U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

REQUEST FOR INFORMATION
Geothermal Concepts and Approaches to Validate Mineral Recovery

DATE: May 11, 2015

SUBJECT: Request for Information (RFI) for information to bridge the gap between Research and Development (R&D) and commercial adoption of geothermal "mining" technologies with cost-shared development of pilot-scale extraction technologies at geothermal mineral recovery and power production sites.

DESCRIPTION: President Obama has announced goals to cut emissions by nearly a third over the next decade. Geothermal energy development is an important part of the United States' (U.S.) strategy for more jobs, better security and a strong economy.

For this RFI, the Department of Energy (DOE) Geothermal Technologies Office (GTO) seeks input on ideas in three (3) categories to encourage increased development of geothermal resources through recovery of dissolved critical materials. What constitutes a strategic, critical or high value material is highlighted in the box below.

Materials identified as strategic, critical or near-critical have been referenced by a number of agencies and organizations and in Congressional testimony by interested parties. For example, the U.S. reliance on imported materials continues to increase, as recently reported in the United States Geological Survey (USGS) Mineral Commodity Summaries 2015[1]. USGS reports that for 2014 the supply for more than one-half of U.S. apparent consumption of 43 mineral commodities came from imports, increasing from 40 commodities in 2013. The U. S. was 100 percent import-reliant for 19 of those commodities. The U.S. Department of Defense (DOD) 2013 report on strategic and critical materials describes the U.S. reliance on a range of materials for both defense and business operations and discusses the need for additional national resources as well as potential substitution[2]. The Critical Materials Institute is ranking various materials relative to the needs of the United States and their current sources and evaluating potential options [3,4]. A 2011 Materials Research Society study also identifies critical materials needs for renewable energy technologies[5] as does a Massachusetts Institute of Technology primer on strategic minerals[6]. These reports, as well as congressional testimony about critical and strategic materials, reinforce the need for identifying and developing additional sources for these materials. Geothermal fluids may be a key pathway for providing access to these resources.

[1] USGS Mineral Commodity Summaries 2015. http://minerals.usgs.gov/minerals/pubs/mcs/2015/mcs2015.pdf
[2] Strategic and Critical Materials 2013 Report on Stockpile Requirements, Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, RefID: 2-9B1D9E6; January 2013.
[3] Dr. Roderick G Eggert, Prospects for New Rare-Earth Mines Outside of China (Sept 2014). https://cmi.ameslab.gov/sites/default/files/2014-cmi-plenary-scenarios.pdf
[4] Dr. Tom Lograsso, (Sept 2014) https://cmi.ameslab.gov/sites/default/files/2013-kickoff-fa4-crosscutting-overview.pdf
[5] Securing materials for Emerging Technologies. http://www.aps.org/policy/reports/popa-reports/upload/elementsreport.pdf
[6] Mission 2016: Strategic Mineral Management

This is a Request for Information (RFI) only. EERE will not pay for information provided under this RFI and no project will be supported as a result of this RFI. This RFI is not accepting applications for financial assistance or financial incentives. EERE may or may not issue a Funding Opportunity Announcement (FOA) based on consideration of the input received from this RFI.

The first category is to explore the opportunities to conduct extensive engineering validation testing of feasible technologies or processes that can efficiently and cost-effectively capture, concentrate, and/or purify high-value materials referenced Item A, that may be contained in geothermal fluids and process streams. GTO seeks to broaden the assessment of available or possible approaches by exploring methodologies that may be adaptable from extractive industries such as oil and gas, mining, and other industries that may utilize chemicals, resins or other approaches to remove, purify or process a material. Food processing, waste processing and chemical preparations are all industries that may have applicable technologies transferable to geothermal mineral extraction.

The second category is to query concepts and approaches for leveraging methods in use or being considered for commercial applications in the geothermal and mining industries. Ideas are sought for combined drilling technologies, rock stimulation technologies such as those used in enhanced geothermal systems (EGS) and mineral extraction technologies as currently applied in solution mining. As explained in the box below, it is thought that essentially combining geothermal/heat mining with mineral extraction from deep-rock systems may be effective.

GTO conducts an extensive EGS research and development program. Because this technology has the potential for accessing the earth's vast resources of heat located at depth, EGS thereby expands access to potential minerals suitable for extraction[7,8]. Examining the potential of mineral recovery in conjunction with these techniques to prove the feasibility could enhance the value proposition for these projects. Solution mining to recover minerals such as salts and uranium through in situ recovery processes has been applied effectively and economically in other industries.[9]

The third category is to broaden the database of knowledge about the existence and concentration of the high-value materials in U.S. geothermal fluids or low-temperature process streams from other operations, such as oil and gas production. The information sought may be site-specific mineral content and/or an overall assessment of the U.S. mineral resource base in geothermal and other produced fluids.

BACKGROUND: The charge of DOE's Office of Energy Efficiency and Renewable Energy (EERE) is to create and sustain American leadership in the global transition to a clean energy economy. This is being achieved through high-impact research, development, and demonstration activities that will help to make clean energy as affordable and convenient as traditional forms of energy, and by breaking down barriers to market entry. Geothermal power is a demonstrated source of sustainable energy production either as baseload power or co-produced power[10,11,12].

