REPORT ON

Trans-Atlantic Workshop on Rare Earth Elements and Other Critical Materials for a Clean Energy Future

Hosted by the MIT Energy Initiative
Massachusetts Institute of Technology
400 Main Street, Building E19-307
Cambridge, Massachusetts
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1. Introduction

Background

Rare earth elements and other critical raw materials are essential to our industrial production, particularly for clean energy options like wind turbines, solar cells, electric vehicles, and energy-efficient lighting. Wind turbines are the most rapidly growing source of electricity generation in both Europe and the United States. Solar photovoltaic cells are steadily declining in cost, and their widespread, cost-effective use on power grids is anticipated within the coming decade. Electric vehicles, meanwhile, offer a means to move away from imported oil for transport towards a mix of coals, gas, wind, solar and nuclear energy with much lower net carbon dioxide emissions. Compact fluorescent and LED lighting offer an avenue to greatly reduce consumption of electricity.

Yet these vital clean energy options will use a large share of available rare earths and other less common materials. Production of some of these materials is concentrated in a very small portion of the globe, so that supplies may become tight and costs prohibitive as markets grow. To cope with this dilemma, there are a few main effective strategies. First, we can try to find new or enhanced recycling technologies to increase available supplies. Second, we can try to find substitute materials or alternate device designs that perform as well or nearly as well at comparable cost. Third, we can look for technology and process design changes to limit the required amounts of crucial materials.

Objectives

The objective of the workshop was to exchange views and information on the material security challenges of rare earths and other elements critical for clean energy generation and use.

What are the most important materials for continued expansion of clean energy markets? Which of these materials are likely to experience supply constraints over the next two decades? Which are the priorities for research, particularly for the substitution of the use of critical elements? To what extent can we alleviate tight supplies through enhanced exploration and development? How can wind turbines and electric vehicles be redesigned so they do not rely on scarce materials? What kinds of advanced materials can substitute the materials now in use? What new technology pathways should we follow to find the substitutes we need? What are the opportunities for Trans-Atlantic cooperation to accelerate our progress along those pathways, and leverage the substantial resources that are being devoted to them?

To address these issues, the workshop gathered 42 experts from the US and the EU, including top scientists, engineers, officials and utility executives, with expertise in advanced materials, materials recycling, electric vehicle drives, wind turbine design, and photovoltaic power systems. Interactions helped examining the practical potential to achieve clean energy functionality with prudent use of critical materials, through substitutes, alternate technologies and more efficient use.

2. Workshop Organisation

The workshop was hosted by the US Department of Energy (DOE) and the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts on December 3, 2010 and was organized in cooperation with the European Commission Directorate General for Research and Innovation, Unit "Materials", under the auspices of the EU-US Energy Council, its Working Group on Energy Technology, and its expert subgroup on advanced materials. This initiative also contributed to the work developed within the Innovation Action Partnership under the EU US Transatlantic Economic Council.

The workshop was limited in size, and all participants were expected to engage actively in discussion. Interested EU member states, U.S. states, laboratories, together with officials of the European Commission and DOE were invited to nominate suitable scientists and experts to participate. A series of brief presentations by researchers in the US and Europe were followed by a discussion of possible areas of collaboration proposed by the co-chairs. The agenda for the day (Annex I) and the list of participants (Annex II) are appended with this document.

The workshop has been organized in four sessions:

A) Setting the Scene - Critical Materials for a Clean Energy Future

Keynote addresses were invited from leading energy policy makers, scientists and executives to highlight findings of the EU Report on Critical Materials, the DOE Critical Material Strategy, and the MIT report on Critical Elements in Energy Technology. The Japanese keynote speaker was Kazuhiro Hono, Magnetic Materials Center Managing Director, NIMS.

B) Strategies and Research for Finding Critical Material Substitutes

This session highlighted ways to substitute critical materials that are used in clean energy devices like EV motors, LED lighting and solar cells. How can science find materials that substitute those used in clean energy devices today and perform just as well? How can R&D efforts help us design devices that perform the same function with relatively inexpensive and readily available materials?

C) Strategies and Research for Using Critical Materials More Effectively

This session highlighted strategies for reducing critical material needs over multiple device lifecycles. These include innovations to reduce waste in manufacturing, enhance recycling of critical materials, and design of molecular structure so that less critical material is required.

D) Opportunities for EU-US Cooperation on Critical Energy Materials

This session identified synergies between U.S. and EU efforts to find substitutes for critical materials and reduce the needs for such materials in clean energy technologies. These synergies might form the core of a Trans-Atlantic Strategic Vision for Critical Materials Research.

Awrap up session identified next steps and actions in pursuing a collaborative research agenda and opportunities for Trans-Atlantic research cooperation.

