**TRILATERAL EU-JAPAN-U.S. CONFERENCE ON**
**CRITICAL MATERIALS FOR A CLEAN ENERGY FUTURE**
**Washington DC, 4-5 October 2011**

**Summary Report**

## Introduction

The conference convened officials and experts from the European Union, Japan and the United States, as well as guests from Australia and Canada, to discuss how best to ensure an adequate supply of critical materials for a clean energy future and how best to cooperate toward this end. A plenary seminar focused on strategic approaches to assuring critical materials supply. Two parallel technical workshops then examined opportunities for technology cooperation.

## Seminar on the Strategic Implications of Global Shortages in Critical Materials

The seminar focused on a variety of strategic challenges that we face with respect to critical materials for rapidly expanding clean energy industries like electric vehicles for the transport sector, wind turbine generators for the electric power sector, and energy-efficient lighting. Supply limitations and higher prices for critical materials such as neodymium, dysprosium, yttrium, terbium and europium are evidence that growth in these clean energy markets needs to be ensured through a mix of approaches to curb requirements and enhance supply.

Recent studies in Europe and the United States have examined supply and demand trends for a wide range of critical materials in order to identify those for which shortages could evolve in the medium- to long-term if new supplies and technologies are not developed. In Japan, the official policy is to address these potential imbalances through an “A-B-C-D-R” program of Alternatives, Broader international cooperation, Conservation, Diversification, and Recycling. Substantial budgetary resources are being devoted to each of these interrelated approaches. In Europe, along similar lines, three basic pillars support the critical materials strategy: fair access to global resources, sustainable domestic production, and efficient use and recycling. The strategy is implemented in four priority areas: mapping, mining, recycling and substitution.

In the United States, research and development priorities for critical materials are identified through an interagency process that focuses on three main themes. The first theme is supply diversification: opening new mines and sources of production outside those countries in which it is currently concentrated. The second theme is risk mitigation throughout the supply chain, for example through development of the professional workforce needed to enhance material supplies and through promotion of more sustainable extraction and processing. The third theme is informed government decision making, with a well-functioning, transparent market.

Corporate approaches to critical materials were also discussed. Among the approaches mentioned were diversification of global supplies and production, technology innovation through efficient and environmentally superior separation and extraction processes, R&D on material substitutes, more efficient use with minimization of waste, and enhanced recycling. The need to get innovative rare earth reprocessing methods to where they are commercially viable and to minimize rare earth use in a variety of products was especially stressed.

**Workshop on Substitutes for and Efficient Use of Rare Earth Magnets**

The focus of this workshop was on ways to reduce requirements for rare earth materials in wind turbine generators and electric vehicle motors – key drivers of energy-efficient, low-carbon growth in the electric power and transportation sectors. The first part of the workshop focused on reducing neodymium and dysprosium requirements in the permanent magnets that wind turbines and EV motors rely upon – with a focus on new compositions or structures that have high energy density and low rare earth content, as well as heat management approaches that reduce dysprosium needs. The second part of the workshop focused on component and system-level substitutions for rare earths – through induction or reluctance motors that do not require permanent magnets, novel magnetic circuit design, advanced hydraulic transmission for drive trains, and high-temperature superconductors.

The first part of the workshop identified several areas of potential focus for cooperation on research and development to reduce critical material requirements in permanent magnets:

- Fundamental studies of coercivity mechanisms (which give permanent magnets their resistance to being demagnetized), including (a) computational modeling of micromagnetic phenomena and (b) better understanding of the behavior of microstructures in single phase materials and nanocomposite materials.

- Improved characterization and measurement tools to substantiate the inferences that can be made from experimental observations about microstructure properties such as anisotropy (magnetic field orientation in a uniform direction to allow practical magnets), origins of coercivity (reasons for permanent magnet strength) and reversal mechanisms (physical phenomena and mechanisms which may cause magnetic fields to be reversed).

- Collaboration between theoretical and experimental scientists to validate and improve models of magnetic behavior and to enhance understanding of magnetic mechanisms (for nanocomposites, non-rare-earth materials, and neodymium-iron-boron magnets).

