U.S. DEPARTMENT OF ENERGY

Small Business Innovation Research (SBIR) and
Small Business Technology Transfer (STTR) Programs

# Topics

## FY 2013
## Phase I Release 2

Ver. 3
November 9, 2012

Participating DOE Research Programs

- Office of Electricity Delivery and Energy Reliability
- Office Energy Efficiency and Renewable Energy
- Office of Environmental Management
- Office of Fossil Energy
- Office of Nuclear Energy

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Please Note: the Following Important Date(s) pertaining to these Topics and the FY 2013 SBIR/STTR Phase I (Release 2) Funding Opportunity Announcement (FOA). All dates are preliminary and subject to change.

| Change Control Table | |
|---|---|
| Date | Change |
| October 29, 2012 | Original Release of Topics |
| November 2, 2012 | Inserted "No Fast-Track" for all Office of Fossil Energy program topics |
| November 9, 2012 | Pg. 15, inserted subtopic 3a reference<br>Pg. 20, deleted subtopic 7a, b references.<br>Pg. 20, corrected subtopic 8a program manager email address.<br>Pg. 24, revised subtopic 10b title and 1st sentence of same subtopic.<br>Pg. 24, changed subtopic 10b program manager contact name and information.<br>Pg. 25 highlighted TTO topic 12 title in blue to differentiate it from other non-TTO titles in black.<br>Pg. 26, changed topic 12 program manager email address.<br>Pg. 60, changed subtopic 20d program manager contact name and information. |

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|---|---|
| · Topics Released: | Monday, October 29, 2012 |
| · FOA Issued: | Monday, November 26, 2012 |
| · Letter of Intent Due Date: | Monday, December 17, 2012 |
| · Application Due Date: | Tuesday, February 5, 2013 |
| · Award Notification Date: | Late April 2013* |
| · Start of Grant Budget Period: | Early June 2013* |

*Preliminary Dates Subject to Change

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## TECHNOLOGY TRANSFER OPPORTUNITIES

Selected topic and subtopics contained in this document are designated as Technology Transfer Opportunities (TTOs). The questions and answers below will assist you in understanding how TTO topics and subtopics differ from our regular topics.

### What is a Technology Transfer Opportunity?

A Technology Transfer Opportunity (TTO) is an opportunity to leverage technology that has been developed at a DOE National Laboratory. Each TTO will be described in a particular subtopic and additional information may be obtained by using the link in the subtopic to the DOE National Laboratory that has developed the technology. Typically the technology was developed with DOE funding of either basic or applied research at a DOE National Laboratory and is available for transfer to the private sector. The level of technology maturity will vary and applicants are encouraged to contact the appropriate Laboratory prior to submitting an application.

### How will applying for an SBIR or STTR grant associated with a TTO benefit me?

By leveraging prior research and patents from a National Lab you will have a significant “head start” on bringing a new technology to market. To make greatest use of this advantage it will help for you to have prior knowledge of the application or market for the TTO.

### How would I draft an appropriate project description for a TTO?

For Phase I, you would write a project plan that describes the research or development that you would perform to establish the feasibility of the TTO for a commercial application. The major difference from a regular subtopic is that you will be able to leverage the prior R&D carried out by the National Lab and your project plan should reflect this.

### Am I required to have a subcontract to the National Lab in my grant application?

No. Your project plan should reflect the most fruitful path forward for developing the technology. In some cases, leveraging expertise or facilities of the National Lab via a subcontract may help to accelerate the research or development effort. In those cases, the small business may wish to negotiate with the National Lab to become a subcontractor on the application.

### Is the National Lab required to become a subcontractor if requested by the applicant?

No. Collaborations with National Labs must be negotiated between the applicant small business and the National Lab. The ability of a National Lab to act as a subcontractor may be affected by existing or anticipated commitments of the National Lab research staff and its facilities.

### Are there patents associated with the TTO?

The TTO will be associated with one or in some cases multiple patent applications or issued patents.

### If selected for award, what rights will I receive to the technology?

Those selected for award under a TTO subtopic, will be assigned rights to perform research and development of the technology during their Phase I or Phase II grants. Please note that these are

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NOT commercial rights which allow you to license, manufacture, or sell, but only rights to perform research and development.

In addition, an awardee will be provided, at the start of its Phase I grant, with a no-cost, six month option to license the technology. It will be the responsibility of the small business to demonstrate adequate progress towards commercialization and negotiate an extension to the option or convert to the option to a license. A copy of an option agreement template will be available at the National Laboratory that owns the TTO.

### How many awards will be made to a TTO subtopic?

Initially we anticipate making a maximum of one award per TTO subtopic. This will insure that an awardee is able to sign an option agreement that includes exclusive rights in its intended field of use. If we receive applications to a TTO that address different fields of use, it is possible that more than one award will be made per TTO.

### Is the review and selection process for TTO topics different from other topics?

No. Your application will undergo the same review and selection process as other applications.

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## FAST-TRACK (COMBINED PHASE I AND PHASE II)

*The following is a brief summary of Fast-Track applications. Please refer to the Funding Opportunity Announcement for more detailed information about submitting a Fast-Track application.*

Fast-Track grants are opportunities to expedite the decision and award of SBIR and STTR Phase I and II funding for scientifically meritorious applications that have a high potential for commercialization. Fast-Track incorporates a submission and review process in which both Phase I and Phase II grant applications are combined into one application and submitted and reviewed together. The Project Narrative portion of a Fast-Track application must specify clear, measurable goals and milestones that should be achieved prior to initiating Phase II work. If these milestones are not met in Phase I, authorization to proceed to Phase II may not be provided and the grant will discontinue following Phase I efforts. The work proposed for Fast-Track, assuming that it proceeds, should be suitable in nature for subsequent progress to non-SBIR/STTR funding in Phase III.

For a specific R&D effort, applicants may submit either a Phase I application or a Fast-Track application, but not both. If both Phase I and Fast-Track applications are submitted, the application with the most recent submission date and time to Grants.gov will be evaluated. A project selected for Fast-Track funding which fails to meet its objectives may not later apply for Phase II funding. All topics are open to Fast-Track grant applications, unless otherwise noted with “No Fast-Track” in the title.

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## PROGRAM AREA OVERVIEW: OFFICE OF ELECTRICITY DELIVERY AND ENERGY RELIABILITY

The U.S. electric power sector is a critical part of our society. The electricity industry is a mix of investor-owned utilities, municipal utilities, cooperatives, and federal power utilities. In addition, electricity is also generated from non-utility power producers. The nation's electric grid must be protected from unacceptable risks, multi-regional blackouts, and natural disasters. Therefore, the mission of the Office of Electricity Delivery and Energy Reliability (OE) is to lead national efforts in applied research and development to modernize the electric grid for enhanced security and reliability. A modernized grid will significantly improve the Nation's electricity reliability, efficiency, and affordability, and contribute to economic and national security.

OE supports research and development efforts to eliminate bottlenecks, foster competitive electricity markets, and expand technology choices. For example, the risk of multi-regional blackouts and natural disasters can be reduced through the application of better visualization and controls of the electric grid, energy storage and power electronics, smart grid technology, cyber security, and advanced modeling.

For additional information regarding the Office of Electricity Delivery and Energy Reliability priorities, click here.

### 1. HIGH VOLTAGE AND HIGH TEMPERATURE CAPACITORS FOR ENERGY STORAGE APPLICATIONS (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

Transportable energy storage systems are becoming readily available for grid-tied applications and are attractive due to less installation time to operation and lower installation cost. They are also similar in design, enabling use at multiple sites, thus optimizing overall system use and efficiency. For the ease of transportability and siting, these systems are typically installed in standard shipping containers which include the energy storage device and/or power conversion system. This containerized approach provides unique challenges for the power conversion system as well as the energy storage system. To achieve an effective power electronics system, optimized form factor, high power density design, and improved component performance is required to increase system efficiency and reliability, reduce thermal management, and reduce overall cost.

Grant applications are sought in the following subtopics:

#### a. High Temperature Capacitors

To address the challenges mentioned above, there has been increased interest in utilizing advanced semiconductor devices, such as SiC and GaN, and advanced packaging to increase the junction temperature of semiconductor devices and reduce overall thermal management requirements. Although the focus on semiconductors is important, there is a need to address DC-link capacitor performance and reliability as well. Electrolytic and polymer capacitor failure at high operating temperature and voltage is a leading cause of overall system failure, and is particularly

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important since emerging SiC and GaN technologies allow 200-300°C operation temperature. Advances in dielectric materials for high temperature (>120°C) and high field (>800V) DC-link capacitors are sought for power conversion systems used in energy storage applications. The DC-link capacitor design should show significant increases in performance and reliability compared to existing solutions.

Questions – contact: Imre Gyuk, imre.gyuk@hq.doe.gov

## b. High Voltage Capacitors

Power conversion systems designs favor higher DC-link voltage and lower current requirements, for the same power, to increase efficiency and reduce cable sizes, ultimately reducing the overall system cost. High voltage DC-link capacitors would be an enabling technology for transportable energy storage systems. Desirable properties of such capacitors may include: (a) 1-5 kV operation voltages, (b) engineered "soft" or "self-clearing" breakdown, (c) low equivalent series resistance (ESR) designs, (d) higher operation frequency (>10 kHz) and (e) high energy density (> 1 J/cc). Proposals are solicited that address these technical needs for improved performance high voltage capacitors.

Questions – contact: Imre Gyuk, imre.gyuk@hq.doe.gov

## c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – contact: Imre Gyuk, imre.gyuk@hq.doe.gov

## References

### Subtopic a:

1. Rojo, R. and Olalla, D., "DC-Link Capacitors for Industrial Applications," CARTS Europe, Finland. Oct. 20-23, 2008. (http://ecadigitallibrary.com/conference.php?cid=23)

2. Wen, H., et al., "Analysis and Evaluation of DC-Link Capacitors for High-Power-Density Electric Vehicle Drive Systems," IEEE *Transactions on Vehicular Technology*, Vol. 61, No. 7. Sept. 2012. (http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=06226484)

3. Dominik, B., et al., "A 120C Ambient Temperature Forced Air-Cooled Normally-off SiC JFET Automotive Inverter System," 26th Annual APEC, Ft. Worth, TX. March 6-10, 2011. (http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=5740654)

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4. Ogihara,H. et al. "High-Energy Density Capacitors Utilizing 0.7 BaTiO3–0.3 BiScO3 Ceramics," *Journal of the American Ceramic Society*, Vol. 92, Iss. 8, pp. 1719–1724. 2009. (http://onlinelibrary.wiley.com/doi/10.1111/j.1551-2916.2009.03104.x/abstract)

Subtopic b:

1. Boggs S. A., Ho J., and Jow, T.R., "Overview of Laminar Dielectric Capacitors," *IEEE Electrical Insulation Magazine*, Vol. 26, Iss. 2, pp. 7-13. March-April 2010. (http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=5482550)

2. Pan, J., et al., "High-Temperature Poly(phthalazinone Ether Ketone) Thin Films for Dielectric Energy Storage," *ACS Applied Materials & Interfaces*, Vol. 2, Iss. 5, pp. 1286-1289. 2010. (http://pubs.acs.org/doi/abs/10.1021/am100146u)

3. Klein, R.J., et al., "Covalently Modified Organic Nanoplatelets and Their Use in Polymer Film Capacitors with High Dielectric Breakdown and Wide Temperature Operation," *IEEE Transactions on Dielectrics and Electrical Insulation,* Vol. 19, Iss. 4, pp. 1234-1238. 2012. (http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6259996)

4. Zhu, L., and Wang, Q., "Novel Ferroelectric Polymers for High Energy Density and Low Loss Dielectrics," *Macromolecules*, Vol. 45, Iss. 7, pp. 2937-2954. 2012. (http://pubs.acs.org/doi/abs/10.1021/ma2024057)

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## PROGRAM AREA OVERVIEW: OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

The mission of the Office of Energy Efficiency and Renewable Energy (EERE) is to strengthen America's energy security, environmental quality, and economic vitality in public-private partnerships in order to enhance energy efficiency and productivity; bring clean, reliable and affordable energy technologies to the marketplace; and make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life. The Office pursues this mission by developing energy efficient technologies for buildings, homes, transportation, power systems, and industry.

EERE leads the Federal government's research, development, and deployment efforts in energy efficiency and renewable energy. EERE's role is to invest in high-risk, high-value research and development that is critical to the Nation's energy future and would not be sufficiently conducted by the private sector acting on its own.

The National Academy of Sciences has estimated that the energy technologies and practices supported by the EERE programs have saved Americans more than $30 billion dollars in energy costs over the past two decades. These savings are projected to dramatically increase as emerging and new energy technologies are developed and commercialized. These energy savings are accompanied by parallel reductions in emissions of pollutants that affect human health and in the production of greenhouse gases. The EERE programs in renewable energy have advanced the state of technologies in such areas as solar, wind, and biomass to the point where renewables have been projected to supply as much as 28 percent of the Nation's energy by 2030.

Program activities are conducted in partnership with the private sector, state and local government, DOE national laboratories, and universities. EERE also works with stakeholders to develop programs and policies to facilitate the deployment of advanced clean energy technologies and practices.

For additional information regarding the EERE priorities, click here.

## 2. ADVANCED MANUFACTURING (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

The Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office (AMO) (www1.eere.energy.gov/manufacturing/) seeks transformational manufacturing process technologies and in-situ metrology and process controls that will reduce energy consumption and cost in manufacturing by 50%. These include process, monitoring, and other innovative manufacturing technologies that provide pathways to significant energy and cost reductions.

Grant applications are sought in the following subtopics:

### a. Manufacturing Process

Multi-material joining techniques (especially joining different and novel materials) are becoming increasingly important in industrial processes in a wide variety of industries. Joined structure materials challenges include i) thermal expansion mismatch, (ii) reduced temperature and load ranges, and (iii) increased directionality. Successful joining also requires increased attention to surface preparation. This subtopic focuses on manufacturing technology innovations that can address these three challenges.

Questions – contact: Bhima Sastri, bhima.sastri@ee.doe.gov

b. In-Situ Metrology and Process Controls

In-situ metrology and process controls are critically important to advanced manufacturing. The ability to characterize materials and monitor processes in real time allows for tighter process control which can contribute to reducing cost, halving energy use, and improving the quality of final products. Projects are sought that could contribute to > 50% energy savings in the manufacturing sector if deployed at a substantial number of the nearly 200,000 manufacturing plants in the U.S., [1] Of particular interest are projects that develop integrated metrology solutions for in-situ, real-time, non-contact, and non-destructive measurement, incorporate numerical techniques (e.g. statistical analysis) and demonstrate value to industry with improved product performance, yield, reduce failure rate, etc. with a cost-competitive solution for different applications.[2],[3].