The workshop was co-chaired by officials from both the US Department of Energy (DOE) and the European Commission (EC). The participants agreed to appoint Nicholas Morley (Oakdene Hollins Ltd) and Thomas Lograsso (The Ames Laboratory) as the official rapporteurs of the workshop, respectively from Europe and the US.

3. Common themes

Themes emerging from the presentations from the both the US and EU included:

- Challenges in co-ordinating input to and responses from national Governments, since the issue of material security and sustainable energy crossed over the responsibilities of several Government departments
- A common need for data, including inventories of metals and minerals below and above ground, and the material flows that connect them
- Common underpinning science giving opportunities for joint research or exchange of research tools. A range of ideas are given in the next section, including separation/extraction; processing; fundamental properties; related geosciences; modelling and characterisation
- The importance of recycling, lead times to discard, collection, pre-processing and product design all highlighted significant challenges to be overcome. Awareness of the "preciousness" of these metals, similar to gold or platinum, might help build understanding of the significance of the richness of the secondary source of critical materials
- The complexity of determining raw material availability when the critical material was a by product and associated dependencies on the economics of other metals. This also extends to the possible need to develop new markets for rare earths in low demand such as cerium.
- The importance of systems design was mentioned, though relatively few examples were given. One example was an alternative motor design that did not require high strength permanent magnets. Another was light weight vehicles enabled by carbon fibre reinforced structures.

4. Ideas for research collaboration

The proposed and discussed ideas were as follows:

Cross-Cutting Topics:

Extraction – Geological Mapping:

- R&D on how to locate critical material deposits
- Sharing information across geological agencies
- Urban mining opportunities (relates to recycling)
- Harmonizing data formats in Europe, United States, globally
- Pairing resources with extractive metallurgy techniques

Processing of raw material – Separation and Refining:

- R&D on environmentally friendly separation techniques (including recycling)
- Pairing resources with separation techniques

Reducing Critical Materials Needs in Device Components
(maintaining functionality)

- Modeling and design tools to find better or alternative materials
- Substitution
- Nanotechnologies
- Reducing catalysts
- Process improvements
- Reduce material needs for specific devices (see slides below)

Recycling:

- Cost-effective mechanisms for collection, separation, recovery,
- Product design for recycling

Information exchange platform

- Research results
- Modeling tools and computer programs
- Best practices and lessons learned
- Researcher exchange

Human capital development

- Materials scientists and engineers

Strategic and Systems Analysis

- Economic analysis of material options
- Life cycle analysis
- Strategic risk management studies
- Materials flow analysis

<u>Doing More with Less for Key Clean Energy Technologies</u>

Wind and EV Motor Magnets

- Permanent magnets s with less critical material
- Devices without permanent magnets

PV cells

- Thinner film layers
- Less deposition waste

Fluorescent lighting

- LEDs with less rare earth element phosphors
- Organic LEDs

Batteries and Fuel Cells

- Better cell architectures
- Components with less critical material
- Substitution of critical material
- Better life cycle analysis of batteries and fuel cells

5. Discussion

In discussing the above topics, the following issues were raised:

With whom should the USGS collaborate? It would currently have to be with national geological surveys, although harmonisation is in progress. Can the EuroGeoSurveys be an appropriate partner representing the whole EU?

Where are the urban mining opportunities? The European project PROMINE will help identify former mines, but there may be other opportunities. How can exploration of materials flows assist?

Which deposits have the potential to be financially viable? There are very many proposed Rare Earth projects, but only a very few will be successful. There is also very few researchers/consultants doing demand/supply research. This will require the pairing of resource knowledge and that of extractive metallurgy in order to understand and qualify geological deposits the economic challenge of exploitation.

The separation of critical metals from recycled materials was commonly felt to be a promising area. Clearly the need for selective separation processes and approaches designed to target a particular element, were highlighted as a pressing need, both in

the ore extraction as well as recycling of the critical materials. Such processes obviously need to be environmentally and economically sound.

How could the human capital elements be developed? An information exchange platform was proposed, and various levels of complexity explored, from a simple list of researchers, to creation of interest groups for the comparison of data, and dissemination of information. Comments on this idea included the need for the research to remain pre-industrial, the preference by some researchers to see funding allocated to this process and difficulties in any EC involvement in a nomination process that did not involve all member states.

Development of communities of interest through exchange and partnership could include tri-lateral networks with Japan to build on the current bi-lateral work that was currently taking place. Visiting scholars at national laboratories, scientific exchanges and possibly work through the Marie Curie fellowships are existing mechanisms that in current use. The possibility of future workshops to develop more detailed ideas was raised, although it was felt important to get maximum value from the current activities.

Conclusions

The workshop was very successful in exchanging views and perspectives on the availability and supply challenges of rare earths and other elements critical for clean energy generation and use. The interesting description of current research topics was followed by a fruitful discussion.