- Techniques to enhance the stability and texture of nanocomposite structures which might be used to reduce needs for neodymium and dysprosium in permanent magnets.

- Evaluation of the manufacturability of candidate materials for permanent magnets.

- Technology roadmaps for the research and development of hard magnets for different applications (such as wind turbine generators and electric vehicle motors).

The second part of the workshop identified several areas of potential cooperation to help design motors and generators without permanent magnets:

- Harmonization and standardization of methods for testing motors and generators; for measuring the specifications, strength and strain of high temperature superconducting wire; and for writing software codes to model the functioning of motors and generators.

- Design and development of traction motors (which use one third as much rare earth elements as do traditional motors), with experimental focus on all aspects of motor behavior – magnetic, electrical, thermal, structural and mechanical.

- Development of new software to optimize the electromagnetic design of motors.

- Improved tools to characterize the properties (such as strength and magnetic loss mechanisms) of High-Temperature Super-Conducting (HTSC) materials.

**Workshop on Critical Material Resource Efficiency: Production, Reuse, Recovery, Recycling**

This workshop focused on ways to use critical materials more efficiently and thereby to reduce requirements for them as their application in clean energy use expands. The first part of the workshop looked at materials and processes for environmentally sound and cost-effective separation of rare earths from ore bodies and recycling streams. These materials and processes include organic solvents, supercritical solvents, membranes, biological processes and ion exchange. The second part of the workshop concentrated on recycling and reprocessing of rare earths from different sources using different techniques and also briefly discussed the design of materials and products to make them easier to recycle.

With respect to materials and processes for rare earth separation, several areas of focus were identified for potential cooperation among the three parties:

- Development of new types of solvent extractants for the extraction of rare earths from ore and recycling streams, including both chloride-based and nitrate-based extractants.

- Demonstration of electrolytic processes for rare earth separation, notably oxide-to-metal processes which are ready to be demonstrated at pilot scale.

- Research on bioseparation of rare earth elements, with attention to the conditions for recovery of elements such as indium, gallium and dysprosium from dilute streams, and research on the organisms that can be used for such bioseparation.

- Research on hydrothermal processing, such as investigated for tungsten-carbide processing to separate tungsten and cobalt, and for separating neodymium from neodymium-iron-based magnets.

With regard to recycling, the following areas for potential cooperation were noted:

- Improved understanding of how to reduce costs of collection, transportation, characterization and sorting, separation, purification, and other processing. This includes understanding the differences between recycling of manufacturing wastes and end-of-life products, in view of the fact that the former have advantages over the latter in terms of uniformity, concentration, proximity and processing requirements.

- Characterization of, standards for, and labeling of recycling streams, in view of the need to ensure certain levels of materials quality out of extremely heterogeneous streams, with sharing of best practices, development of labeling systems for specific types of materials or products (such as magnets or computer disk drives), and joint work to better characterize potentially valuable materials in major recycling streams. Particular emphasis was given to labeling of magnet compositions contained within electronic scrap. Possible partners include NIST (USA), AIST (Japan), and a European counterpart.

- Development and demonstration of processes to separate and recover rare earths from magnets, lighting, manufacturing wastes and end-of-life products, including processes for magnetic separation, pyrometallurgy, hydrometallurgy, liquid-liquid metal extraction, precipitation, redox manipulation, ion exchange methods, super critical fluid extraction, magneto-archimedes separation and hydrogen decrepitation.

- Analysis of material flows and their life-cycle impacts on energy use and environmental emissions, especially for products containing the 'critical' elements identified by recent European, Japanese, and U.S. studies. These analyses would examine material flows from mine to product to waste to recycling process to new raw material or product.

**Concluding Points**

It was agreed that a follow-up workshop should be organized in Japan in spring 2012. Results could be reported to the international workshop on Rare Earth Permanent Magnets to be held in Nagasaki in the following fall. The group also discussed developing a proposal for a Gordon Research Conference on critical materials (Gordon Research Conferences are designed to stimulate scientific collaboration; see http://www.grc.org). Further, it was suggested to develop collaboration on revised automotive propulsion standards to better accommodate competing electric drive systems with new designs having lower critical material requirements.