Questions – contact: Bhima Sastri, bhima.sastri@ee.doe.gov

References

Subtopic b:

1. "Manufacturing Energy Consumption Survey." EIA. 2006. (http://www.eia.gov/emeu/mecs/).

2. Hayashi, K. "Review of the applications of x-ray refraction and the x-ray waveguide phenomenon to estimation of film structures," *Journal of Physics-Condensed Matter,* Vol. 22, Issue 47. 2010. (http://iopscience.iop.org/0953-8984/22/47/474006).

3. Quiroga, S. D., A. Shehu, et al. "A high-vacuum deposition system for in situ and real-time electrical characterization of organic thin-film transistors." *Review of Scientific Instruments,* Vol. 82, Issue 2. 2011 (http://www.ncbi.nlm.nih.gov/pubmed/21361636)

3. BIOMASS (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

The Office of Energy Efficiency and Renewable Energy, Office of the Biomass Program (OBP) (www.eere.energy.gov/biomass/) supports research, development, deployment, and demonstration activities to support diverse, cost-effective bioenergy technologies.

Grant applications are sought in the following subtopics:

a. Measuring and Improving Biomass Quality throughout the Feedstock Supply Chain

Producing biofuels, biopower, and other bioproducts at commercial scale depends on supply systems that ensure high-volume and reliable delivery of on-spec biomass feedstocks. The United States has abundant and sustainable biomass resources, but biomass in its raw form is not necessarily an optimal feedstock for biomass processors. Raw feedstock sub optimality includes (i) low bulk density and (ii) low energy density, (iii) lack of compatibility with the existing grain and other crop transportation infrastructure, (iv) poor handling characteristics, and (v) potential instability during long periods of storage. Transforming raw biomass into a high-quality, on-spec, uniform, commodity feedstock that enables cost-effective feedstock supply systems will require innovations in harvest, storage, preprocessing, and transportation steps.

Understanding the impact of each of these steps on the physical and chemical characteristics of the biomass, as well as the ultimate impact of the downstream conversion process is essential in order to adequately determine cost/benefit ratios. Grant applications are sought for the development of innovative methods or tools to harvest, store, preprocess, or transport biomass feedstock and to measure feedstock specifications throughout the supply chain. The feedstock specifications to be measured must be directly linked to a specific downstream conversion process to adequately assess the impact of each step, for example, a measuring ash content that impacts gasification or measuring sugar content that impacts fermentation. Methods and tools directed towards high-moisture biomass supply chains (i.e. sorghum, energy cane, wood chips, other feedstocks with >30% moisture) are encouraged.

By the end of Phase I, projects should benchmark the performance of existing technology and demonstrate that the proposed technology can effectively improve and/or measure relevant biomass specifications throughout the supply chain. During Phase II, applicants should conduct field studies that demonstrate the performance of the new technology and quantify any change in the physical and chemical characteristics of the feedstock.

Questions – contact: Travis Tempel, travis.tempel@ee.doe.gov

b. Design and Fabrication of Solids Handling for Biomass Conversion Systems

Solids handling is one of the main challenges to continuous operation of biomass conversion systems. Robust systems are needed to continuously introduce feedstock from ambient conditions into a controlled reactor environment and to remove and upgrade solids such as ash, char, and lignin. To date the bioenergy industry has drawn on the experience of other industries, such as mining or pulp and paper, for similar equipment. But the unique properties of biomass solids handling prevents such equipment repurposing in many cases. Grant applications are sought for designs and prototype equipment that will enable continuous biomass solids handling into a controlled reactor environment. Consideration will be given to ideas that would allow for multiple feedstocks, easy manufacturability including use of non-specialized materials of construction, or other features that would appeal to multiple conversion technology providers. Applications are also sought for innovative methods to remove and/or upgrade the solids from biomass conversion reactors, such as ash, char, or lignin.

Questions – contact: Prasad Gupte, prasad.gupte@ee.doe.gov

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Reference

Subtopic a:

1. Herbaceous or woody biomass benchmarks in design report from Idaho National Laboratory: https://inlportal.inl.gov/portal/server.pt?open=512&objID=421&PageID=5806&cached=true&mode=2&userID=1829.

4. BUILDINGS: ELECTRIC LIGHTING (PHASE I, $225,000/PHASE II, $1,500,000) NO FAST TRACK

Buildings use more energy than any other sector of the U.S. economy, consuming more than 70% of electricity and 50% of natural gas. Electric lighting consumes ~1/10 of the primary energy delivered annually in the U.S. representing ~22% of the electricity produced. The DOE estimates that over 50% of this energy could be conserved by aggressive adoption of solid-state lighting (SSL) technologies. As a result, the DOE founded a program to research SSL technologies (www1.eere.energy.gov/buildings/ssl/), but to realize this level of energy conservation, widespread commercialization of this technology must occur. While current efforts focus on key technology hurdles, the purpose of this effort is to encourage and accelerate SSL adoption in buildings and other lit spaces, such as parking lots or roadways, by identifying innovations whose commercial successes are likely to have a profound impact on the evolution of SSL. The Office of Energy Efficiency and Renewable Energy's Building Technologies Program (BTP) web page is at www1.eere.energy.gov/buildings/.

Grant applications are sought in the following subtopic:

a. Energy Conservation Applications for Solid-State Lighting (OLEDs)

Since the initial introduction of white phosphorescent designs almost 20 years ago, Organic Light Emitting Diodes (OLEDs) have made remarkable progress. As with many other electronic organic materials systems that are popular today, a number of more basic, fundamental technical hurdles remain but for this subtopic only applications of emerging OLED technology specifically applied to energy conservation, efficient and practical OLED luminaries, panels, or constituents are sought. For example, commercial OLED panels purchased from a handful of manufacturers worldwide might be used to create a family of imaginative lighting products that compete in efficiency and value with LEDs or incandescents. Incorporation of existing and proven materials and components into practical and cost-effective products whose performance and value can be quantitatively compared to other competing solutions also are sought and encouraged. Since OLED technology currently has only a small fraction of the overall LED market, key enabling, and even disruptive applications are relevant to this topic. Please note, proposals that seek to advance more fundamental understanding of essential OLED science and technology are not sought under this topic. Failure to clearly define the specific innovation and provide quantitative, realistic performance projections will result in proposals being rejected during the initial review process. All successful applications must:

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1. Be consistent with and have performance metrics linked to the DOE SSL Multi-Year Program Plan (MYPP) available for download directly at: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_mypp2012_web.pdf;
2. Clearly define the proposed application and innovation;
3. Include quantitative projections for price and/or performance improvement that are tied to representative values included in the MYPP or in comparison to existing products. Projections of price or cost advantage due to manufacturing improvements, materials use or design simplification for example should provide references to current practices and pricing to enable informed comparison to present technologies. All performance claims must be fully justified with either thoughtful and justified theoretical predictions or relevant experimental data.

Questions – contact: James R. Brodrick, james.brodrick@ee.doe.gov

## 5. GEOTHERMAL (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

The heat energy from the earth represents an enormous and underutilized domestic resource. The Office of Energy Efficiency and Renewable Energy Geothermal Technologies Office (GTO) (www1.eere.energy.gov/geothermal/) works in partnership with industry (including small businesses), academia, and DOE's national laboratories to establish geothermal energy as an economically competitive contributor to the U.S. energy supply. Technologies for electricity generation or energy utilization from marine geothermal resources will not be considered under this topic. Information on GTO priorities and future directions can be found in the FY2013 Budget overview at www.eere.energy.gov/geothermal/pdfs/gtp_fy13_budget_request_overview.pdf. Information on GTO's focus areas in technologies that reduce the risk and cost of finding new geothermal resources are at www.eere.energy.gov/geothermal/pdfs/iet_needs_assessment_06-2011.pdf and in demonstrating the technical feasibility and cost competitiveness of EGS at www.eere.energy.gov/geothermal/pdfs/evaluation_egs_tech_2008.pdf, and www.eere.energy.gov/geothermal/pdfs/egs_well_contruction.pdf.

Grant applications are sought in the following subtopic:

### a. Non-Prime Mover Technologies that Reduce Energy Costs

The GTO seeks non-prime mover technologies that have the potential to contribute to reducing the levelized cost of electricity from new hydrothermal development to 6¢/ kWh by 2020 and Enhanced Geothermal Systems (EGS) to 6¢/ kWh by 2030. Applications should include a clear and detailed pathway to such cost reduction using the proposed technology. Applicants should consider using the Geothermal Electricity Technology Evaluation Model (GETEM) developed by GTO to model power generation costs and the potential for technology improvements to affect these costs. Areas of interest to the GTO include identifying, accessing, creating, and sustaining hydrothermal and EGS reservoirs.

Information on GETEM may be found at www.eere.energy.gov/geothermal/getem.html and information on its use is at www.eere.energy.gov/geothermal/news_detail.html?news_id=17496. In its small business topic, the GTO is NOT seeking and will not consider "prime mover" technologies

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(i.e., technologies for electricity generation from geothermal heat and fluid resources). Excluded technologies include both conventional Rankine/binary power conversion units and other prime mover technologies for transforming the energy contained in the geothermal resource into electricity.

Questions – contact: Joshua Mengers, joshua.mengers@ee.doe.gov

## 6. HYDROGEN DISPENSER TECHNOLOGIES (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

The widespread use of hydrogen for transportation will require cost effective and energy efficient hydrogen dispensing technologies. The goal of the DOE-EERE Fuel Cell Technologies program's Hydrogen Delivery sub-program is to reduce the costs associated with delivering hydrogen to <$2 per gallon of gas equivalent (gge) in order to achieve an as-produced, delivered, and dispensed threshold cost of $2-$4/gge H2 by 2020 which, based on current analysis, would make hydrogen fuel cell vehicles competitive on a cents per mile basis with competing vehicle technologies. In order to be competitive with gasoline dispensers, the cost, safety, and maintenance of hydrogen dispensers should be equivalent to or better than current commercial gasoline dispensers which see approximately 70 fills per day or 25,550 fills per year. Providing the same safety and reliability for 700 bar Hydrogen (H70) service is challenging. The fill pressure exceeds that of compressed natural gas which is typically 250 bar and is not subject to all of the same material concerns. To fill systems at 700 bar the storage and dispenser system must be rated above this pressure at 860 bar (typically 25% overpressure). With each fill, wetted components of the dispenser system are exposed not only to an 860 bar pressure cycle, but also to a thermal cycle due to the Joule-Thompson effect. In addition the low temperature extreme can be lower than the $-40^{o}$C, typical for compressed natural gas systems and specified in ANSI/CSA HGV 4.2-2012, when cryo-compressed hydrogen is used or cooling algorithms exceed specifications.

Grant applications are sought in the following subtopics:

### a. Dispenser Hose Assemblies

The difficulty of meeting the service requirement of 25,550 fills per year is further increased by the need for flexibility in the dispenser hose throughout the full temperature range. Permeation of hydrogen through the flexible materials can be exacerbated by the thermal fluctuations and must also be overcome. In addition to these concerns hydrogen embrittlement of the materials may also occur, further accelerating the wear on components in the dispenser.

These complex material interactions require advanced materials and multi-layer designs which are also cost effective for the design of a safe and reliable hose assembly. This subtopic seeks proposals to develop hose assemblies which can ensure reliability and safety in H70 service while helping to lower the cost of the overall dispenser system from the current status of $50,000 to the 2015 target $40,000 for an 860 bar dispenser. This target assumes there are two hoses on each dispenser, one on each side of the dispenser, similar to gasoline dispensers. Grant applications are sought to develop the design and cost estimate of hose assemblies for use in H70 service which have a maximum working pressure of at least 860 bar, meet or exceed the requirements of

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ANSI/CSA HGV 4.2-2012 for class D hoses, and improve upon the reliability and safety of hose assemblies in use. Additionally the hose should be designed such that, if integrated into a dispenser system, the dispenser could be made compliant with SAE TIR J2601 and NIST Handbook 44 where relevant. Phase I would include the detailed design and preliminary cost analysis of a hose assembly for use in H70 service with a maximum working pressure of at least 860 bar. An estimate of the design life of the assembly and a full analysis of how the design will meet or exceed the requirements described in ANSI/CSA HGV 4.2-2012 is required. Phase II would entail the construction and demonstration of the proof-of-concept hose assembly designed in Phase I.

Questions - contact: Erika Sutherland, erika.sutherland@ee.doe.gov

b. Other

In addition to the specific subtopic listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions - contact: Erika Sutherland, erika.sutherland@ee.doe.gov

References

Subtopic a:

4. Record 1107, Hydrogen Threshold Cost Calculation. 2011. (www.hydrogen.energy.gov/pdfs/11007_h2_threshold_costs.pdf)

5. Delivery Chapter of the Hydrogen & Fuel Cell Technologies MYRD&D plan. 2012; under final review.

6. SAE-2719- Hydrogen Fuel Quality Guideline for Fuel Cell Vehicles. June 2011.

## 7. SOLAR (PHASE I, $225,000/PHASE II, $1,500,000) NO FAST-TRACK

The DOE SunShot Initiative (www.energy.gov/SunShot) aims to achieve subsidy-free, cost competitive solar power by the end of the decade. SunShot seeks proposals for the development of innovative technologies in the broad areas of: (a) PV Module Degradation, (b) Module and System Manufacturing Metrology, Diagnostics, and Process Control, (c) Balance of System (non-hardware) (d) Concentrated Solar Power.

Grant applications are sought in the following subtopics:

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## a. PV Module Degradation

Applications to commercialize technologies that solve module degradation and failure issues, such as water ingress and temperature stress are sought. Degradation leading to failure in photovoltaic modules depends on multiple factors including the degradation of packaging materials, adhesion losses, degradation due to moisture intrusion, degradation of cell/module interconnects, and semiconductor device degradation. Successful applicants should offer solutions to model or eliminate all or some causes of module degradation through physics based degradation software for lifetime predictions, novel cost-effective photovoltaics module components, new module architectures, or innovative low cost and small floor print manufacturing methods, processes, and tests of modules and module subcomponents.

Questions - contact: Victor Kane (solar.sbir@ee.doe.gov)

## b. Module and System Manufacturing Metrology, Diagnostics, and Process Control

The rapid scale-up of PV manufacturing is challenging the ability of conventional techniques and tools to make real-time non-destructive measurements of modules or cells in a high-production-rate environment, and to implement real-time control over manufacturing processes. Applications for innovative, high performance, intelligent process control, and real-time nondestructive material characterization devices for use in metrology, diagnostics, and process quality control on the manufacturing lines for PV modules and systems are sought.

