunction with a 1999 visit to Inner Mongolia, where China's largest deposit of rare earth minerals is located, then-President Jiang Zemin wrote: "Improve the development and applications of rare earth, and change the resource advantage into economic superiority."[14]

Although China has reportedly abandoned a provision in its Rare Earths Industry Development Plan 2009-2015 that would have placed an absolute ban on the export of five of the 17 rare earths, a ban on exports of raw ores continues, as does the progressive lowering of exports quotas on other forms of the materials that began in 2006. Officials in China make no secret of their desire to bring the manufacturing of the high-value-added products containing rare earths into China. "We want rare-earth industries to locate in Inner Mongolia," Zhao Shuanglin, vice chairman of Inner Mongolia Autonomous Region, stated in September 2009.[15] At around the same time, Zhang Peichen, the deputy director of Baotou Rare Earth Research Institute in Inner Mongolia, predicted: "Rare earth usage in China will be increasingly greater than exports."[16]

While its current near-monopoly in rare earths gives it a potent stick, China has had outstanding success in using the carrot to enlist foreign-based corporations' help in building up its economy. For the past 15 years or more, multinational companies have shown themselves eager to establish a presence in China to gain access to the country's potentially huge market. But that is not the only reason they have sited production and, more recently, research capacity there. "China has attracted the world's largest manufacturers by offering discounted land, energy, and taxes to relocate in China and to use China as a global export platform," according to the U.S.-China Economic and Security Review Commission. As a result, "more than half of China's exports originate from foreign-invested manufacturing enterprises located in China."[17]

"Preferential Policies" designed to attract foreign firms to the Baotou National Rare Earth Hi-Tech Industrial Development Zone, located less than 100 miles from China's huge rare earths mine at Bayan Obo in Inner Mongolia, include both funding mechanisms and significant tax incentives. For example, "hi-tech enterprises" and venture capital

[13] A similar plan is in place for the country's seven "Strategic" industries: armaments; power generation and distribution; oil and petrochemicals; telecommunications; coal; civil aviation; and shipping. The firms in this sector are to be subject to "absolute control" by the government, while, in the "Heavyweight" sphere, the government is looking for no more than a "dominant presence." U.S.-China Economic and Security Review Commission, *Hearing on China's Industrial Policy and its Impact on U.S. Companies, Workers, and the American Economy*, testimony of George Haley, March 24, 2009.
[14] "Rare Earth: An Introduction," Baotou National Rare Earth Hi-Tech Industrial Development Zone, accessed at http://www.rev.cn/en/int.htm, January 29, 2010.
[15] Chuin-Wei Yap, "Will China Tighten 'Rare Earth' Grip?," *Wall Street Journal*, September 3, 2009; p. C12.
[16] Bradsher, *loc. cit*.
[17] U.S.-China Economic and Security Review Commission, *2009 Report to Congress* (Washington: U.S. Government Printing Office, November 2009); p. 43.

companies are exempt from income tax for their first five years operating in the Zone, then pay at only half of the regular 15 percent rate during a second five-year period. They receive breaks on VAT and operations taxes as well.[18] The Baotou Industrial Development Zone's website lists 25 options on a page titled "Projects Seeking Investment," many of them focusing on rare earths and several of them in the area of "green technologies." Among these projects are:

- "Nickel Hydrogen Power Battery Polar Plate";
- "Hydrogen-Store Alloy Powder Cathode Material of Ni-Hydrogen Power Battery";
- "Industrialization of Rare Earth Ceramic Piston Ring";
- "Production Line of Rare Earth Giant Magnetostrictive Alloy";
- "The Technology of Special Rare Earth Ceramic Thermocouple Tube";
- "Industrialization of Nanometer Crystal Rare Earth Alloy Magnetic Powder"; and
- "Annual Production of 200000 Units of Magnet Motor for Electric Bicycle."[19]

Reviving Research

Iowa State University (ISU) became a hub of rare earth research as its contribution to the Manhattan Project.[20] Dr. Gschneidner carries on the tradition in rare earth research, focusing today on the behavior of rare earths at low temperatures or in high magnetic fields. He is currently receiving funds from the Department of Energy to build a refrigerator that achieves cooling by magnetism, employing magnets containing rare earths. Dr. William McCallum has recently begun seeking a cheaper or more readily available substitute for the rare earths incorporated into the permanent magnet used in a hybrid vehicle's generator. If his project is successful, a potential bottleneck for hybrid vehicle manufacturers will be eliminated. These are elements of the broader effort on magnet development at the Lab.[21] Both Drs. Gschniedner and McCallum served as director for the Rare Earth Information Center at Ames. Established as an information clearinghouse on the minerals by the Atomic Energy Commission in 1966, it was closed in 2002.

