U.S. DEPARTMENT OF ENERGY

2011 Critical Materials Strategy Summary

The 2011 *Critical Materials Strategy* examines the role of rare earth metals and other materials in the clean energy economy. It is an update of the 2010 *Critical Materials Strategy*, which highlighted the importance of certain critical materials to wind turbines, electric vehicles, photovoltaic thin films and energy-efficient lighting. The 2011 *Critical Materials Strategy* includes updated criticality assessments, market analyses and technology analyses to identify critical materials challenges. It was prepared by the U.S. Department of Energy (DOE) based on data collected and research performed during 2011.

The report's main highlights are the following:

- Several clean energy technologies—including wind turbines, electric vehicles, photovoltaic thin films and fluorescent lighting—use materials at risk of supply disruptions in the short term (Table 1). Those risks will generally decrease in the medium and long term.
- Supply challenges for five rare earth metals (dysprosium, terbium, europium, neodymium and yttrium) may affect clean energy technology deployment in the years ahead.
- In the past year, DOE and other stakeholders have scaled up work to address these challenges. This includes new funding for priority research, development of DOE's first critical materials research plan, international workshops bringing together leading experts and substantial new coordination among federal agencies working on these topics.
- Building workforce capabilities through education and training will help address vulnerabilities and realize opportunities related to critical materials.
- Much more work is required in the years ahead.

This report is focused on a several clean energy technologies expected to experience high growth in coming years. The scenarios presented are not predictions of the future. Future supply and demand for materials may differ from these scenarios due to breakthrough technologies, market response to material scarcity and other factors. This analysis is intended to help inform policymakers and the public. For more information, or to download the full 2011 *Critical Materials Strategy*, visit www.energy.gov.

Table 1. Materials in Clean Energy Technologies and Components

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

Figure 1. Short-Term (present–2015) Criticality Matrix

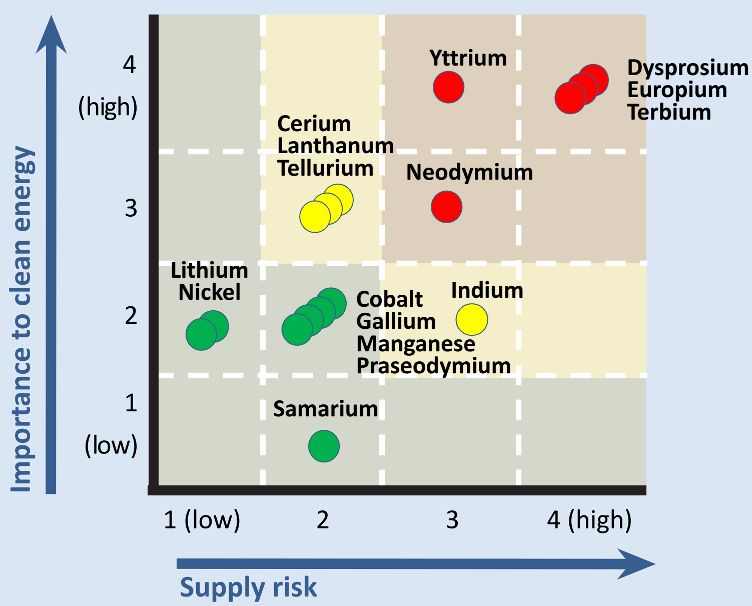
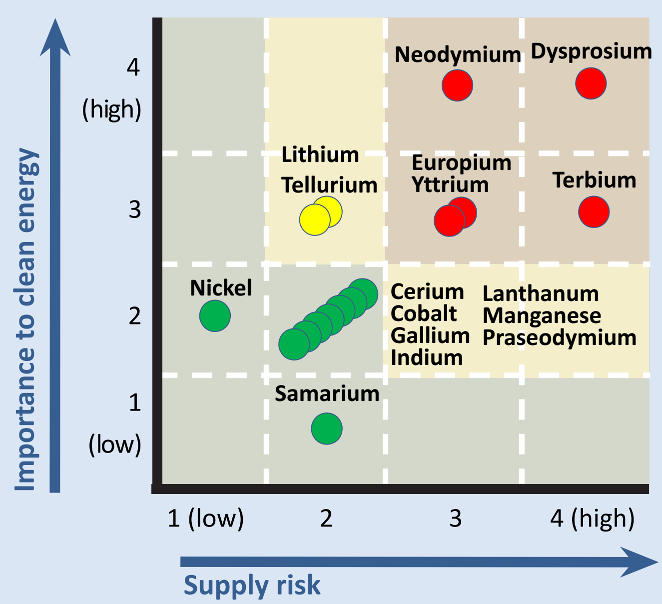