Questions – contact Victor Kane, (solar.sbir@ee.doe.gov)

## c. Balance of System (non-hardware)

Applications that develop of an online, graphical user interface-friendly calculator of the wind-loads on PV ground-mount and roof-mount systems are sought. The developed calculator must be able to perform preliminary assessments of the uplift and downforce loads on a PV mounting system, and provide viable solutions from available mounting systems, with the final goal of reducing the cost of the mounting system and installation. The calculator must be based on the existing code-writing bodies that apply directly to PV systems, like the American Society of Civil Engineers (ASCE) - 7 standards, and Solar America Board for Codes and Standards (Solar ABCs). The user must be able to enter the location, topography, desired roof dimensions and pitch, PV panel dimensions, total number of PV panels, local weather patterns, etc. The software output should yield an assessment of the wind loads on the given design, best configuration of PV system on the roof, and the wind loads that the PV mounting system and that configuration needs to overcome. Additionally, solutions for fastening methods should be provided (ballast requirements, or structural fasteners).

Questions – contact: Mike Cliggett, (solar.sbir@ee.doe.gov)

## d. Concentrating Solar Power (CSP)

The DOE SunShot CSP program (http://www1.eere.energy.gov/solar/sunshot/csp.html) seeks proposals for distributed CSP with storage. (DOE defines CSP as solar technology that converts

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sunlight to heat before converting it to electricity; CPV systems, which concentrate light onto a Photovoltaic cell, are not included in this topic). In order to qualify as distributed, the CSP system should fall within the size range of 1kW to 1MW. The storage technology the system is coupled to should be capable of at least 6 hours of electricity generation when running at full capacity. Any technology proposed should be capable of achieving the SunShot target of 6cents/kWh by 2020. All systems proposed must generate electricity as the main function of the system. The system may additionally provide combined heat and power (CHP), solar hot water, or any other useful product; however, ≥ 50% of the incident sunlight on the system should be used for electricity generation in order to be considered responsive to the topic.

Questions – contact: Joseph Stekli, (solar.sbir@ee.doe.gov)

## 8. VEHICLES (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

EERE's Vehicles Technologies Program (VTP) (www1.eere.energy.gov/vehiclesandfuels/) is focused on developing technologies to enable average new vehicle fuel economy of more than 60 miles per gallon for cars and more than 43 miles per gallon for trucks by 2025. Proposals that duplicate research already in progress or are similar to proposals already reviewed by DOE this year will not be funded; all submissions therefore should clearly explain how the proposed work differs from other work in the field.

Grant applications are sought in the following subtopics:

### a. Electric Drive Vehicle Batteries

Applications are sought for electrochemical energy storage technologies that support commercialization of micro, mild, and full HEVs, PHEVs, and EVs. Specific improvements of interest include: new low-cost materials, high voltage and high temperature non-carbonate electrolytes, improvements in manufacturing processes, speed or yield, improved cell/pack design minimizing inactive material, significant improvement in specific energy (Wh/kg) or energy density (Wh/L), and improved safety. Proposals must clearly demonstrate how they advance the current state of the art and address the performance metrics at www.uscar.org/guest/article_view.php?articles_id=85.

When appropriate, evaluation of the technology should be performed in accordance with applicable test procedures or recommended practices as published by the Department of Energy (DOE) and the U.S Advanced Battery Consortium (USABC). These test procedures can be found at, www.uscar.org/guest/article_view.php?articles_id=86. Phase 1 feasibility studies must be evaluated in full cells (not half cells) greater than 200mAh in size while Phase II technologies should be demonstrated in full cells greater than 2Ah. Proposals will be deemed non-responsive if the proposed technology is cost prohibitive to market penetration; requires substantial infrastructure investments or industry standardization to be commercially viable; or cannot accept high power recharge pulses from regenerative breaking.

Questions – contact: Brian Cunningham, brian.cunningham@ee.doe.gov

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## b. Combustion

Lean-burn combustion in gasoline engines introduces physical conditions that severely impede reliable ignition of fuel-air mixtures. Advanced ignition concepts are sought that (i) extend the lean ignition limit to air/fuel ratio > 20, (ii) enable reliable ignition under high in-cylinder pressures (up to 100 bar at the time of ignition) thus enabling high load operation, (iii) enable operation under high levels of exhaust gas recirculation, and (iv) lower or maintain ignitability (coefficient of variance of IMEP < 3%). Advanced ignition systems such as, laser ignition, microwave ignition, plasma jet ignition, or those using advanced concepts such as pulse trains, pre-chamber spark plugs, etc. are considered candidates.

Questions – contact: Gurpreet Singh, gurpreet.singh@ee.doe.gov

## c. Dual-Fuel Vehicle Technologies

Dual-fuel light-duty vehicle concepts are typically limited to operation on one fuel at a time with the engine optimized for one specific fuel. Dual-fuel concepts are sought for light-duty passenger car applications that (i) increase engine efficiency by exploiting the fuel properties, (ii) displace/reduce petroleum usage, (iii) enable use of existing emissions controls, (iv) meet all emissions and on-board diagnostic requirements, and (v) where the engine can switch between operation on 100% gasoline, 100% other fuel, or a combination of both without having to refuel. The technology must be able to be retrofitted into existing on-road vehicles or incorporated into current production models and demonstrate at least a 50% petroleum reduction. Fuel savings must occur over a typical drive cycle and the technology must be capable of being retrofit into multiple models of 2005 model year or newer vehicles. The cost of retrofitting or additional production costs must be recovered by fuel savings within 15,000 miles.

Questions – contact: Steven Przesmitzki, steven.przesmitzki@ee.doe.gov

## d. Electric Drive Vehicle Power Electronics Subcomponent Improvements

Power electronic inverters and converters are essential for electric drive vehicle operation, and currently add significant cost to these vehicles, therefore limiting their commercialization potential. Improvements in their performance can lead to cost reduction or better utilization of their capabilities in vehicles, as outlined in the U.S. DRIVE partnership Electrical and Electronics Technical Team Roadmap at www.eere.energy.gov/vehiclesandfuels/pdfs/program/eett_roadmap_12-7-10.pdf.

Applicants are sought to develop subcomponent-level improvements to power electronic inverters or converters which would support commercialization of micro, mild, and full HEVs, PHEVs, and EVs. Specific improvements sought for this topic are:

1. Small, lightweight low loss magnetic materials for passive inductors

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2. High temperature (250°C capable) thermal interface materials with low electrical resistivity
3. High temperature (250°C capable) on-chip high voltage gate drivers

The Phase I effort should involve the development and validation of the proposed technology or material with demonstrated performance under simulated operating conditions. In Phase II, the technology should be further advanced and demonstrated through the production of prototype devices.

Questions – contact: Steven Boyd, steven.boyd@ee.doe.gov

## 9. WATER (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

EERE is seeking the development of innovative technologies in targeted broad areas identified by its the Water Power Technology Program (www.eere.energy.gov/topics/water.html) seeks proposals that contribute to large cost reductions in the deployment of U.S. water (hydro- and marine power resources including (a) Marine and Hydrokinetic Energy and (b) Hydropower Applications.

Grant applications are sought in the following subtopics:

### a. Marine and Hydrokinetic Energy

DOE is investing in marine and hydrokinetic (MHK) technologies to harness energy from waves, tides, currents, and ocean thermal gradients. Grant applications are sought to develop approaches that can advance wave and current energy technologies. Areas of interest include wave energy converters and energy conversion technologies for tidal, river, and ocean currents. DOE will fund analytical studies of innovative concepts (TRL 1-3) or projects that propose a sound but novel approach to a potentially important water power technology, science, or engineering breakthrough that can be applied to, or add to the portfolio of, innovative water power technologies. This can be a solution or an improvement to an existing component or system, or the pursuit of a new technology or system, with the principal focus on systems capable of producing utility-scale electricity. These concepts must demonstrate the potential for a 20% improvement in performance or cost relative to existing devices or technologies of similar function.

Questions – contact: Tim Ramsey, tim.ramsey@go.doe.gov

### b. Hydropower Applications

Proposals that can dramatically reduce costs (e.g. substantially contribute to reducing the levelized cost of energy (LCOE)) and improve performance are sought. Specifically, proposals are sought in the following four areas of interest:

i. ADVANCED COATINGS: Advanced coatings are needed for flow passages of hydraulic turbines. Such coatings may improve the overall efficiency of turbines through reduction of friction, and may also improve the environmental performance of turbines by reducing injury to fish that come into contact with coated surfaces. Advances may also be made in

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lowering application cost, improving durability, and reducing maintenance costs for coated surfaces.

ii. WATER QUALITY SENSORS: Advanced sensor designs for monitoring dissolved oxygen and total dissolved gas in the forebays and tailraces of hydropower facilities are needed. Improvements are sought in the accuracy, durability, and maintainability of sensors to lower costs of monitoring compliance with water quality requirements for project operations and scheduling.

iii. LOW-COST FLOW AND VELOCITY SENSORS: Advances are sought that would dramatically reduce the cost of accurate water velocity and flow sensors for rapid, low-cost deployment in absolute flow measurement systems and testing of hydraulic turbines. Individual velocity sensor accuracy and cost must be improved to achieve flow measurement accuracy in conduits. Innovations may include miniature of acoustic or electro-magnetic sensors or their functional equivalents, along with integrated telemetry for systems integration of multiple sensors.

iv. SMALL HYDROPOWER TURBINE-GENERATOR TECHNOLOGY: Turbine designs and components with potential to dramatically reduce the cost of deployment in sites with less than 30 feet of head are sought. Such technologies may include innovative designs with modular components with low-cost manufacturing including turbines without wicket gates using suitable alternate controls. Engineering prototypes of a power converter modular controller using with integrated gate-commutated thyristor (IGCT) semiconductors for Small hydropower generation at the 5MW level that is scalable up to100MW in 5MW increments using the same control topology also will be considered

Questions – contact: Rajesh Dham, rajesh.dham@ee.doe.gov

## 10. WIND (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

The Office of Energy Efficiency and Renewable Energy Wind Technology Program (www.eere.energy.gov/wind/) seeks proposals for innovations that significantly advance the goal of large cost reductions in the deployment of U.S. wind power resources, including (a) Development of a Met-Ocean Package for Offshore Wind and (b) Wide Band-gap Semiconductors for Wind Turbine Power Conversion.

Grant applications are sought in the following subtopics:

### a. Development of a Met-Ocean Package for Offshore Wind

Proposals that substantially contribute to development of a Standardized Met-Ocean Monitoring Package that would serve as one of the core elements of a standardized backbone data collection network for the offshore renewable energy industry are urgently sought. In particular projects that develop one or more standardized, commercially viable monitoring equipment package configurations to address met-ocean data needs, with emphasis on offshore wind, along with support likely needed for full validation are of interest. Key requirements are that measurements must support improved assessment of wind speed and direction, atmospheric stability, ocean waves, swells and currents, data sampling and communication rates consistent with advanced

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rapid refresh weather modeling data assimilation needs. These monitoring packages must also be able to serve as companion measurement platforms to specialized floating LIDAR systems for now in early stages of application. Applicants are required to justify the economic viability of the proposed package assuming near term (< 5 years) industry deployment for project resource characterization. Examples of current standard met-ocean packages include the NOAA Automated Surface Observing System (ASOS) and the NDBC Coastal-Marine Automated Network stations (www.nws.noaa.gov/asos/); NOAA National Data Buoy Center (NDBC) buoys (www.ndbc.noaa.gov/); and the University of Maine NERACOOS buoy package (gyre.umeoce.maine.edu/buoyhome.php).

Questions – contact: Joel Cline, joel.cline@ee.doe.gov

### b. Wide Band-gap Semiconductor-Based Power Electronics for Wind Turbine Power Conversion

Development of semiconductor components that contribute to a system that translates output from various generator technologies at medium voltages (600 – 2kV) into distribution-level voltages (10-15kV), could significantly reduce wind turbine balance of station costs, and thus reduce wind's levelized cost of energy. Direct generation at up to 13.6 kV would provide several benefits such as enabling the use of less copper and more flexible integration at medium voltage (MV) distribution voltages in wind farms as well as eliminating the need for a pad-mounted transformer at ground level. Projects are sought to develop higher voltage rated SiC or GaN (Wide Band-gap Semiconductors) for up-tower wind applications.

Questions – contact: Charlton Clark, Charlton.clark@ee.doe.gov

## 11. BUILDINGS – SOLAR JOINT TOPIC (PHASE I, $225,000/PHASE II, $1,500,000) NO FAST-TRACK

The Solar and Buildings Technologies Programs are cosponsoring a topic at the nexus of the two programs--(a) Low Cost Solar Cogeneration Systems for Residential and Commercial Buildings Applications.

Grant applications are sought in the following subtopic:

### a. Low-Cost Solar Cogeneration Systems for Residential and Commercial Buildings Applications

Solar cogeneration or other hybrid solar technologies provide electric and thermal energy that can be designed to meet typical residential and commercial building's heating, cooling, and electric energy demand. Cost-effective solar cogeneration requires a systems' approach to integrate energy efficiency, energy generation, conversion, and storage for specific building applications. The technology must be capable of producing site electricity at a levelized cost of less than 10¢ /kWh for residential applications or less than 8¢/kWh for commercial applications when savings

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from reduced building energy consumption related to heating, cooling, and/or water heating demand are included.

Applications are sought that achieve this target through innovations including advancement in hybrid solar collector design and/or solar cell packaging, improved hybrid solar collector efficiency and reliability, reduced hybrid solar collector cost, integrated system optimization, development of development of easily-installed packaged solutions, development of solar powered cooling subsystems, development of solar powered or solar regenerated dehumidification and advancements in energy storage and delivery subsystems. Innovations are sought that service the heating, cooling, and/or water heating demand with a simple payback period of less than 7 years compared to the most energy efficient individual technologies.

Applicants are encouraged to devise plug-and-play package solutions for retrofit and new buildings applications. Cost savings from reduced building energy consumption should be calculated using the 2011 national average electric and natural gas rates published by the Energy Information Administration (Residential electric: 11.8¢/kWhr, Residential gas: $11.02/Thousand cubic feet, Commercial Electric: 10.29¢/kWhr, Commercial gas: $8.93/Thousand cubic feet). The levelized cost of electricity should be calculated using a nominal discount rate of 6%. The applicants are encouraged to identify a specific target market segment for their solutions and the potential national impact. All performance claims must be fully justified with calculations, theoretical predictions, and/or relevant experimental data.

Questions – contact: Bahman Habibzadeh, bahman.habibzadeh@ee.doe.gov

References

Subtopic a:

1. Sun Shot Vision Study. 2012 (http://www1.eere.energy.gov/solar/pdfs/47927.pdf).

2. Average Retail Price of Electricity to Ultimate Customers, EIA. (http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_03).

3. Selected National Average Natural Gas Prices, 2007-2012. EIA (http://www.eia.gov/naturalgas/monthly/pdf/table_03.pdf).

4. Average Retail Price of Electricity to Ultimate Customers, EIA. (http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_03).

5. Selected National Average Natural Gas Prices, 2007-2012. EIA (http://www.eia.gov/naturalgas/monthly/pdf/table_03.pdf).