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[18] "Preferential Policies," Baotou National Rare Earth Hi-Tech Industrial Development Zone, accessed at http://www.rev.cn/en/pre.htm, January 29, 2010.

[19] "Catalog," Baotou National Rare Earth Hi-Tech Industrial Development Zone, accessed at http://www.rev.cn/en/pro.htm, January 29, 2010.

[20] The first chain reaction, initiated December 2, 1942, used natural uranium, which is very low in the fissionable isotope U-235. When a U-235 atom splits, rare earths may be among the resulting fragments. Because these might soak up the excess neutrons in the reactor that would sustain the chain reaction, research was needed on how to separate rare earths from uranium and plutonium. Iowa State succeeded in developing separation methods that could produce rare earths that were sufficiently purified to permit the needed research program. Harry J. Svec, "Prologue," in Gschneidner and Eyring, eds., *Handbook on the Physics and Chemistry of the Rare Earths*, Vol. 11 (Amsterdam: Elsevier Science Publishers, BV, 1988); p. 15. In 1947, the newly-formed Atomic Energy Commission chose the school as the home for the Ames National Laboratory and appointed Dr. Frank Spedding as its first director. Spedding, a leader in rare earth chemistry, improved his original processing methods to the point where Ames became the major supplier to the scientific community and the AEC laboratories. Spedding oversaw an extensive basic research effort characterizing the properties of rare earths in solutions and continued to develop industrial-scale processing for these materials. *Ibid*., p. 16.

[21] Communication from Iver Anderson, Senior Metallurgist, Ames National Laboratory, January 7, 2010.

In discussing the needs for research in minerals and materials, the NRC Committee on Critical Mineral Impacts on the U.S. Economy drew heavily on a 2006 industry study by the Industrial College of the Armed Forces.[22] That analysis placed rare earths in a category recommended for government support to develop materials offering superior properties for defense and commercial applications. Designers and engineers prefer materials with well-understood properties, but this conservative tendency can stymie innovation by limiting the opportunity to improve performance or efficiency. Agencies like NASA and the Department of Defense invest in studies of materials to put real-world data into the handbooks that program managers consult when writing system specifications. The decision to employ a new material often requires reworking existing production methods or introducing entirely new processes. Perfecting these can consume years, and the government may be alone in its willingness to support a project lasting that long.[23]

The NRC report notes: "Many government efforts specifically focus on innovative research in materials specialties. These efforts support a variety of worthwhile research in materials science. However, individual agencies award many of these grants on an individual or somewhat ad hoc basis that is not the product of a coordinated research strategy. In particular, they rarely address mineral information needs or consider mineral supply and demand data or criticality, either short or long term."[24] The panel therefore calls for:

- Theoretical geochemical research to better identify and quantify virgin stocks that are potentially minable;
- Research on extraction and processing technology to improve energy efficiency, decrease water use, and enhance material separation;
- Research on remanufacturing and recycling technology, key components in increasing the rate and efficiency of material reuse; and
- The characterization of stocks and flows of materials, especially imports and exports, as components of products, and of losses upon product discard. This lack of information impedes planning on many levels.[25]

This proposed program is consistent with the research effort required by the National Materials and Minerals Policy, Research and Development Act of 1980.[26]

The Policy Framework

Thirty years ago, the National Materials and Minerals Policy, Research and Development Act was enacted because

> …[T]he United States lacks a coherent national materials policy and a coordinated program to assure the availability of materials critical for

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[22] Lt. Col Carl Buhler, USAF *et al*. *Strategic Materials: AY 2005-2006 Industry Study Final Report.* Industrial College of the Armed Forces, National Defense University, Ft. McNair, Washington, D.C., 2006. (hereafter cited as *ICAF Report*)
[23] *Ibid*., pp. 6-9.
[24] *NRC Report*, p. 195.
[25] *Ibid*., p. 192.
[26] 30 USC 1602(2).

national economic well-being, national defense, and industrial production, including interstate commerce and foreign trade….[27]

The Congress declared it the President's responsibility to coordinate a plan of research and other actions that would "…promote an adequate and stable supply of materials necessary to maintain national security, economic well-being and industrial production with appropriate attention to a long-term balance between resource production, energy use, a healthy environment, natural resources conservation, and social needs."[28] Our current situation with rare earth minerals indicates that successive Administrations failed to carry out this policy.