Figure 2. Medium-Term (2015–2025) Criticality Matrix



Critical Near-Critical Not Critical

Criticality Assessment

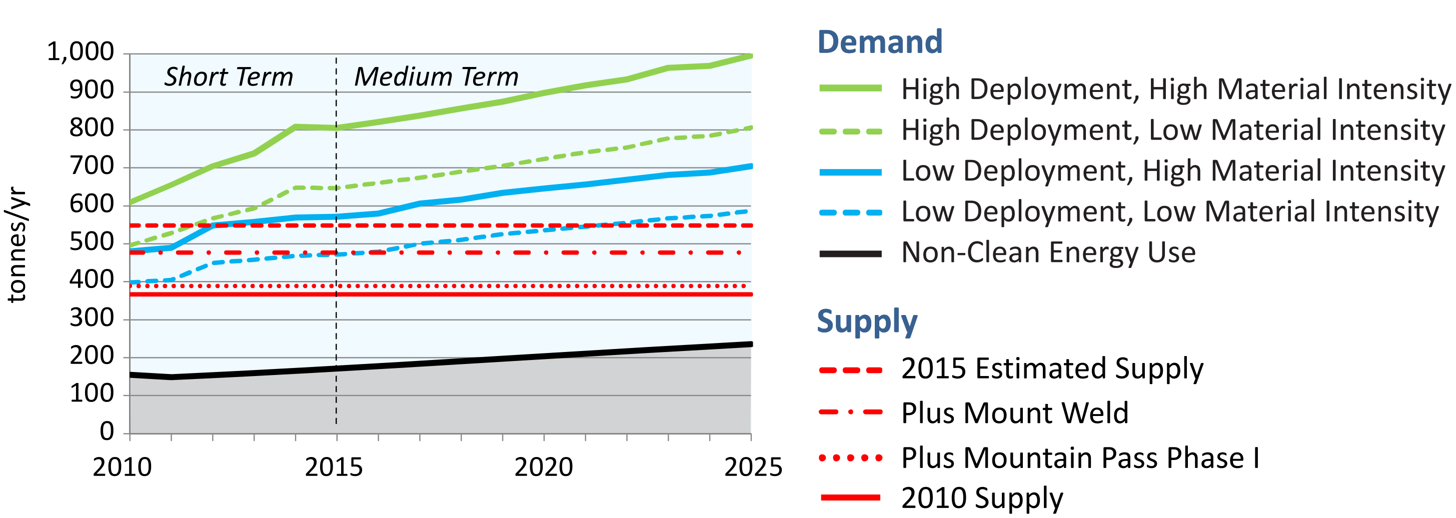
The 2011 *Critical Materials Strategy* assesses sixteen elements for criticality in wind turbines, electric vehicles, photovoltaic cells and fluorescent lighting. Nickel and manganese were added to last year's element set. The assessment frames criticality in two dimensions: importance to clean energy and supply risk. To inform the assessment, the Strategy presents supply and demand projections for each element. An example is shown in Figure 3. Five rare earth elements used in magnets for wind turbines and electric vehicles or phosphors for energy-efficient lighting were found to be critical in the short term (present–2015). These critical elements are dysprosium, terbium, europium, neodymium and yttrium. Other elements (cerium, indium, lanthanum and tellurium) were found to be near-critical. Between the short term and the medium term (2015–2025), the importance to clean energy and supply risk shift for some materials (Figure 1 and 2).