## 12. TECHNOLOGY TRANSFER OPPORTUNITY: ENERGY EFFICIENCY AND RENEWABLE ENERGY (PHASE I, $225,000/ PHASE II, $1,500,000) NO FAST-TRACK

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*Applicants to Technology Transfer Opportunities should review the section describing Technology Transfer Opportunities on page 3-4 of this document prior to submitting applications.*

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Grant applications are sought only in the following sub-topic:

a. Alternating Current PV Building Block

This technology (US Patent: 6750391,6/15/2004 http://patft.uspto.gov/...6750391) provides a fully integrated and self-containing alternating current (AC) photovoltaic (PV) Building Block device and method that allows photovoltaic applications to become true plug-and-play devices. The Building Block combines, contains, and integrates almost all of the electrical and mechanical elements of a PV system while eliminating the traditional DC voltage concerns of today's PV systems. The building block consists of an innovative module and method by which AC PV power is generated in the form of direct current (DC). Furthermore, the DC will be converted to AC and power will be exported through one or more power conversion and transfer units attached to the module. The Building Block can be used as a PV power source that has only AC power out and can be used alone or in an array.

Sandia National Laboratories Information:
TTO tracking number: SD 6968.1
Contact: Elizabeth Kistin Keller, 505-844-1017, ejkisti@sandia.gov
Website: https://ip.sandia.gov/

Questions – contact: Victor Kane, solar.sbir@ee.doe.gov

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## PROGRAM AREA OVERVIEW: OFFICE OF ENVIRONMENTAL MANAGEMENT

With the end of the Cold War, the Department of Energy (DOE) is focusing on understanding and eliminating the enormous environmental problems created by the Department's historical mission of nuclear weapons production. The DOE's Office of Environmental Management (EM) seeks to eliminate these threats to human health and the environment, as well as to prevent pollution from on-going activities. The goals for waste management and environmental remediation include meeting regulatory compliance agreements, reducing the cost and risk associated with waste treatment and disposal, and expediently deploying technologies to accomplish these activities. While radioactive contaminants are the prime concern, hazardous metals and organics, as defined by the Resource Conservation and Recovery Act (RCRA), are also important.

DOE has approximately 91 million gallons of liquid waste stored in underground tanks and approximately 4,000 cubic meters of solid waste derived from the liquids stored in bins. The current DOE estimated cost for retrieval, treatment and disposal of this waste exceeds $50 billion to be spent over several decades. The highly radioactive portion of this waste, located at the Office of River Protection (Hanford Reservation), Idaho, and Savannah River sites, must be treated and immobilized, and prepared for shipment to a future waste repository.

DOE also manages some of the largest groundwater and soil contamination problems and subsequent cleanup in the world. This includes the remediation of 40 million cubic meters of contaminated soil and debris contaminated with radionuclides, metals, and organics [1]. The Office of Groundwater and Soil Remediation focuses on four areas of applied research including the Attenuation-Based Remedies for the Subsurface Applied Field Research Initiative (Savannah River Site), the Deep Vadose Zone Applied Field Research Initiative (Hanford Site), the Remediation of Mercury and Industrial Contaminants Applied Field Research Initiative (Oak Ridge Site), and Advanced Simulation Capability for Environmental Management. The following topic solicits grant applications to develop technologies for characterizing tank wastes, nuclear materials and disposition, deactivation & decommissioning. The subtopics provide more detailed descriptions of specific needs.

For additional information regarding the Office of Environmental Management priorities, please visit us on the web at http://www.em.doe.gov.

## 13. NOVEL MONITORING CONCEPTS (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

Current long-term monitoring and maintenance strategies and technologies are sometimes inadequate to verify cleanup performance, potentially invalidating selected remedies and escalating cleanup costs. This Initiative is aimed at developing and deploying cost effective long-term strategies and technologies to monitor closure sites (including soil, groundwater and surface water) with multiple contaminants (organics, radionuclides, and metals including mercury) to verify integrated long-term cleanup performance. Long-term monitoring and maintenance is one of the largest projected cost centers in the overall lifecycle of environmental management; moreover, costs associated with the implemented systems will extend into future legacy management. Much of the cost is associated with frequent analyses of contaminants in a large number of monitoring

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wells. Such measurements are often expensive and the resulting datasets are inefficient and inadequate for meeting long term monitoring objectives.

We propose to solicit the best concepts from industry in the following four broad themes:

1. Spatially integrated monitoring tools
2. Onsite and field monitoring tools and sensors,
3. Engineered diagnostic components
4. Integrated risk management and decision support tools

Grant applications are sought in the following subtopics:

### a. Spatially Integrated Monitoring Tools

Spatially integrated monitoring tools help to document plume stability and/or natural attenuation and provide a physical assessment of potential problems (e.g., subsidence in isolated waste). Note that the technologies needed include methods that measure the concentration/distribution of contaminants to support traditional plume mapping and monitoring paradigms, as well as methods that measure the hydrologic and physical boundary conditions responsible for moving contaminated water and the geochemical master variables (e.g., pH, eH and ionic strength) responsible for the mobility of many contaminants. Example technologies include meteorological data and satellite imagery to document boundary conditions, to specifically measure the driving forces for plume migration; permanent geophysical survey systems using emplaced electrodes; ecosystem monitoring; push pull methods; and the like.

Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov

### b. Onsite and Field Monitoring Tools and Sensors

Onsite and field monitoring tools and sensors would reduce laboratory analysis costs. Example technologies include field analysis sensors, deployed sensors, screening tools and other concepts to reduce the number of lab-based analyses or to reduce sampling costs (e.g., reduce investigation-derived waste). This would also include identification of indicator or surrogate parameters and documentation that such parameters would provide equal or better documentation of environmental protection to concentration measurements. This focus area includes applications relevant to the in situ detection and monitoring of mercury species, including elemental mercury, in water and soil.

Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov

### c. Engineered Diagnostic Components

Engineered diagnostic components are designed to provide a clear indication of system performance. These system components include early warning indicators, easily and inexpensively detected tracers that are added to the waste or facility, systems that control and collect water to a single location, and other similar ideas. Such system components are particularly useful for radioactive wastes where predicted transport times are often 1000s of years and traditional monitoring (downgradient monitoring wells in the groundwater) provide little indication that models and predictions are valid. Once a problem is detected, it may be too late to perform a cost effective contingency. Engineered diagnostic components provide opportunities for vadose zone monitoring, gas phase analysis, and more control on the amount of data needed and the costs to collect the data, while simultaneously increasing confidence and sensitivity of the monitoring system.

Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov

## d. Integrated Risk Management and Decision Support Tools

Integrated risk management and decision support tools facilitate implementation of isolation/monitoring systems and assure that they are both effective and optimized (i.e., reduced cost). This is critical to the overall success and includes technologies for the optimization process (e.g., models), engineering designs of waste isolation that allow/encourage detoxification of the contaminants over time, reasonable contingency plan development, and the like.

Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov

## e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas relevant to this Topic.

Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov

## References:

1. Otto, M., and Bajpai, S., “Treatment Technologies for Mercury in Soil, Waste, and Water” *Remediation*, Vol. 18, pp. 21-27. 2007 http://onlinelibrary.wiley.com/doi/10.1002/rem.v18:1/issuetoc.

2. “Treatment Technologies for Mercury in Soil, Waste, and Water”, Office of Superfund Remediation and Technology Innovation, U.S. Environmental Protection Agency, EPA 542-R07-003. 2007 http://www.epa.gov/tio/download/remed/542r07003.pdf.

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## PROGRAM OFFICE OVERVIEW – OFFICE OF FOSSIL ENERGY

Fossil fuels are projected to remain the mainstay of energy consumption (currently 80% of U.S. energy consumption) well into the next century. Consequently, the availability of these fuels, and their ability to provide clean affordable energy, is essential for global prosperity and security. As the nation strives to reduce its reliance on imported energy sources, the DOE's Office of Fossil Energy (FE) supports R&D to help ensure that new technologies and methodologies will be in place to promote the efficient and environmentally sound use of America's abundant fossil fuels. As the economy expands, and the demand for hydrocarbons increases accordingly, FE seeks to develop advanced fossil energy technologies that are environmentally sound and economically competitive.

Particular attention will be focused on finding new ways to extract the power from coal – America's largest domestic energy resource – while simultaneously expanding environmental protection and confronting the issue of global climate change. Key R&D programs include: 1) Crosscutting fossil energy research including materials, sensors, monitors, controls, biotechnology, computational processes, and new concepts that will be needed for these technologies to be commercially competitive; 2) Advanced energy systems including developments in advanced gasification technologies such as gas separation membranes, gas cleanup, clean fuels including hydrogen, synthetic natural gas, and ultra clean liquid fuels; advanced combustion including oxy-combustion, improved turbines and solid oxide fuel cells for future coal-based combined cycle plants; 3) Carbon dioxide capture and compression including innovations for new and existing power plants and industrial sources such as technologies that can capture, separate, and transport greenhouse gases; 4) Carbon dioxide storage including geologic storage, monitoring and beneficial reuse and; 5) Oil and gas technologies including improvements in our ability to recover oil, natural gas, methane hydrates, and shale gas as well as environmental, safety and risk assessment studies. Approximately two-thirds of our national petroleum reserve is "unrecoverable"; it cannot be extracted economically by conventional means. This unused resource could play a major role in supplementing the national petroleum supply if efficient approaches were developed for improved extraction. Natural gas production and utilization could also be increased through improved characterization of reserves and through better infrastructure. The most plentiful supplies of natural gas throughout the world may be the methane molecules trapped in ice-like structures called hydrates. Therefore, FE supports research to help unlock the mysteries of hydrates and develop future ways to tap their massive energy potential.

For additional information regarding the Office of Fossil Energy priorities, click here.

### 14. CROSSCUTTING FOSSIL ENERGY RESEARCH (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

The Crosscutting Research Program (formerly, Advanced Research program) within the DOE National Energy Technology Laboratory's (NETL) Office of Coal and Power R&D fosters the development of innovative, cost-effective technologies for improving the efficiency and environmental performance of advanced coal and power systems. In addition, Crosscutting Research (CCR) bridges the gap between fundamental research into technology alternatives and applied research aimed at scale-up, deployment, and commercialization of the most promising

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technologies identified. The CCR program encompasses three major subprograms: Sensors and Controls Innovations; High Performance Materials; and Computational Energy Sciences.

For the foreseeable future, the energy needed to sustain economic growth will continue to come largely from the Nation's most abundant and lowest cost resource, coal. Maintaining low-cost energy in the face of growing demand and increasing environmental pressures requires new technologies that will enable higher efficiency.

The implementation of sensors and advanced controls in power systems can provide valuable methods to improve operational efficiency, reduce emissions, and lower operating costs. These sensors and controls must provide reliable and consistent data, longevity of use, and ease of calibration. However, it has been a challenge to develop sensors and controls that are able to endure the harsh environments associated with advanced power systems. This environment includes high temperatures (800-1500°C), high pressures (500-1000 psi), and corrosion due to abrasive materials.

High performance materials research cuts across many scientific and technological disciplines to address materials requirements for all fossil energy systems, including innovative advanced power systems. The goal is to bridge the gap between basic and applied research, often by pursuing "breakthrough" concepts based on mechanistic understanding from any discipline to develop materials with unique thermal, chemical, and mechanical capabilities.

Computational Energy Sciences is a comprehensive research and development program aimed at developing and applying computation tolls to address issues, explore new concepts, and analyze energy options in a virtual environment. Approaches to modeling include materials through full-scale plant operation are under develop with the overall goal of reducing the time from concept to application and lowering the risk and cost associated with scale-up of novel concepts.

Grant applications are sought in the following subtopics:

a. High Performance Materials

New materials, processing methods and other materials technology are required to enable the development of new fossil energy power generation systems with increased efficiencies. The Fossil Energy Materials Program conducts research and development on high-performance materials for longer-term fossil energy applications. The program is concerned with operation in the hostile conditions created when fossil fuels are converted to energy. These conditions include high temperatures, elevated pressures, and corrosive environments (reducing conditions, gaseous alkali). Examples of such environments are:

1. Combustion gas turbines in IGCC cycles that are being designed to operate in both $H_2$ and $CO/H_2$ environments at inlet temperatures up to 1700 deg C and pressures to 650 psi.
2. Advanced Ultra-Super Critical (AUSC) steam power plant cycles operating at steam conditions of 760 deg C and 5000 psi.
3. Oxy-fueled combustion systems where components will be exposed to $CO_2$ and $CO_2$ steam.
4. Chemical looping where stable, affordable oxygen carriers are required.

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Grant applications are sought for the development of materials technology that will enable the deployment of the aforementioned fossil energy power generation technologies in the next 5 – 20 years. This includes:

1. Development of materials, both structural and functional, that have the potential to improve the performance and/or reduce the cost of the technologies.
2. Development of a technology base in the synthesis, manufacturing, processing, life-cycle analysis, and performance characterization of advanced materials that are slated to be used in these applications.

Questions – contact: Patricia Rawls, patricia.rawls@netl.doe.gov

## b. Low Cost Rapid Manufacturing of Fiber Optic Sensing Systems

Fiber optic sensor systems offer significant advantage over traditional measurement techniques for sensing in high temperature harsh environments especially environments with high electromagnetic interference (EMI). While significant progress has been made on viable optical sensor designs and measurement approaches, developments are needed to manufacture sensor systems so that the cost of the fiber optic sensor system is competitive with traditional measurement devices. If comparable costs can be obtained, the superior performance of the fiber optic sensors over traditional techniques will support a broad application of these devices. Research in the following areas will support a viable commercialization pathway for a variety of measurements/applications readily made by fiber optics sensors: 1) low cost interrogation techniques, 2) rapid manufacturing techniques of sensor elements for high temperature applications (500-1000 C), and/or 3) robust packaging for energy applications. Primary application of fiber optic based sensors includes temperature, pressure, stress/strain, and/or vibration for power generation applications where temperature ranges from 500-1000 C. The advantages of the proposed developments must be compared with current techniques especially the perceived cost and time advantages.

Grant applications are sought for technologies and techniques to rapidly manufacture low cost fiber optic based sensors systems for high temperature energy related applications.

Questions – contact: Robie Lewis, robie.lewis@netl.doe.gov

## c. CPU and GPU Parallel Development of an Eulerian-Lagrangian Multiphase Model

Multiphase science based computer simulations will play a significant role in the design, operation, and troubleshooting of multiphase flow devices in fossil fuel processing plants. Simulations of industrial scale problems require reasonable time-to-solution and the computational speed-up offered by an Eulerian-Lagrangian model offers the opportunity to conduct computer-based simulations to aid in the design, optimization, and scale-up of industrial scale reacting gas-solids or liquid-solids processes. Eulerian-Lagrangian models which treat the gas/liquid phase as a continuum or Eulerian field and the solids as discrete Lagrangian computational particles have

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shown tremendous computational speed-up over traditional Eulerian-Eulerian or Two Fluid Models. Furthermore, this speed-up is generally achieved without sacrificing fidelity and when comparing an Eulerian-Lagrangian model running in serial on a single core of a desktop machine over an Eulerian-Eulerian model running in parallel across many CPU's. One of the key components to meeting this vision is the need to further increase the speed-up of an Eulerian-Lagrangian model.