A platform for cooperation has been established, which will facilitate cooperation in research between Europe, US and also Japan.

Annex I. Agenda of the workshop

Session A 8:30 – 10:30 am

Keynotes: Setting the Scene - Critical Materials for a Clean Energy Future

Chairs/Animateurs:

Jeff Skeer, DOE Office of Policy and International Affairs

Renzo Tomellini, EC Directorate General for Research and Innovation

Speakers (15 minutes presentations):

Diana Bauer, Office of Policy and International Affairs, U.S. Department of Energy, Highlights of the DOE Critical Materials Strategy

Antje Wittenberg, Directorate General for Enterprise and Industry, The EU Raw Materials Initiative and the Report of the Ad-hoc Group (tbc)

Tom Lograsso, Ames Laboratory (Iowa State University), Future Directions in Rare Earth Research: Critical Materials for 21st Century Industry

Derk Bol, Materials Innovation Institute M2i (Netherlands) M2i, Material Scarcity Report and Industrial Perspectives

Bob Jaffe, Massachusetts Institute of Technology, Insights from the Energy Critical Elements Policy Study by the American Physical Society and Material Research Society

Renzo Tomellini, EC Directorate General for Research and innovation, Preliminary Findings on the Role of Rare Metals as Supply Chain Bottlenecks for Priority Energy Technologies

Kazuhiro Hono, Magnetic Materials Center Managing Director, NIMS, Research Trends on Rare Earth Materials in Japan

Edward Jones, Lawrence Livermore National Laboratory, Outcomes of U.S.-Japan Roundtable on Rare Earth Elements R&D for Clean Energy Technologies (18-19 November 2010)

QUESTIONS AND ANSWERS TIME AND DISCUSSION

Coffee Break (10:30 – 11:00 am)

Session B: 11:00 am - 12:30 pm

Strategies and Research for Finding Critical Material Substitutes

Chairs/Animateur:

Linda Horton, DOE Office of Basic Energy Sciences

Speakers (10 minutes presentations):

George Hadjipanayis, Chairman, Department of Physics and Astronomy, University of Delaware, Moving Beyond Neodymium-Iron Permanent Magnets for EV Motors

Bertrand Fillon, Commissariat à l'Energie Atomique et aux Energies Alternatives, Challenges for the Future Sustainable Energy Generation, Distribution and Use

John Hsu, Oak Ridge National Laboratory, Flux Coupling Machines and Switched Reluctance Motors to Replace Permanent Magnets in Electric Vehicles

Spomenka Kobe, Jozef Stefan Institut, Rare Earth Magnets in Europe

Madhav Manjrekar and Elena Arvanitis, Siemens Corporate Research, Research Priorities for Critical Material Substitutes from a European Corporate Perspective

Anne de Guibert, SAFT, Critical Materials and Alternatives for Storage Batteries

QUESTIONS AND ANSWERS TIME AND DISCUSSION (30 minutes)

Lunch (12:30 – 1:30 pm) Hosted by the Delegation of the European Union to the United States of America

Session C: 1:30 - 3:00 pm

Strategies and Research for Using Critical Materials More Effectively

Chairs/Animateur:

Pilar Aguar, EC Directorate General for Research and Innovation

Speakers (10 minutes presentations):

Iver Anderson, Division of Materials Sciences and Engineering, The Ames Laboratory, Current and Future Direction in Processing Rare Earth Alloys for Clean Energy Applications

Michael Heine, SGL Group - The Carbon Company, Carbon Fibers in Lightweight Systems for Wind Energy and Automotive Applications: Availability and Challenges for the Future

Steve Duclos, Chief Scientist, GE Global Research, Research Priorities for More Efficient Use of Critical Materials from a U.S. Corporate Perspective

Mark Caffarey, UMICORE, "Opportunities and Limits to Recycling of Critical Materials for Clean Energies

Peter Dent, Electron Energy Corporation, Strategies for More Effective Critical Materials Use

Daniel Beat Müller, Norwegian University of Science and Technology, Material Flow Analysis

QUESTIONS AND ANSWERS TIME AND DISCUSSION (30 minutes)

Refreshment Break (3:00 – 3:30 pm)

Session D: 3:30 - 4:30 pm

Opportunities for EU-US Cooperation on Critical Energy Materials

Chairs/Animateurs:

Jeff Skeer, DOE Office of Policy and International Affairs

Renzo Tomellini, EC Directorate General for Research and Innovation

Session E: 4:30 – 5:00 pm

Wrap Up Session

Chairs/Animateurs:

Jeff Skeer, DOE Office of Policy and International Affairs and

Renzo Tomellini, EC Directorate General for Research and Innovation

Close (5:00 pm)

Annex II. List of participants

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