[7] GTO Enhanced Geothermal Systems, http://energy.gov/eere/geothermal/enhanced-geothermal-systems-0
[8] Center for Climate and Energy Solutions: Enhanced Geothermal Systems. http://www.c2es.org/technology/factsheet/EGS
[9] In Situ Recovery Facilities. http://www.nrc.gov/materials/uranium-recovery/extraction-methods/isl-recovery-facilities.html
[10] U.S. Energy Information Administration, http://www.eia.gov/renewable/
[11] 2015 Annual U.S. and Global Geothermal Power Production Report, Geothermal Energy Association. http://geo-energy.org/reports.aspx.
[12] International Energy Agency, http://www.iea.org/statistics/

However, most geothermal power operations require high resource temperatures (typically >150°C). This higher temperature requirement constrains the economic viability of some lower temperature geothermal resources from development for energy production. The higher temperature requirement also limits potential geographic expansion because the identified high temperature resources in the U.S. are exclusively in the West and Southwest.

There is considerable research and approaches reduced to practice in other lines of business that may be transferable to mineral recovery at low or high temperatures. For example, solution mining is common practice for extraction of numerous minerals and precious metals[13, 14, 15]. Enhanced recovery approaches are common in the oil and gas industry. Chemical solvents, resins and operations are also common practice in many industries to treat, recover a purify products. All of these operations may have technologies and/or approaches that may be transferable to mineral recovery in a geothermal setting.

In previous work, the DOE GTO implemented R&D from the Funding Opportunity Announcement DE-FOA-0001016, *Low-Temperature Geothermal Mineral Recovery Program*. Research is now underway to develop experimental approaches for possible methods to recover high-value materials, including rare earth elements (REE), strategic, critical, and other valuable materials that may be contained in geothermal fluids and process streams . Awards are also in progress to establish publically available sampling and testing methods and provide limited data about high-value materials in U.S. geothermal waters and process streams. All these projects are described in a recent paper.[16]

PURPOSE: The purpose of this RFI is to solicit feedback from the extractive and process industries, academia, research laboratories, government agencies, and other stakeholders about the opportunities for validating new or existing technologies or processes to efficiently and cost-effectively capture, concentrate, and/or purify rare earth elements, strategic, critical, or other valuable materials contained in geothermal fluids and process streams. GTO is seeking information about potentially adaptable approaches that need engineering-level testing or pilot evaluation to validate them for a known percentage of U.S. geothermal fluids. Approaches that may be adaptable are those already in use. These could be approaches used in extractive businesses such as solution or seabed mining, or techniques used in treating industrial process streams using high temperature chemistry or solvents from low and high temperature processes. In addition, feedback and comments are sought about useful avenues to collaborate and leverage drilling and rock stimulation technologies, methodologies and information with geothermal/heat mining. Ideas of avenues for geothermal technologies to benefit from current knowledge from

[13] In-situ Uranium Mining. http://www.earthworksaction.org/issues/detail/in_situ_leach_uranium_mining#.VT_zSxrF_QI

[14] Solution Mining and Cavern Storage, Solution Mining Research Institute. http://www.solutionmining.org/?title=SolutionMiningandCavernStorage

[15] Gold Mining without a Mine; Institute of Materials, Minerals and Mining. Materials World 1 June 2010. http://www.solutionmining.org/?title=SolutionMiningandCavernStorage

[16] Stanford Geothermal Workshop; Thomas, Reinhardt 2015. http://www.geothermal-energy.org/pdf/IGAstandard/SGW/2015/Thomas.pdf?

mineral extraction from deep rock systems are sought. For these two topics, the difference would be that the additive value is in the rock and the waters, not just in the geothermal fluid. And finally, feedback is also sought about approaches to economically and quickly build the knowledge base about the existence of dissolved critical and high-value resources on a site-specific, region-wide or national assessment basis. Ideas about how to obtain information about the values contained in site-specific geothermal fluids or low-temperature process streams from other operations, such as oil and gas production for a U.S.-wide resource assessment is requested.

This is solely a request for information and not a Funding Opportunity Announcement (FOA). EERE is not accepting applications.

DISCLAIMER AND IMPORTANT NOTES: This RFI is NOT a Funding Opportunity Announcement (FOA); therefore, EERE is not accepting applications at this time. EERE may issue a FOA in the future based on or related to the content and responses to this RFI; however, EERE may also elect not to issue a FOA. There is no guarantee that a FOA will be issued as a result of this RFI. Responding to this RFI does not provide any advantage or disadvantage to potential applicants if EERE chooses to issue a FOA regarding the subject matter. Final details, including the anticipated award size, quantity, and timing of EERE funded awards, will be subject to Congressional appropriations and direction.