Applications are sought for the development of parallel Eulerian-Lagrangian models which utilize multiple CPU's each running in conjunction with multiple graphical processor units (GPU's), which demonstrate an increase in the computational speed-up and result in a model which could run orders of magnitude faster than the current state-of-the-art Eulerian-Eulerian parallel models. These models must maintain the high degree of fidelity found in Eulerian-Eulerian Models.

Questions – contact Steven Seachman, Steven.Seachman@netl.doe.gov

### d. Multi-Dimensional (3-D) Reconstruction of Flow Characteristics in High Temperature Reacting Systems and Operating Components

Next generation power systems require higher efficiencies, greater flexibility, and lower emissions to meet the needs of consumers while adhering to increased regulatory standards. Plant operators will require data from critical locations where harsh environments exist in order to meet these needs. The use of real-time 3-D reconstruction of these locations is an approach to improving plant operations and providing more efficient power generation. The ability to measure multiple variables such as concentration, pressure, velocity, temperature, and composition would be a valuable asset to provide a greater understanding of the physical characteristics of a power plant for which to control and efficiently operate future advanced power generation systems.

Applications are sought for development of technologies that enable real-time multi-dimensional (3-D) reconstruction of high temperature reacting systems and operating components. Using the data from these technologies, reconstruction may include, but is not limited to, (1) cross-sectional, volumetric reconstruction of flows within a fossil fuel reactor (single- or multi-phase); (2) mapping (temperature, pressure, deformation) of internal system components such as turbine blades; (3) cross-sectional, volumetric reconstruction of gas species within a reactor; and (4) volumetric reconstruction of the combustion flame. The data reconstruction generated from these sensors shall emulate the 3-D graphical representations generated using Computational Fluid Dynamics and Finite Element software. The technologies proposed must be high fidelity reconstructions of the flow field and be able to withstand the high temperatures (600-1500$^{o}$C, depending on application), high pressures (near 1000 psi), and harsh environments found within an advanced power system. Applications must be direct measurements of the components or flow field that the technology is proposed to measure.

Extrapolation of single point or "near the wall" measurements to generate 3-D reconstruction as well as technologies that cannot measure an entire cross-sectional volume representative of those found within components of industrial power systems <u>are not of interest</u>.

Questions – contact Steven Seachman, Steven.Seachman@netl.doe.gov

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e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – contact: Robie Lewis, robie.lewis@netl.doe.gov

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1. Romanosky, R. "Development of Harsh Environment Sensor Platform for Fossil Energy Applications", 2008. (http://www.netl.doe.gov/technologies/coalpower/advresearch/pubs/G3-ICMS%20Presentation%20080707f1b.pdf).

Subtopics c and d:

3. National Energy Technology Laboratory: Coal and Power Systems Advanced Research, http://www.netl.doe.gov/technologies/coalpower/advresearch/index.html)

## 15. ADVANCED ENERGY SYSTEMS (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

The U.S. DOE Office of Fossil Energy's Advanced Energy Systems Program (AES) is developing a new generation of clean coal-fueled energy conversion systems capable of producing competitively priced electric power while reducing $CO_2$ emissions, with a focus on improving efficiency, increasing plant availability, reducing cooling water requirements, and achieving ultra-low emissions of traditional pollutants. A key aspect of this area of research is targeted at improving overall system thermal efficiency, reducing capital and operating costs, and enabling affordable capture. Key component areas of AES include:

1. **Gasification** is focused on converting coal into clean synthesis gas (syngas) that can in turn be converted into electricity, chemicals, hydrogen, and liquid fuels to suit market needs.
2. **Hydrogen Turbines** is focused on developing advanced technology for the integral, hydrogen-fueled gas turbine component in an Integrated Gasification Combined Cycle (IGCC) plants configured for carbon capture.

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3. **Solid Oxide Fuel Cells** is focused on developing low-cost, reliable SOFC technology suitable for deployment as a component in advanced Integrated Gasification Fuel Cell (IGFC) systems configured for carbon capture.
4. **Advanced Combustion** is focused on new high-temperature materials and the continued development of high-efficiency oxy-combustion technologies amenable to lower cost carbon capture.

Grant applications are sought in the following subtopics, one for each AES component area noted above:

### a. Separation of Oxygen from Air under Magnetic Gradients

Oxygen is a paramagnetic gas and it is possible to exploit the paramagnetic property to separate oxygen from other constituents of air. There have been several studies of oxygen separation by magnetic field.

1. Yutaka Asako numerically investigated the characteristics of oxygen separation/enrichment from atmospheric air in a capsule and air flow in a parallel-plate duct using a magnetizing force.
2. Jun Cai, et al, experimentally studied a novel method to separate oxygen by utilizing a gradient magnetic field.
3. Fengchao Li reported a new device for oxygen enrichment based on the interception effect on oxygen molecules by a gradient magnetic field.
4. The concept of oxygen separation by magnetic gradient is in the idea generation stage. However, the concept has high potential to emerge as an enabling low-cost, energy efficient alternative to conventional cryogenic oxygen production. Another application could be for the argon manufacturing process by using the magnetic gradient technique to purify argon from argon-oxygen streams.

Applications are invited to experimentally study oxygen separation under magnetic field gradients at the proof-of-principle scale, and conduct theoretical and process economic analysis to demonstrate the practical feasibility and scale-up potential of the approach.

Questions – contact: Arun Bose, arun.bose@netl.doe.gov

### b. Rapid Manufacturing of Advanced Turbine Components

Rapid manufacturing technologies, including layer manufacturing techniques (LMTs), have the capability to broaden the dimensional complexity of industrial gas turbine components while reducing the cycle time to produce verified parts. Today's state of art processes, such as 3D printing (stereo lithography), laser sintering, EB melting, etc. are generally used for facsimile parts, where dimensional accuracy and material properties may be compromised when compared to production components. To this end, these parts, such as those manufactured by powder metallurgy, cannot currently replace conventionally-produced parts in gas turbines even if they are compositionally identical. In addition rapid manufacturing technologies are currently more expensive than conventional techniques in volume production, limiting the range of production

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applicability and the number of prototype iterations which could potentially be explored throughout a development process.

Grant applications are sought for research and development to explore innovative approaches to increase the production throughput, improve the mechanical properties, and improve tolerances and surface finish, and reduce internal porosity, for rapid manufacturing of parts for high-temperature gas turbine applications. Reductions in machine and material costs combined with increases in machine throughput and improved LMT material properties are important steps for rapid manufacturing components to compete with their molded, forged, wrought, welded, or brazed counterparts as an efficient production process with end use in mind.

Grant applications must provide reliable data and processes for high temperature capable rapid manufactured materials in line with industry standards for gas turbine material systems with key requirements including minimizing porosity and the ability to maintain tight tolerances (+/- 0.001") for critical part dimensions. Throughput and process yield should be investigated, as they are critical to overall cost. Supporting processes such as joining, finishing, or inspecting may also be explored. Applicants can also highlight the comparison of the rapid manufacturing methodology to current state of the art manufacturing processes when considering the overall time and cost to market, as well as the facilitation of part geometries that are not feasible by conventional manufacturing, in order to further reduce manufacturing or product energy usage and the associated carbon footprint.

Questions – contact: Robin Ames, robin.ames@netl.doe.gov

### c. Ceria Barrier Layer Processing for Solid Oxide Fuel Cells

State-of-the-art SOFC cathodes based on lanthanum strontium cobalt iron oxide (LSCF) react with yttria-stabilized zirconia (YSZ) electrolytes to form insulating phases, in particular Sr-Zirconate, resulting in poor performance. This can be mitigated by fabricating a cell architecture that contains a thin (1-5 microns) dense doped-ceria (Sm-doped Ceria or Gd-doped Ceria) layer in between the cathode and the electrolyte layers. Currently, developers that use LSCF-based cathodes fabricate this doped-ceria "barrier" layer with low-cost, scalable powder processing techniques, such as screen-printing, followed by a high-temperature sintering step between 1200°C and 1400°C to achieve adequate density (80-90%, with minimal interconnected porosity). However, several recent experiments have shown that substantial increases in cell performance could be obtained when barrier layers were processed to full density using Pulsed Laser Deposition (PLD) and Magnetron Sputtering techniques. These particular techniques have not be evaluated or developed for the low-cost, mass production of large-area (>100 $cm^2$) cells nor has a comprehensive review of other applicable fabrication approaches been completed.

Applications are sought for the comprehensive evaluation of potential approaches for fabricating doped-ceria barrier layers for SOFCs and the development and demonstration of a process to do so in an economically-viable manner amenable to the mass-production (>250 MW/yr) of large-area SOFC cells. Ultimate commercial viability will be determined not just by the density of the barrier layer but more importantly by the increase in cell performance. Applicants are encouraged to

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consult with the SECA Industrial Teams to ensure their fabrication route is minimally disruptive to current fabrication schedules.

Phase I should focus on the review of applicable fabrication approaches and the preliminary development and demonstration of the ability to fabricate a dense doped-ceria barrier layer. Phase II should include a techno-economic analysis, a barrier layer fabrication development effort, and electrochemical testing that demonstrates the benefit of the proposed fabrication route over screen-printing and sintering.

Questions – contact: Briggs White, briggs.white@netl.doe.gov

## d. Advanced Oxy-Combustion Technology

Oxy-combustion power systems for $CO_2$ capture rely on combustion of coal with relatively pure oxygen diluted with recycled flue gas such that the primary products of combustion are $CO_2$ and water. Current challenges with oxy-combustion systems include the cost of cryogenic air separation plant (both capital and operating), materials requirements for new, high temperature systems, air in-leakage and excess flue gas constituent removal (such as excess $O_2$, $SO_2$, $NO_x$, Hg, etc). Grant applications are sought to develop either advanced oxygen production systems that are fully integrated with the coal-based oxy-combustion power plant or novel oxy-combustion boiler configurations.

In responding to this subtopic, applicants must demonstrate a thorough understanding of the technology being proposed and how its advantages are particularly important to the overall oxy-combustion based, coal-fired power plant. In particular, the applicant should give technical detail in regard to the mechanisms/reactions utilized in the proposed technology and how they have the potential to provide a significant improvement over state-of-the-art, cryogenic oxygen production based oxy-combustion systems. Additionally, applicants must provide information describing the anticipated benefits of the advanced oxy-combustion technology in terms of overall plant efficiency (HHV based) and environmental performance. A block flow diagram of advanced oxy-combustion system integrated into a coal-fired power plant should be provided that includes all necessary process streams and equipment. Membrane-based oxy-combustion systems and minor adjustments to air-fired coal boiler configurations will be considered non-responsive to this topic.

Questions – contact: Timothy Fout, timothy.fout@netl.doe.gov

## e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – contact: Travis Shultz, travis.shultz@netl.doe.gov

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Subtopic a:


1. "Oxygen Separation/Enrichment from Atmospheric Air Using Magnetizing Force: Air Flow in a Duct under Magnetic Field Gradient." ASME 2005 International Mechanical Engineering Congress and Exposition (IMECE2005), Sponsor: Materials Division, Orlando, Florida. November 5 – 11, 2005. Paper no. IMECE2005-79812, pp. 321-327; (http://dx.doi.org/10.1115/IMECE2005-79812; ISBN: 0-7918-4234-7)

2. Cai, Jun et al. "Study on oxygen enrichment from air by application of the gradient magnetic field." *Journal of Magnetism and Magnetic Materials*, Vol. 320, issue 3-4, pp. 171-181. February 2008. (ISSN: 0304-8853; DOI: 10.1016/j.jmmm.2007.05.020)

3. Li, F. et al. "Study on gradient magnetic fields of cascading magnets for oxygen enrichment." J. Phys. D: Appl. Phys. 42 185003 (DOI:10.1088/0022-3727/42/18/185003)


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2. Wu, H., et al., "Rapid Fabrication of Alumina-based Ceramic Cores for Gas Turbine Blades by Stereolithography and Gelcasting," *Journal of Materials Processing Technology*. 2008.
3. (DOI: 10.1016/j.jmatprotec.2009.07.002; http://www.sciencedirect.com/science/article/pii/S0924013609002490).

4. Laoui, T., et al. "Rapid Manufacturing of Metal Components by Laser Forming," *International Journal of Machine Tools & Manufacture*, Vol. 46, pp.1459-1468. 2006.
5. (http://www.sciencedirect.com/science/article/pii/S0890695505002683).


Subtopic c:


1. Lu, Z. et al., "Enhanced Performance of an Anode-Supported YSZ Thin Electrolyte Fuel Cell with a Laser-Deposited $Sm_{0.2}Ce_{0.8}O_{1.9}$ Interlayer," *Electrochemistry Communications*, Vol. 12., Iss.179. 2010. (www.sciencedirect.com/science/article/pii/S1388248109005682).

2. Lu, Z. et al. "Performance of Anode-Supported Solid Oxide Fuel Cell with Thin Bi-Layer Electrolyte by Pulsed Laser Deposition," *J. Power Sources*, Vol. 210, Iss. 292. 2012. (www.sciencedirect.com/science/article/pii/S0378775312006350).

3. Jordan, N. "$Ce_{0.8}Gd_{0.2}O_{2-\delta}$ protecting layers manufactured by physical vapor deposition for IT-SOFC," *Solid State Ionics,* Volume 179, Issues 21–26, pp. 919–923 2008. (http://www.sciencedirect.com/science/article/pii/S0167273807004134).


Subtopic d:

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1. U.S. DOE NETL Existing Plants Oxy-combustion Web Page (http://www.netl.doe.gov/technologies/coalpower/ewr/co2/OxyCombustion.html)

2. "DOE/NETL Carbon Dioxide Capture and Storage Roadmap", U.S. DOE National Energy Technology Laboratory (NETL), DOE/NETL-CCS Roadmap, December 2010 (http://netl.doe.gov/technologies/carbon_seq/refshelf/CCSRoadmap.pdf)

## 16. CARBON DIOXIDE CAPTURE AND COMPRESSION (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

Coal-fired utility boilers generate nearly 42% of the electricity in the United States. The DOE Energy Information Administration (EIA) projects that the 312 GW of coal-fired electricity generating capacity currently in operation will decline to 270 GW by 2035. For the foreseeable future, coal will continue to play a critical role in powering the Nation's electricity generation, especially for base-load power plants.