Market Dynamics

In the past year, the prices of many of the elements assessed in the report have been highly volatile, in some cases increasing ten-fold. This year's Strategy includes a chapter exploring market dynamics related to rare earth metals and other materials. Among the points in the chapter:

- In recent years, demand for almost all the materials examined has grown more rapidly than demand for commodity metals such as steel. Growing demand for the materials studied comes from clean energy technologies as well as consumer products such as cell phones, computers and flat panel televisions.
- In general, global material supply has been slow to respond to the rise in demand over the past decade due to a lack of available capital, long lead times, trade policies and other factors.
- A number of universities and other institutions are preparing a future science and engineering workforce through courses, research opportunities and internships that provide important transdisciplinary knowledge.
- Businesses at various stages of the supply chain are adapting to market dynamics. Some are taking defensive measures to protect themselves from price volatility and material scarcity, while others are proactively responding to market opportunities by offering additional sources of supply or potential substitutes.
- Many governments are recognizing the growing importance of raw materials to economic competitiveness and taking an active role in mitigating supply risks.

Figure 3. Future Demand and Supply for Europium



Technology Analyses

Building on the 2010 *Critical Materials Strategy*, the report features three in-depth technology analyses, with the following conclusions:

- **Rare earth elements play an important role in petroleum refining, but the sector's vulnerability to rare earth supply disruptions is limited.** Lanthanum is used in fluid catalytic cracking (FCC) catalysts in petroleum refining. However, lanthanum supplies are less critical than some other rare earths, and refineries have some ability to adjust input amounts. Recent large increases in lanthanum prices likely have added less than a penny to the price of gasoline.

- **Manufacturers of wind power and electric vehicle technologies are pursuing strategies to respond to possible rare earth shortages.** Permanent magnets containing neodymium and dysprosium are used in wind turbine generators and electric vehicle motors. Manufacturers of both technologies are currently making decisions on future system design, trading off the performance benefits of neodymium and dysprosium against vulnerability to potential supply shortages.
- **As lighting energy efficiency standards are implemented globally, heavy rare earths used in lighting phosphors may be in short supply.** In the United States, two sets of lighting energy efficiency standards coming into effect in 2012 will likely lead to an increase in demand for fluorescent lamps containing phosphors made with europium, terbium and yttrium.

DOE's Strategy

DOE's strategy to address critical materials challenges rests on three pillars. First, diversified global supply chains are essential. To manage supply risk, multiple sources of materials are required. This means taking steps to facilitate extraction, processing and manufacturing here in the United States, as well as encouraging other nations to expedite alternative supplies. In all cases, extraction, separation and processing should be done in an environmentally sound manner. Second, substitutes must be developed. Research leading to material and technology substitutes will improve flexibility and help meet the material needs of the clean energy economy. Third, recycling, reuse and more efficient use could significantly lower world demand for newly extracted materials. Research into recycling processes coupled with well-designed policies will help make recycling economically viable over time.

Progress

Research and development. DOE has developed a research and development (R&D) plan with respect to critical materials that is aligned to the three pillars of the DOE strategy and draws on five technical workshops convened by DOE between November 2010 and October 2011. Among the investments in the past year, the Advanced Research Projects Agency-Energy and the Energy Efficiency and Renewable Energy Office supported over $40 million in magnet, motor and generator substitute research.

Interagency coordination. Issues surrounding critical materials touch on the missions of many federal agencies. Accordingly, DOE is working with other departments to develop a coordinated, cross-government critical materials agenda. In the coming year, DOE's R&D plan will also inform the development of a larger interagency roadmap.

Since March 2010, the White House Office of Science and Technology Policy has convened an interagency working group on critical materials and their supply chains. The group has been examining issues including market risk, critical materials in emerging high-growth industries and opportunities for long-term benefit through innovation.

International engagement. International cooperation on critical materials can help all countries achieve their clean energy goals. In the past year, DOE organized several workshops with the European Union, Japan, Australia and Canada identifying possible R&D collaboration topics such as resource mapping, separation, processing, substitutes and recycling. DOE is also pursuing international information sharing to help improve transparency in critical materials markets. DOE will continue to engage with international partners through dialogues and collaborative institutions.

For more information:
www.energy.gov

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