Any information obtained as a result of this RFI is intended to be used by the Government on a non-attribution basis for planning and strategy development; this RFI does not constitute a formal solicitation for proposals or abstracts. Your response to this notice will be treated as information only. EERE will review and consider all responses in its formulation of program strategies for the identified materials of interest that are the subject of this request. EERE will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that EERE is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind EERE to any further actions related to this topic.

PROPRIETARY INFORMATION: Because information received in response to this RFI may be used to structure future programs and FOAs and/or otherwise be made available to the public, **respondents are strongly advised to NOT include any information in their responses that might be considered business sensitive, proprietary, or otherwise confidential.** If, however, a respondent chooses to submit business sensitive, proprietary, or otherwise confidential information, it must be clearly and conspicuously marked as such in the response.

Responses containing confidential, proprietary, or privileged information must be conspicuously marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The

U.S. Federal Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

If your response contains confidential, proprietary, or privileged information, you must include a cover sheet marked as follows identifying the specific pages containing confidential, proprietary, or privileged information:

> **Notice of Restriction on Disclosure and Use of Data:**
> Pages [list applicable pages] of this response may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for the purposes described in this RFI, DE-FOA-0001327. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

In addition, (1) the header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure" and (2) every line and paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets or highlighting.

EVALUATION AND ADMINISTRATION BY FEDERAL AND NON-FEDERAL PERSONNEL: Federal employees are subject to the non-disclosure requirements of a criminal statute, the Trade Secrets Act, 18 USC 1905. The Government may seek the advice of qualified non-Federal personnel. The Government may also use non-Federal personnel to conduct routine, nondiscretionary administrative activities. The respondents, by submitting their response, consent to EERE providing their response to non-Federal parties. Non-Federal parties given access to responses must be subject to an appropriate obligation of confidentiality prior to being given the access. Submissions may be reviewed by support contractors and private consultants.

REQUEST FOR INFORMATION CATEGORIES AND QUESTIONS:
Responses may be provided to any or all of the Categories, and to any or all questions.

CATEGORY 1: Validation testing of processes and technologies to economically recover high-value materials from geothermal or low-temperature produced fluids.

1. It is possible that other industries, such food or chemical processing or preparation, waste treatment that are adaptable to extracting minerals from geothermal fluids. Do you know of technologies or processes that exist in other lines of business that may be adaptable to recovering high-value minerals from low-temperature geothermal fluids? If so please describe them.
2. What stakeholder group do you represent; e.g., Owner, Investor, Operator, etc.?
3. What barriers or problems exist, or are possible, related to each specific process or technology you list? For example, how efficiently do they work, how sensitive are they to particular characteristics, such as temperature, alkalinity or acidity?

4. What would be a reasonable expected cost to validate a technology or process for effective extraction or recovery of high-value dissolved materials and what is the basis of this estimate?
5. Would there be significant capital costs required in order to validate the process
6. Are you aware of any techno-economic analyses of the recovery of high-value dissolved minerals in other industries? Please provide any information or references.

Note: References supporting a particular position or perspective are encouraged.

CATEGORY 2: Concepts and approaches for leveraging combined drilling technologies, rock stimulation technologies and mineral extraction technologies (for example solution mining) to combine geothermal/heat mining with mineral extraction from deep rock systems.

1. What stakeholder group and business type do you represent: e.g., Owner, Investor, Operator, etc. and type of business?
2. Are you currently involved in mineral/material extraction from deep rock systems? Please describe.
3. Are there significant technical or cost barriers that would need to be addressed?
4. What would be a reasonable expected cost to validate this technology?
5. Would there be significant capital costs required in order to validate the process?

Note: References supporting a particular position or perspective are encouraged.

CATEGORY 3: Existence and concentration of high-value materials in U.S. geothermal fluids or low-temperature process streams or assessing U.S. resources as a whole.

1. What stakeholder group do you represent: e.g., Owner, Investor, Operator, etc.?
2. Are you currently evaluating fluids for contained high-value materials? Please describe.
3. What would be the most effective approach for sampling and analyzing a large number of the U.S. geothermal fluids? What is a reasonable goal to assess the resource, such as 50% of the known geothermal wells? Why?
4. Can you suggest ways to overcome the issue of proprietary information in order to make this information available to the public?
5. What do you see as the key issues that need to be addressed, and how should they be resolved?

Note: References supporting a particular position or perspective are encouraged.

REQUEST FOR INFORMATION RESPONSE GUIDELINES: Responses to this RFI must be submitted electronically to LowTValidation@hq.doe.gov, no later than 5:00 pm (ET) **Monday, June 8, 2015.** Responses must be provided as attachments to an email. Responses must be provided as a Microsoft Word (.docx) attachment to the email, of no more than three pages in length, 12 point font, one inch margins. Only electronic responses will be accepted.

Please identify your answers by responding to a specific question or topic if possible. Respondents may answer as many or as few questions as they wish.

EERE will not respond to individual submissions or publish publicly a compendium of responses. A response to this RFI will not be viewed as a binding commitment to develop or pursue the project or ideas discussed.

Respondents are requested to provide the following information at the start of their response to this RFI:

- Company / institution name
- Company / institution contact
- Contact's address, phone number, and e-mail address