Coal-fired power plants have made significant progress in reducing emissions of sulfur dioxide ($SO_2$), nitrogen oxide (NOx), particulate matter (PM), and recently mercury (Hg), since the passage of the Clean Air Act. However, on the near horizon there is the possibility for new regulations requiring a reduction in carbon dioxide ($CO_2$) emissions. Greenhouse gases such as $CO_2$ have increased over the past century and have been linked to increasing global temperatures. The amount of $CO_2$ produced from the combustion of fossil fuels in the United States will exceed 5.5 billion metric tons in 2013 according to EIA, with about 33% coming from the coal-fired electric power sector.

This topic is specifically focused on developing technologies for $CO_2$ capture that can be retrofitted to existing coal-fired power plants and for novel $CO_2$ compression technologies. This is driven by the fact that existing coal fired power plants produce a large fraction of the current $CO_2$ emissions from all fossil-fuel-based sources. Therefore, it is possible that future climate change regulations could target a reduction in $CO_2$ emissions from the existing fleet of coal boilers. To prepare for this possibility, significant research and development is currently being pursued for new technologies to separate and capture $CO_2$ from flue gas streams produced by existing coal-fired electric generating power plants. Aqueous amine absorption is the state of- the-art technology for post-combustion $CO_2$ capture from flue gas. However, amine absorption has a number of drawbacks, including significant capital and operating costs.

Applications are being sought, in any of the subtopics listed below, for development and testing of <u>advanced</u>, cost effective post-combustion $CO_2$ capture technologies and for <u>novel</u> $CO_2$ compression technologies. Technologies should be capable of 90% or greater reduction in $CO_2$ emissions per net kWh and when technologies are mature, result in less than a 35% increase in the cost of energy services. It is anticipated that the technologies developed under this funding may also have application to new coal-fired power plants as well.

Applications that address pre-combustion $CO_2$ capture technologies, oxy-combustion technologies, chemical looping combustion technologies, and stand-alone auxiliary components (i.e. incremental improvements to existing processes such as corrosion resistant coatings, heat integration techniques, etc.) will be considered non-responsive to the topic area.

### a. Post-Combustion $CO_2$ Capture Processes – Advanced Solvents

Solvent-based systems, typically using amines, are in commercial use in scrubbing $CO_2$ from industrial flue gases and process gases. However, they have not been applied to removing large volumes of $CO_2$ as would be encountered in a PC-fired utility boiler flue gas. Grant applications are sought for solvent based $CO_2$ capture technologies that address the key technical challenges to solvent based systems for capturing $CO_2$ from coal-fired power plants. These challenges include: (1) large flue gas volume; (2) relatively low $CO_2$ concentration; (3) flue gas contaminants; and (4) high parasitic power demand for solvent recovery. The liquid and gas are typically contacted in a countercurrent packed column or a spray tower.

In responding to this subtopic applicants should demonstrate a thorough understanding of the technology being proposed. The applicant should provide information relevant to overcoming the technical challenges identified above in achieving the DOE goal. The applicant should also provide a description of all auxiliary power required, theoretical maximum $CO_2$ capacity and target working capacity (in lb $CO_2$/lb solution), description of the stripper configuration, information about the chemical and thermal stability of the solvent, the chemical reactions for the $CO_2$ absorption/regeneration cycle (and if available, kinetic data, expected operating temperatures, theoretical regeneration energy, and target regeneration energy as a function of working capacity), the solvent composition and anticipated cost range (if manufactured in large quantities), the solvent molecular weight or average molecular weight (mixed solvents) and the boiling point of the solvent (or solvents if mixed solvents). Since this subtopic deals with capture from an existing coal-fired power plant, applicants should include a block flow diagram of how their technology would be retrofitted to a typical pulverized coal fired power plant.

Questions – contact Andy Aurelio, isaac.aurelio@netl.doe.gov

### b. Post-Combustion $CO_2$ Capture Processes – Advanced Sorbents

Solid particles can be used to capture $CO_2$ from flue gas through chemical absorption, physical adsorption, or a combination of the two effects. Possible configurations for contacting the flue gas with the solid particles include fixed, moving, and fluidized beds. Grant applications are sought to develop sorbent based systems for capturing $CO_2$ from existing coal-fired power plants. Solid sorbents used for flue gas $CO_2$ capture must be capable of having high $CO_2$ loading capacities while being able to maintain particle performance in the presence of flue gas contaminants. The applicant should describe how their sorbent-based CO2 capture system will overcome the following technical challenges: (1) large flue gas volume; (2) relatively low $CO_2$ concentration; (3) flue gas contaminants; (4) high parasitic power demand for sorbent recovery; (5) sorbent attrition/strength/agglomeration; and (6) sorbent interaction with flue gas saturated with water.

In responding to this subtopic, applicants should demonstrate a thorough understanding of the technology being proposed. In particular, grant applications must describe the auxiliary power required, the proposed configuration for contacting the flue gas with the sorbent, the $CO_2$ working capacity (the difference between the "loaded sorbent" at breakthrough and the sorbent after regeneration, measured at steady-state when cycling between $CO_2$ absorption and $CO_2$ regeneration) and theoretical maximum capacity (in mol $CO_2$/kg sorbent), any anticipated effects of flue gas contaminants, chemical reactions for the $CO_2$ adsorption/regeneration cycle, heats-of adsorption data for adsorption/desorption reactions, the effects of water vapor in the adsorption reaction, the estimated sorbent cost (in $/kg sorbent) if manufactured in large quantities, the expected performance of the sorbent in terms of attrition or blinding, the sorbent particle size and surface area, and the concentration of the active component. Since this subtopic deals with capture from an existing coal-fired power plant, applicants should include a block flow diagram of how their technology would be retrofitted to a typical pulverized coal fired power plant. This diagram should include the relationship of the sorbent capture system with respect to the coal-fired boiler and any associated (or required) pollution cleanup systems.

Questions – contact Andy Aurelio, isaac.aurelio@netl.doe.gov

## c. Novel $CO_2$ Compression Technologies

Most $CO_2$ capture systems under development today will require significant amounts of compression in terms of both compressor size and power. Depending upon the configuration and type of $CO_2$ capture system, $CO_2$ compression may represent up to 40% of the auxiliary power and at least 10% of the capital required for the $CO_2$ capture system. In order to achieve the DOE's aggressive targets for $CO_2$ capture and its associated costs, the cost and efficiency of $CO_2$ compression systems needs to be improved as well. Grant applications are sought to develop novel, advanced $CO_2$ compression systems to overcome the key challenges for the compression of $CO_2$ captured from an existing coal-fired power plant flue gas. These challenges include: (1) large $CO_2$ flow rates (both mass and volume); (2) possible $CO_2$ contaminants (SOx, NOx, Hg, $H_2O$, $O_2$, etc); and (3) large overall compression ratio.

In responding to this subtopic, applicants must demonstrate a thorough understanding of the technology being proposed and how its advantages are particularly important to the compression of large volumes of $CO_2$ captured from a coal-fired power plant. In particular, the applicant should give technical detail in regard to the mechanism used for the $CO_2$ compression in the proposed technology and how it represents a significant improvement over state of the art, high volumetric flow, multi-stage centrifugal compressor systems. Additionally, applicants must provide information describing the anticipated benefits of the $CO_2$ compression system in terms of compression efficiency, overall power use per ton of $CO_2$ compressed to 2,200 psi, compressor capital cost estimate along with the expected operating conditions of the compressor (and stages). A block flow diagram of the $CO_2$ compression system should be provided that includes all intercoolers, recycle, and other $CO_2$ compression process streams. $CO_2$ compression systems that are a collection of off-the-shelf, standard compression and pumping equipment will be determined to be non-responsive to this sub-topic.

Questions – contact Andy Aurelio, isaac.aurelio@netl.doe.gov

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d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – contact: Andy Aurelio, isaac.aurelio@netl.doe.gov

References:

All Subtopics:

EIA Annual Energy Outlook 2012 with Projections to 2035, Report #:DOE/EIA-0383(2012), June 2012.

Subtopic a:

1. U.S. DOE NETL Existing Plants Post-Combustion $CO_2$ Control Web Page (http://netl.doe.gov/technologies/coalpower/ewr/co2/PostCombustion.html# )

2. U.S. DOE NETL Existing Plants, Emissions, and Capture – CO2 Emissions Control Web Page (http://netl.doe.gov/technologies/coalpower/ewr/co2/index.html)

3. "DOE/NETL Carbon Dioxide Capture and Storage Roadmap", U.S. DOE National Energy Technology Laboratory (NETL), DOE/NETL-CCS Roadmap, December 2010 (http://netl.doe.gov/technologies/carbon_seq/refshelf/CCSRoadmap.pdf)

Subtopic b:

1. U.S. DOE NETL Existing Plants Post-Combustion $CO_2$ Control Web Page (http://netl.doe.gov/technologies/coalpower/ewr/co2/PostCombustion.html#).

2. U.S. DOE NETL Existing Plants, Emissions, and Capture – CO2 Emissions Control Web Page (http://netl.doe.gov/technologies/coalpower/ewr/co2/index.html).

3. "DOE/NETL Carbon Dioxide Capture and Storage Roadmap", U.S. DOE National Energy Technology Laboratory (NETL), DOE/NETL-CCS Roadmap, December 2010 (http://netl.doe.gov/technologies/carbon_seq/refshelf/CCSRoadmap.pdf).

Subtopic c:

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2. "DOE/NETL Carbon Dioxide Capture and Storage Roadmap", U.S. DOE National Energy Technology Laboratory (NETL), DOE/NETL-CCS Roadmap, December 2010 (http://netl.doe.gov/technologies/carbon_seq/refshelf/CCSRoadmap.pdf)

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3. "Cost and Performance Baseline for Fossil Energy Plants – Volume 1: Bituminous Coal and Natural Gas to Electricity, Revision 2" U.S. Department of Energy, National Energy Technology Laboratory, DOE/NETL-2010/1397. November 2010.
4. (http://www.netl.doe.gov/energy-analyses/pubs/BitBase_FinRep_Rev2.pdf)

## 17. CARBON STORAGE TECHNOLOGIES (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

Coal is predicted to continue to dominate power generation for the next 25 years, and since power generation from coal is a significant source of carbon dioxide ($CO_2$) emissions, the reduction of these emissions is a critical research need. The United States has made a commitment to work toward the long-term reduction of $CO_2$ emissions, which in the USA originate mainly from the combustion of fossil fuels for energy production, transportation, and industrial processes, with about one third of US anthropogenic $CO_2$ emissions coming from power plants. The DOE continues to make progress toward the goals of lowering the cost of $CO_2$ capture and ensuring that $CO_2$ can be safely and permanently stored in geologic formations in a process known as carbon capture, utilization, and storage (CCUS). Additionally, as carbon capture technology has advanced, the concept of $CO_2$ utilization has attracted more interest due to its potential not only to reduce emissions but also as a means to generate revenue to possibly offset a portion of the cost of capture. To assist in accelerating the implementation of CCUS at commercial scale DOE seeks innovative technologies and methods that 1) mitigate releases from wellbores used for geologic $CO_2$ storage; 2) reduce the cost and improve accuracy of field monitoring instrumentation; and 3) promote the use of $CO_2$ as a raw material.

Grant applications are sought in the following subtopics:

### a. Advanced Geologic Storage Technologies

DOE is the lead agency supporting research and development of technologies to ensure that greater than 99% of injected $CO_2$ remains permanently stored in deep geologic formations. Mitigation may be needed on injection, abandoned, and monitor wells that are structurally unsound to ensure that this goal is met. Operating permits under the Environmental Protection Agency (EPAs) Safe Drinking Water Act and Clean Air Act requires that $CO_2$ be stored in a manner to ensure that potable groundwater sources and sensitive ecosystems are protected. The EPA has developed a Class VI injection permit for $CO_2$ geologic storage. A Corrective Action Plan and Emergency and Remedial Response Plan for leaking wellbores would be included in a Class VI permit application. These plans would describe any chemicals, materials, and equipment that will be deployed to ensure that $CO_2$ remains in the injection zone.

Grant applications are sought for cost effective chemicals, materials, and/or equipment that may be used to mitigate leaking $CO_2$ emissions. Any chemicals, materials, or equipment should be compatible with the subsurface environment (geology, pressure, temperature, $CO_2$, saline waters, and petroleum hydrocarbons) at depths greater than 3,000 feet. It is envisioned that these technologies would be utilized in the unlikely event that $CO_2$ migrates out of the injection zone through leakage pathways such as faults, fractures, and/or wellbores. Proposals are sought that

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focus on developing new, or enhancing existing, chemicals, materials, and equipment to mitigate $CO_2$ leakage and ensure greater than 99% permanence. Preference will be given to technologies that demonstrate enhanced performance and permanence at reduced cost.

Questions – contact Brian Dressel, Brian.Dressel@netl.doe.gov

## b. Advanced Monitoring Technologies

A "Monitoring Verification and Accounting (MVA)" program is designed to confirm permanent storage of carbon dioxide ($CO_2$) in geologic formations through monitoring capabilities that are reliable and cost effective. Monitoring is an important aspect of $CO_2$ injection, since it serves to confirm storage permanence. Monitoring technologies can be developed to ensure that injection, abandoned, and monitoring wells are structurally sound and that-$CO_2$ will remain within the injection formation. Operating permits under the Safe Drinking Water Act and Clean Air Act for geologic storage projects require monitoring to account for $CO_2$ that has been stored underground to ensure that potable groundwater sources and sensitive ecosystems are protected and to account for the $CO_2$.

Grant applications are sought for technologies involving field-based MVA hardware that quantify $CO_2$ emissions from geologic storage fields in the unlikely event that $CO_2$ migrates out of the injection zone. Proposals are sought that focus on developing new, or enhancing existing, MVA tools for monitoring atmospheric (surface) $CO_2$ that can cover a large area with improved accuracy, continuous (real-time) monitoring capabilities, and/or reduced cost. Preference will be given to technologies that demonstrate enhanced performance at reduced cost.

Approaches in developing new or enhancing existing modeling technologies are not of interest for this subtopic. Grant applications using these approaches will be declined.

Questions – contact Joshua Hull, joshua.hull@netl.doe.gov

## c. $CO_2$ Use and Reuse

As CCUS technologies have advanced, the concept of $CO_2$ utilization has attracted more interest due to the potential of $CO_2$ as a useful commodity chemical. In a future carbon-constrained economy it is anticipated that large volumes of $CO_2$ will be available from fossil fuel–based power plants and other $CO_2$-emitting industrial plants equipped with $CO_2$ emissions control technologies. While DOE is supporting efforts to demonstrate the safe and permanent storage of captured $CO_2$, a large surplus of captured $CO_2$ presents an opportunity to use it as an inexpensive raw material.