The 1980 Act directed development of a plan that would, among other outcomes, produce continuing assessments of demand for minerals and materials in the economy; conduct a "vigorous" research and development effort; collect, analyze and disseminate information; and cooperate with the private sector and other nations.[29] In April 1982, President Reagan delivered a response to that directive.[30]

Dissatisfied with the plan and its implementation, Congress decided in the National Critical Materials Act of 1984 to establish a National Critical Materials Council in the Executive Office of the President to serve as the focal point for critical materials policy. The Council was tasked to assist the President in carrying out the requirements of the 1980 Act.[31] Yet by 1989, as the first Bush Administration took office, reports indicated that the Council was effectively moribund and that President Reagan's final budget request recommended that it be eliminated.[32] Senator Harry Reid took strong exception to the view of Acting Council Chairman Thomas Moore "…that there is no need for a centralized agency like the council because other agencies already are authorized to address critical material issues."[33] The Council survived that brush with extinction, but ultimately succumbed to a recommendation by President Clinton's science advisor, Director of the Office of Science and Technology Policy (OSTP) Dr. John Gibbons, to terminate the Council and transfer its responsibilities to the National Science and Technology Council (NSTC) established within OSTP by Executive Order 12881.[34] Funding for the Critical Materials Council was dropped in the Fiscal Year 1994 General Government Appropriation Act.[35]

In 1995 and 1996, the NSTC published reports on *The Federal Research and Development Program in Materials Science and Technology*. No equivalent report has

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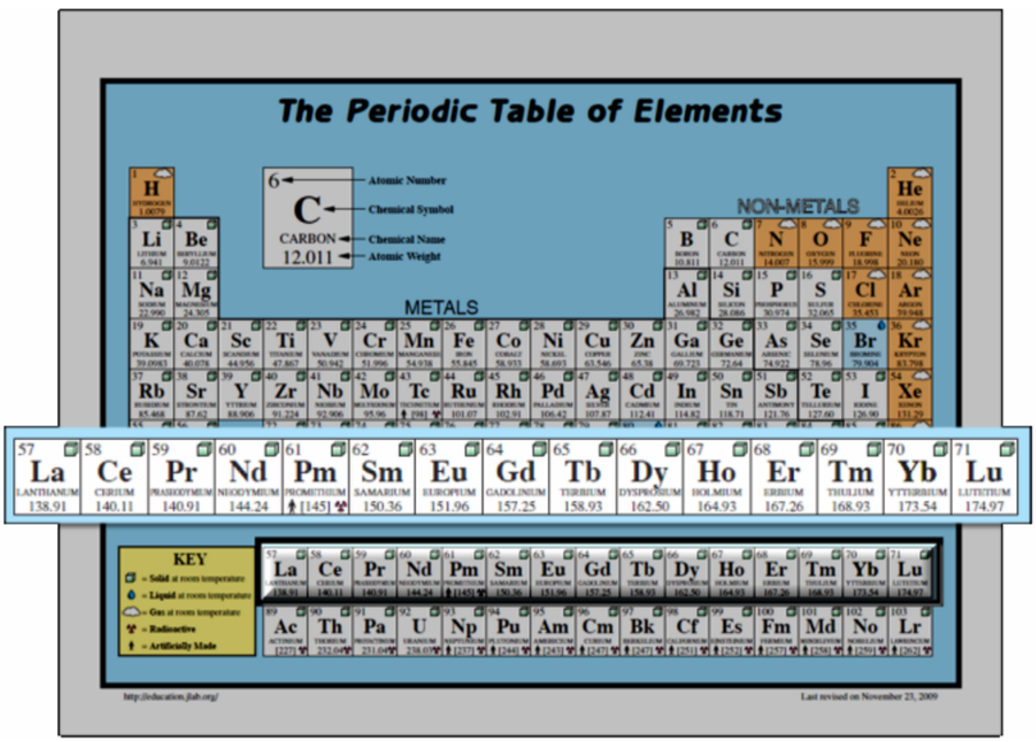
[27] 30 USC 1601(a)(6).
[28] 30 USC 1602.
[29] 30 USC 1603.
[30] "National Materials and Minerals Program Plan and Report to Congress," April 1982.
[31] 30 USC Chapter 30.
[32] "New budget to cut NCMC, R&D at Mint and land purchases," *Metals Week*, January 16, 1989; p. 3.
[33] Marilyn Werber, "Senator Blasts Plan to Abolish NCMC," *American Metal Market*, April 6, 1989; p. 2.
[34] Ex. Ord. 12881, "Establishment of the National Science and Technology Council," November 23, 1993; 58 *Fed. Reg*. 62491. Dr. Gibbons tied the reorganization both to President Clinton's decision to reduce staff within the White House and to the National Performance Review conducted by Vice President Gore. Bill Loveless, "Gibbons to Propose Formation of Science and Tech Council," *Federal Technology Report*, September 2, 1993; p. 1.
[35] Public Law 103-123, October 28, 1993.