To explore this concept, the DOE has created a $CO_2$ Utilization Core Research Focus Area as part of its Carbon Storage Program. The goals of the $CO_2$ Utilization focus area are to identify and develop a suite of technologies that can (1) increase the value and demand for $CO_2$, (2) contribute to reducing $CO_2$ emissions, and (3) contribute to reducing the demand for petroleum-based or hazardous feedstocks. Grant applications are sought for the development or enhancement of novel technologies that support at least one of these goals. For this release, approaches of most interest are (1) $CO_2$ as feedstock for making polymers or high-value commodity chemicals other than fuels; and (2) $CO_2$ as a feedstock for building materials.

Preference will be given to proposals that effectively demonstrate the potential cost competitiveness of the technology. Additionally, the proposal should include a cursory life cycle analysis to demonstrate that the proposed technology will not create more $CO_2$ than is utilized. Other desirable attributes that will enhance a proposal's technical merit are:

1. Improves energy efficiency (i.e., requires less power per unit of product than the conventional process)
2. Has no or low water requirement
3. Utilizes and/or reduces waste streams
4. Replaces one or more toxic materials that require special handling to protect human health and the environment

DOE is currently supporting multiple small- and large-scale RD&D projects to demonstrate the technical and economic feasibility of CCUS. While advances have been made to reduce the cost of implementation, cost remains a primary concern. Recent studies support the approach that $CO_2$ utilization should focus on identifying technologies and opportunities that assist in reducing $CO_2$ capture costs as a means to accelerate industrial-scale implementation of geologic storage. Consequently, technologies that support this approach are of particular interest.

IMPORTANT NOTE: other DOE programs are supporting R&D efforts to develop technologies that use $CO_2$ for $CO_2$-Enhanced Oil Recovery (EOR), $CO_2$-Enhanced Coalbed Methane (ECBM) production, $CO_2$-Enhanced Gas Recovery (EGR), $CO_2$-Enhanced Geothermal Systems (EGS), and algae cultivation, as well as $CO_2$ conversion to fuels, biofuels, fuel precursors or additives, syngas, hydrogen, and carbon monoxide. Therefore these approaches are not of interest for this subtopic, and proposals based on these approaches will be declined. Approaches that are not definitively ruled out by the restrictions above (i.e., falls in a gray area) and are responsive to the $CO_2$ Utilization goals may be considered.

Questions – contact Darin Damiani, darin.damiani@netl.doe.gov

## d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – contact Andrea Dunn, andrea.dunn@netl.doe.gov

References:

Subtopic a:

1. "Best Practices for Carbon Storage Systems and Well Management Activities", U.S. DOE National Energy Technology Laboratory (NETL). April 2012

(http://www.netl.doe.gov/technologies/carbon_seq/refshelf/BPM-Carbon-Storage-Systems-and-Well-Mgt.pdf).

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3. Carbon Sequestration Program: Technology Program Plan," U.S. DOE National Energy Technology Laboratory (NETL). February 2011. (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/2011_Sequestration_Program_Plan.pdf).

4. "Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO2) Geologic Sequestration (GS) Wells,' U.S. Environmental Protection Agency. December 2010 (http://www.gpo.gov/fdsys/pkg/FR-2010-12-10/pdf/2010-29954.pdf).

5. The Clean Air Act, U.S. Environmental Protection Agency, 2011 (http://www.epa.gov/ghgreporting/reporters/subpart/index.html).

Subtopic b:

1. "Best Practices for Monitoring, Verification, and Accounting of CO2 Stored in Deep Geologic Formations," U.S. DOE National Energy Technology Laboratory (NETL). January 2009 (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/MVA_Document.pdf).

2. "Carbon Storage Program Research and Development Needs Workshop Report," U.S. DOE National Energy Technology Laboratory (NETL). January 2012 (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/Carbon-Storage-Program-RD-Needs-Workshop.pdf).

3. "DOE/NETL Carbon Dioxide Capture and Storage RD&D Roadmap," U.S. DOE National Energy Technology Laboratory (NETL). December 2010 http://www.netl.doe.gov/technologies/carbon_seq/refshelf/CCSRoadmap.pdf).

4. "Carbon Sequestration Program: Technology Program Plan," U.S. DOE National Energy Technology Laboratory (NETL). February 2011 (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/2011_Sequestration_Program_Plan.pdf).

5. "Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO2) Geologic Sequestration (GS) Wells," U.S. Environmental Protection Agency. December 2010 http://www.gpo.gov/fdsys/pkg/FR-2010-12-10/pdf/2010-29954.pdf).

6. The Clean Air Act, U.S. Environmental Protection Agency. 2008 (http://www.gpo.gov/fdsys/pkg/USCODE-2008-title42/pdf/USCODE-2008-title42-chap85.pdf).

Subtopic c:

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1. "NETL Carbon Sequestration Program: Technology Program Plan," U.S. DOE National Energy Technology Laboratory (NETL). February 2011 (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/2011_Sequestration_Program_Plan.pdf).

2. DOE/NETL Carbon Dioxide Capture and Storage RD&D Roadmap," U.S. DOE National Energy Technology Laboratory (NETL). December 2010 (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/CCSRoadmap.pdf).

3. Damiani, D et al., "The U.S. Department of Energy's R&D program to reduce greenhouse gas emissions through beneficial uses of carbon dioxide," *GHG Sci & Tech*, Issue 4. (http://www.netl.doe.gov/technologies/carbon_seq/refshelf/project%20portfolio/2011/SelectedPubs/GHG35_final.pdf).

4. "Accelerating the uptake of CCS: industrial use of captured carbon dioxide," Global CCS Institute. March 2011 (http://www.globalccsinstitute.com/resources/publications/accelerating-uptake-ccs-industrial-use-captured-carbon-dioxide).

5. Carbon Dioxide as a Chemical Feedstock. Edited by Michele Aresta. 2010. Wiley-VCH.

6. Metz, B., et al (eds.), "Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage: Chapter 7 – Mineral Carbonation and Industrial Uses of Carbon Dioxide," Cambridge University Press, p. 319-337. 2005. (http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml).

## 18. OIL AND GAS TECHNOLOGIES (PHASE I, $150,000/PHASE II, $1,000,000) NO FAST-TRACK

Much of the remaining oil resource in the U.S. cannot be recovered by conventional means, and advanced technologies are required for economical and environmentally benign extraction. DOE is interested in technologies that will improve the ultimate recovery of domestic oil resources. Accordingly, this topic seeks to develop technology that will lead to more efficient production of oil by furthering the development of innovative tools or methods to reduce field development costs – and/or improve recovery efficiency – related to the responsible environmental development and production of oil from residual oil, heavy oil, and oil shale resources.

Grant applications are sought in the following subtopics:

### a. Enhanced Recovery of Petroleum Resources

Grant applications are sought to develop innovative tools or methods to reduce environmental impacts or field development costs – and/or improve recovery efficiency – related to the development and production of oil from residual oil, heavy oil, and oil shale resources. For these unconventional oil resources, approaches of interest include methods to: (1) reduce the technical

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and environmental constraints on production, (2) improve overall oil recovery efficiency. Specific subtopic technology interests include:

Residual Oil:
1. Optimized well design and placement methodologies
2. Technologies for increasing the viscosity of injected CO2 relative to reservoir fluids
3. Miscibility extension technologies
4. Novel approaches for increasing CO2 injection volumes
5. Enhanced reservoir visualization technologies

Heavy Oil:
1. Reducing sand production from thermally stimulated wells
2. Improving the efficiency of steam generation and injection
3. Advanced technologies for improving steam or hot water sweep efficiency
4. Advancing crude upgrades for heavy oil (pre-pipeline)
5. Enhanced reservoir visualization technologies

Oil Shale:
1. Increased process energy efficiency (net energy balance) for surface or *in situ* processes
2. Reduced high net water requirements
3. Improved the reliability of downhole heating sources
4. Reduce or control air emissions (including CO2)
5. Reduce or control water contamination, either surface or subsurface
6. Reduced water consumption
7. Enhanced reservoir visualization technologies

Grant applications must include a succinct discussion of the potential technical and economic advantages of the proposed technology, as compared to existing state-of-the-art systems.

Contact: Eric Smistad, eric.smistad@netl.doe.gov

## b. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Grant applications must include a succinct discussion of the potential technical and economic advantages of the proposed technology, as compared to existing state-of-the-art systems.

Questions – contact: Eric Smistad, eric.smistad@netl.doe.gov

References:

Subtopic a:

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1. NETL's Oil and Natural Gas Program. (http://www.netl.doe.gov/technologies/oil-gas/index.html).

2. "Unconventional Fossil Energy: Domestic Resource Opportunities and Technology Applications". September 2011. (http://www.netl.doe.gov/technologies/oil-gas/publications/EPreports/2011-005539-unc-fe-report-congress-final-oct-2011.pdf).

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## PROGRAM AREA OVERVIEW – OFFICE OF NUCLEAR ENERGY

Continued use of nuclear power is an important part of the Department's strategy to provide for the Nation's energy security, as well as to be responsible stewards of the environment. Nuclear energy currently provides approximately 20 percent of the U.S. electricity generation and will continue to provide a significant portion of U.S. electrical energy production for many years to come. Also, nuclear power in the U.S. makes a significant contribution to lowering the emission of gases associated with global climate change and air pollution.

The primary mission of the Office of Nuclear Energy (NE) is to advance nuclear power as a resource capable of meeting the Nation's energy, environmental, and national security needs by resolving technical, cost, safety, nonproliferation, and security barriers through research, development, and demonstration as appropriate [1].

For additional information regarding the Office of Nuclear Energy priorities, http://nuclear.energy.gov/

### 19. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY (PHASE I, $225,000/PHASE II, $1,500,000)

New methods and technologies are needed to address key issues that affect the future deployment of nuclear energy and to preserve the U.S. leadership in nuclear technology and engineering, while reducing the risk of nuclear proliferation. This topic addresses several of these key technology areas: improvements in nuclear reactor technology for existing light water reactors (LWR) and evolutionary LWR and advanced reactor designs, advanced instrumentation and control (I&C) for multiple advanced reactor concepts and fuel cycle applications, technologies that support the commercialization of innovative small modular reactor designs, advanced technologies for the fabrication, characterization, irradiation testing, and non-destructive testing of new fuels and materials for LWR and Generation IV reactor designs of varying power level and advanced fuel cycle technologies.

Grant applications are sought in the following subtopics.

#### a. Advanced Sensors and Instrumentation

Improvements and advances are needed in the technical area of Advanced Sensors and Instrumentation technologies to enhance economic competitiveness for nuclear power plants and promote a high level of nuclear safety [2,3,4]. Grant applications are sought for: (1) Advanced Sensors that can withstand harsh environments (such as under accident conditions, in reactor applications, or during in-pile irradiation for fuel testing) to detect and monitor behavior of reactor or fuel cycle systems to achieve needed accuracy/resolution and minimize measurement uncertainty (2) Digital Monitoring and Control systems that increase nuclear plant system reliability, availability, and resilience by detecting and managing faults and failures of either I&C systems or plant components; (3) Nuclear Plant Communication technologies that securely and reliably support greater data generation and transmission demands expected to accompany advancements in digital sensor, measurement, and control technologies; and (4) Innovative human-system

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interactions approaches and human-machine interface technologies to enable Advanced Concepts of Operation for future nuclear energy systems based on more highly automated control and unconventional roles and responsibilities for both human and system.

Successful applications will describe truly innovative sensors and instrumentation that offer the potential for revolutionary gains in reactor and fuel cycle performance and that can be applied to multiple reactor designs and fuel cycle concepts.

Grant applications that address the following areas are NOT of interest and will be declined: nuclear power plant security, homeland defense or security, or reactor building/containment enhancements; radiation health physics dosimeters (e.g., neutron or gamma detectors), and radiation/contamination monitoring devices; U. S. Nuclear Regulatory Commission probabilistic risk assessments or reactor safety experiments, testing, licensing, and site permit issues.

Questions – contact: Suibel Schuppner, Suibel.Schuppner@nuclear.energy.gov

### b. Advanced Technologies for the Fabrication, Characterization of Nuclear Reactor Fuel

Improvements and advances are needed for the fabrication, characterization and non-destructive examination of nuclear reactor fuel with technologies that could: (1) develop advanced automated, accurate, continuous vs. batch mode process techniques to improve TRISO coated particle fuel: (a) fabrication, (b) accurate sorting methods to replace manual sieving or "tabling" methods that determine size, shape, and aspect ratio to remove aspherical or under/over-sized particles, (c) characterization, and (d) non-destructive evaluation testing of TRISO particles and compacts for Advanced Gas-Cooled Reactors/NGNP applications [8, 9]; (2) provide new innovative LWR fuel concepts with a focus on improved performance (especially under accident scenarios) [10], and; (3) develop radiation-tolerant electronics for characterization instrumentation for use in hot cell fuel/clad property measurements [5, 6]. Grant applications may use non-fueled surrogate materials to simulate uranium, plutonium, and minor actinide bearing fuel pellets or TRISO particles for demonstration. Actual nuclear fuel fabrication and handling applications which require use of the INL ATR National Scientific User Facility [7], and its hot cells and fuel fabrication laboratories, or the Oak Ridge National Laboratory Advanced Gas Reactor TRISO fuels laboratory facilities [8, 9] to demonstrate the techniques and equipment developed may be proposed. Actual nuclear fuel specimens may be considered for ATR or ORNL High Flux Irradiation Reactor (HFIR) but will need to prove technical feasibility prior to their insertion into the ATR or HFIR for irradiation testing. Access to the aforementioned facilities is not guaranteed as part of this solicitation and must be obtained independent of an SBIR/STTR award.

Grant applications that address the following areas are NOT of interest and will be declined: Spent fuel separations technologies used in the Fuel Cycle Research and Development Program [5, 6] and applications that seek to develop new glove boxes or sealed enclosure designs.

Questions – contact: Frank Goldner, Frank.Goldner@nuclear.energy.gov

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## c. Materials Protection Accounting and Control for Domestic Fuel Cycles

Improvements and advances are needed for the development, design and testing of new sensor materials and measurement techniques for nuclear materials control and accountability (including process monitoring) that increase accuracy, resolution, radiation hardness, while decreasing intrusiveness on operations and the cost to manufacture. In addition, concepts and integration of safeguards features into facility/process design are being sought. Grant applications are sought for: (1) Sensors based on radiation detection; (2) New technologies to replace He-3 for neutron detection in accountability instruments; (3) New active interrogation methods, including basic nuclear data (neutron and photo fission, nuclear resonance fluorescence); (4) Non-radiation based (stimulated Raman, laser-induced breakdown spectroscopy, fluorescence, etc.); and (5) Safeguards and security by design concepts. Grant applications are also sought for the development of new methods for data validation and security, data integration, and real time analysis with defense-in-depth and knowledge development of facility state during design.

Detectors that may indicate unauthorized materials diversion can be equally useful in identifying system upsets and the need for control changes. Grant applications are sought for the development of dual-use as well as single purpose instruments and detectors. Proposed concepts used exclusively for separations process control should be submitted under subtopic g.

Grant applications that address border security or remote monitoring [6] are NOT sought.

Questions – contact: Daniel Vega, Daniel.Vega@nuclear.energy.gov

## d. Modeling and Simulation

Computational modeling of nuclear reactors is critical for their design and operation. Nuclear engineering simulations are increasingly predictive and able to leverage high performance computing architectures. Writing software which works on leadership class facilities and is able to be used by nuclear engineers in industry presents many challenges. Grant applications are sought that:

1. Can provide supporting software for nuclear engineering analyses, such as advanced meshing tools (*e.g*., for generation of reactor spacer grid fluid flow or structural mechanics simulations), advanced visualization tools (*e.g*., for projecting 1-D network flow simulation results as color maps onto 2-D graphical icons created by the user), and data exchange capability between codes (*e.g*., for duplication of a large mesh-based data set onto an array of similar, coarser meshes); and
2. Can integrate the resultant tools and codes into a web services framework, with emphasis on the ability to connect to an open science computing framework like the open science grid.

Questions – contact: Dan Funk, Dan.Funk@nuclear.energy.gov

## e. Non-Destructive Examination (NDE) of materials used in nuclear power plants

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The development of innovative and new methods of non-destructive evaluation of key reactor components and material systems is needed. New sensors and techniques to quantify material integrity and/or degree of degradation for cable insulation, concrete and civil structures, cast stainless steel piping, low alloy steel piping, reactor pressure vessel steels and weldments, stainless steels, and/or Ni-base alloy piping are requested.

Questions – contact: Rich Reister, Rich.Reister@nuclear.energy.gov

## f. Advanced Methods for Manufacturing

Data and resource management programs are currently being considered by reactor vendors and their EPC contractors for the construction of new nuclear power plants. New nuclear plant owners will be required to manage and control the configuration of the nuclear plant through the complete nuclear plant lifetime. Significant project cost and schedule advantage can be achieved by effectively managing and maintaining configuration management (CM) of plant data beginning in the design and construction phases of the nuclear plant. Advanced methods are needed to acquire, process and compare construction as-built configurations against the design. Grant applications are sought for (1) methods and technology improvements in laser, GPS and photometric systems to assure the as-built configuration matches the design, and (2) improvements in radiofrequency (RF) tags and similar devices to assure correct materials, placement, test criteria, and spare parts inventories.

Questions – contact: Alison Krager, Alison.Krager@nuclear.energy.gov

## g. Separations and Waste Forms for Advanced Domestic Fuel Cycles

Separations and waste forms play critical roles in both current and future nuclear fuel cycles. Currently, research reactor fuels are being processed in the U.S. for their stabilization while large nuclear waste treatment processing plants are in operation and are being constructed to convert cold war liquid waste into safely storable solid waste forms. An additional plant is being built to convert weapons-grade plutonium into commercial nuclear fuel. In the future, chemical processing plants may be constructed in the U.S. to recycle used nuclear fuel for improved resource utilization and reduced environmental impact. In all cases, modest improvements in chemical processing technologies can effect significant cost reductions.

In addition to the use of advanced sensors and measurement technologies for materials protection, accounting and control (as outlined in subtopic c), grants are sought for the development of related systems useful for separations process control. For example, detectors that may indicate unauthorized materials diversion can be equally useful in identifying system upsets and the need for control changes. Grant applications are sought for the development of dual-use as well as single purpose instruments and detectors used exclusively for process control. However, proposals that are focused on materials protection, accounting and control related applications are more appropriate for subtopic c and should be submitted there.

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Most liquid high-level nuclear waste in the world is being converted to a solid form as a borosilicate glass. Such waste forms, while extremely durable, generally contain low concentrations of radioactive materials. Several approaches are under investigation to increase radioactivity concentrations and thus to decrease the total waste mass and volume for storage and disposal. Examples include the possible use of metal alloys and ceramics as advanced waste forms. Innovations are needed in waste forms chemistry and crystallinity to increase waste concentrations without the sacrifice of glass durability. Acceptability of such new waste forms as alternatives to borosilicate glass will depend upon sufficient knowledge of their degradation processes to be able to predict their performance over geologic time periods. Collaboration with national laboratory scientists involved in related studies is encouraged.

For nuclear energy to remain a sustainable energy source, there must be assurance that an economically viable supply of nuclear fuel is available. Although uranium is present in very low concentrations in seawater (3.3 part per billion), the oceans contain over 4,500 million tons of uranium, which would last for centuries even with aggressive nuclear energy growth. Economic extraction of uranium from seawater could ensure a feasible fuel supply for nuclear power for millennia to come. Grant applications are sought in (1) development of new polymer sorbents via surface grafting techniques; (2) design and synthesis of functional ligands; (3) development of advanced adsorbent materials; and (4) development of innovative elution processes to improve adsorbent durability. Grant applications will be accepted that address uranium extraction from unconventional resources.

Questions – contact: James Bresee, James.Bresee@nuclear.energy.gov

References:

Subtopics a-g:

1. U.S. DOE Office of Nuclear Energy, Home Page. (http://www.nuclear.gov).

2. Miller, D. W., et al., "U. S. Department of Energy Instrumentation, Controls and Human-Machine Interface (IC & HMI) Technology Workshop," Gaithersburg, MD, May 15-17, 2002, IC&HMI Report. September 2002 (http://www.nuclear.gov/pdffiles/NE1_ICHMI_Report.pdf).

3. Hallbert, B. P., et al., "Report from the Light Water Reactor Sustainability Workshop on Advanced Instrumentation, Information and Control Systems and Human-system Interface Technologies, LWRS Program, Columbus, Ohio, March 20-21, 2009. INL/EXT-09-16631. August 2009. (https://inlportal.inl.gov/portal/server.pt/community/lwrs_program/442/program_documents).

4. Dudenhoeffer, D., et al, "Technology Roadmap on Instrumentation, Control, and Human Machine Interface to Support DOE Advanced Nuclear Power Plant Programs," INL/EXT-0611862, March 2007 (http://www.inl.gov/technicalpublications/Documents/4511504.pdf).

5. Hashemian, H. M., "The state of the art in nuclear power plant instrumentation and control," *Int. J. Nuclear Energy Science and Technology*, Vol. 4, No. 4, pp 330- 354. 2009. (www.inderscience.com/info/inarticle.php?artid=28597).

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6. U.S. DOE Office of Nuclear Energy, "Nuclear Energy Research and Development Roadmap, Report to Congress," April 2010. (http://nuclear.energy.gov/pdfFiles/NuclearEnergy_Roadmap_Final.pdf).

7. U. S. Department of Energy, Fuel Cycle Research and Development Program. (http://nuclear.energy.gov/fuelcycle/neFuelCycle.html).

8. Idaho National Laboratory Advanced Test Reactor National Scientific User Facility: (http://nuclear.inl.gov/atr/).

9. "Technical Program Plan for the Next Generation Nuclear Plant/Advanced Gas Reactor Fuel Development and Qualification Program," Idaho National Laboratory, Rev. 3, INL/EXT-05-00465. August 2010. (https://inlportal.inl.gov/portal/server.pt/community/ngnp_public_documents/452/home).

10. Petti, D. et al., "The DOE Advanced Gas Reactor (AGR) Fuel Development and Qualification Program," 2005 International Congress on Advances in Nuclear Power Plants, INEEL/CON-04-02416: (http://www.inl.gov/technicalpublications/Documents/3169816.pdf).

11. Advanced Fuels Campaign FY 2011 Accomplishments Report – Fuel Cycle Research and Development, INL/EXT-11-24049. November 2011. (http://www.inl.gov/technicalpublications/Documents/4731813.pdf).

h. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – contact: Bradley Williams, Bradley.Williams@nuclear.energy.gov

## 20. ADVANCED TECHNOLOGIES FOR NUCLEAR WASTE MANAGEMENT (PHASE I, $225,000/PHASE II, $1,500,000)

With the need to store used nuclear fuel for prolonged periods of time (in excess of 100 years), it becomes necessary to address technical performance issues of the nuclear materials with time. Improvements and advances are needed for the development, design, and testing of new sensors, transmitters, and measurement techniques for used nuclear fuel stored in dry storage systems for long periods of time. While long-term material performance studies are planned within the Used Fuel Disposition (UFD) program, there are limited opportunities to perform reliable real-time monitoring of the material condition in a sealed container or a dry storage cask. There are several monitoring devices that can be used for conventional non-destructive examinations. However, the current monitoring devices only provide limited information and the long-term reliability of the data could be questionable. Of interest to the UFD program are grant applications that propose new

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devices based on the long-term material behavior characteristics and/or propose new data collection and advance analyses methods that can support reliability of long-term storage options.

Grant applications are sought only in the following subtopics.

## a. Used Fuel Disposition, Generic Repository Research, Development, and Demonstration: Deep Boreholes

New methods and technologies are needed to address key issues that affect the future of nuclear energy, in particular, resolution of materials disposition associated with the back-end of the nuclear fuel cycle. Disposition of defense program high-level nuclear waste products and used nuclear fuel from civilian reactors remains a significant national challenge. The U.S. DOE Office of Nuclear Energy, Office of Fuel Cycle Technologies, Office of Used Nuclear Fuel Disposition R&D [1,2, 3] is currently investigating generic repository disposal systems in crystalline/granite, shale, salt, and deep borehole environments.

Proposals are sought in the following general areas.

Improvements and advances in drilling and testing technologies, and understanding of generic deep borehole environments (drilled to 5 km depth into “crystalline basement” rock) are sought; consideration should be given to examination of the feasibility of using existing drilling and testing systems and component technologies and innovative techniques to provide information to be used in the design, construction, testing, characterization, and performance assessment modeling of the deep geologic system borehole environment (chemical, hydrologic, mechanical, thermal).

Deep borehole (3-5km depth, crystalline basement rock) disposal of nuclear waste [4-19] has been considered by several nations. Research, development and demonstration challenges abound and provide opportunities for contribution to the USA’s ongoing efforts in this area including but not limited to:

1. Seal integrity studies,
2. Canister design and prototyping,
3. Drill rig design specifications / modification for emplacement,
4. Bentonite and cement degradation evaluation,
5. Borehole, casing, and liner design and emplacement operations,
6. Waste form degradation studies at expected environmental conditions,
7. Selected radionuclide (I129, Tc99, Cl36) characterization at expected environmental conditions,
8. Studies of I129 sorbent additive in seal zone: system modeling investigations to examine long-term (up to 1 million years) changes in system processes and performance for deep basement rock environments
9. Age dating methods and reliability for very old groundwater (millions to billion years); including test specifications, materials, hardware requirements, test methods, distinguishing age of pore waters and fracture waters or determination of hydrologic system character and formation water residence time [19-23].

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Proposals are sought to evaluate, improve, and or optimize the reliability, accuracy, and/or performance of drilling technologies and instrumentation, testing methods and applications, and modeling or analysis of deep borehole systems. Predictive and post-testing computational component, process, and system modeling and simulations are important for confidence building; it may also be advantageous to leverage high performance computing architectures and capabilities. Of particular interest are applications that propose the use of cooperative research efforts (e.g., with the National Laboratory's, other research institutions) in examination of the deep borehole disposal option; proposals are invited in other areas that fall within the scope of the topics described above.

Questions – contact Mark Tynan, Mark.Tynan@nv.doe.gov

### b. New Technology for Devices for Evaluating Internal Conditions of Nuclear Waste Storage Casks Nondestructively

Grant applications are sought: (1) to improve and optimize instrumentation devices using advanced techniques that relate to the fundamental properties of degrading nuclear materials, Develop a monitoring system for internal conditions in used fuel dry storage systems to identify or predict fuel cladding failure and fuel assembly structural degradation/corrosion [1, 2, 3, 4]. The attributes to be monitored might include radiation levels, temperatures, pressures, detection of certain gasses including corrosion products and radioactive decay elements, etc. (2) Develop remote and long-term monitoring of nuclear waste casks in a passive manner. The monitoring sensors might be located inside the containment canister or externally, depending on the proposed measurement technique. If internal, there shall be no penetrations through the canister; they would have to be powered without direct connections and the signals would have to be transmitted without direct connection (through thick steel shells and, possibly, concrete over-packs). The sensors and transmitters would have to sustain harsh environments (including high radiation, high temperatures, and vibration) for long periods of time (centuries) without accessibility for maintenance or calibration. The sensors and transmitters would have to sustain reorientation and vibration associated with loading and shipping the used fuel canisters from the reactors to the storage facilities. There might be several ways to solve each of these requirements. (3) Develop sensing technology to record and warn operators of events exceeding threshold of preset damage values for internals of a waste containing casks.

Questions - contact John Orchard, John.Orchard@nv.doe.gov or Prasad Nair, Prasad.Nair@nv.doe.gov

### c. Advanced Data Analyses Methodology for Nuclear Waste Containers/Casks Currently in Use

There are several monitoring devices that provide data based on interpretation of physics, chemistry, or radiological aspects of the material/structure performance. These data very often get filtered or amplified for purposes of identifying a phenomenon under consideration. However the raw data may contain additional information that could be valuable, if one is able to perform detailed or new analyses of these data. Grant applications are sought: (1) to develop methodology to extract more usable information from current monitoring devices for material degradation processes, and (2) develop and demonstrate advanced data analysis schemes with the use of multiple devices of various kinds.

Questions - contact John Orchard, John.Orchard@nv.doe.gov or Prasad Nair, Prasad.Nair@nv.doe.gov

References:

Subtopic a:


1. U.S. DOE Office of Nuclear Energy, Home Page. (URL: http://www.nuclear.gov).

2. U.S "Nuclear Energy Research and Development Roadmap, Report to Congress,". April 2010, (http://nuclear.energy.gov/pdfFiles/NuclearEnergy_Roadmap_Final.pdf).

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Subtopics b-c:

1. 10 CFR 72.122, LICENSING REQUIREMENTS FOR THE INDEPENDENT STORAGE OF SPENT NUCLEAR FUEL, HIGH-LEVEL RADIOACTIVE WASTE, AND REACTOR- RELATED GREATER THAN CLASS C WASTE, General Design Criteria, Overall Requirements

2. 10 CFR 72.128, LICENSING REQUIREMENTS FOR THE INDEPENDENT STORAGE OF SPENT NUCLEAR FUEL, HIGH-LEVEL RADIOACTIVE WASTE, AND REACTOR- RELATED GREATER THAN CLASS C WASTE, General Design Criteria, Criteria for spent fuel, high-level radioactive waste, and other radioactive waste storage and handling.

3. US Department of Energy, FCRD-USED-2011-000136 Rev. 0, USED FUEL DISPOSITION CAMPAIGN Gap Analysis to Support Extended Storage of Used Nuclear Fuel Rev. 0, JANUARY 31, 2012, Section 4.6 Monitoring

4. Ibid. Table S-1.

## d. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

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