been produced since, however, and inquiries made of OSTP failed to locate the "long-range assessments of materials needs related to scientific and technological concerns" or "scientific and technical changes over the next five years" whose annual preparation the statute requires.[36] It empirically demonstrates the failure to implement the responsibilities assigned by Congress in the 1980 Act through multiple administrations. The Committee has learned that the situation with rare earth supplies has galvanized OSTP to convene a group of senior officials and subject-matter experts from a number of Federal agencies to discuss the potential utility of White House coordination in the matter. The Committee has decided to revisit policy issues it thought it had settled decades ago to determine how to avoid finding ourselves in similar straits in the future.

Appendix: The Value of Rare Earth Minerals

The subject of today's hearing is the 15 elements found in the so-called lanthanide series of the Periodic Table.[37] The U.S. Geological Survey describes them as "iron gray to silvery lustrous metals that are typically soft, malleable, ductile, and usually reactive, especially at elevated temperatures or when finely divided."[38]



These elements are normally obtained as byproducts from mining for other materials. The chemical properties of these elements are quite similar, which complicates

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[36] 30 USC 1604(b)(2) and (3).

[37] As scandium and yttrium fall within the same period (column) on the Periodic Table, they are often counted as rare earths. The actinide series (the elements between actinium and lawrencium) can also be included, but they are noted mostly for their radioactive properties and are not the subject of the hearing.

[38] James D. Hedrick, *2007 Minerals Yearbook*: Rare Earths (Reston: U.S. Geological Survey, 2009); p. 60.1.

separating them; the production process must be tailored to the composition of the ore extracted from a given deposit.

Industry tends to divide these into "light" and "heavy" elements, moving from lanthanum to the right along the row. The "heavy" elements tend to have greater economic value. One aspect of the supply problem for the United States is that the Mountain Pass deposit lacks many of the heavier elements, whereas the major Chinese producer, the Bayan Obo mine, can provide the more valuable dysprosium and terbium.

Rare earths contribute to a number of industries, usually incorporated into metal alloys to enhance electrical or magnetic capabilities. The hearing today will consider their major contributions to renewable energy applications. Electrical generators need magnets; a smaller magnet producing a stronger field can reduce the final size of a wind turbine even as its power output increases. Combining neodymium with iron and boron, or samarium with cobalt, can produce these more efficient components. Hybrid automobiles, such as Toyota's Prius or the new Chevrolet Volt, depend on rechargeable batteries. Incorporating lanthanum into the nickel-metal-hydride battery electrolyte enhances the power output, resulting in increased vehicle range even as the battery itself gets smaller and lighter.

The following chart gives some sense of the breadth of other uses:

Cerium	Optical lens polishing; petroleum cracking catalysts
Praseodymium	High-strength metals in aircraft engines
Promethium	Portable X-ray units
Europium	Compact fluorescent bulbs; red phosphors for computer monitors
Gadolinium	Neutron radiography
Terbium	Magnets; generates green spectrum in fluorescent light
Holmium	Glass tinting
Erbium	Signal repeaters in fiber-optic cables
Thulium	Lasers
Ytterbium	Stainless steel

Having applied the criticality matrix developed as part of their study, the NRC committee concluded:

> The relatively high composite weighted score for REs [rare earths] of 3.15… [on a scale of 1-4] reflects the diversity of applications for the RE family, the importance of those applications, and the steady growth in consumption and has led our committee to suggest that disruptions in the availability of REs would have a major negative impact on our quality of life… In our view, most of the applications are somewhat to very important since substitutes are generally less effective.[39]

[39] *NRC Report*, p. 133.