REQUEST FOR INFORMATION

Research Needs Related to Unconventional Oil and Natural Gas, Beneficial Use of Produced Water, Offshore Spill Prevention, Natural Gas Conversion, and Offshore Carbon Dioxide Storage/Enhanced Oil Recovery

DATE: October 25, 2016

SUBJECT: This Request for Information (RFI) is issued by the Department of Energy (DOE) Office of Fossil Energy (FE) National Energy Technology Laboratory (NETL) and seeks input on critical gaps in oil and natural gas technology that must be addressed through scientific research.

STRATEGIC OBJECTIVE: The objective of this RFI is to support DOE's mission to lead research and technology development that promotes the prudent development of oil and gas resources and reduces the environmental footprint of oil and gas activities. This includes efforts to ensure that promising technologies progress through subsequent technology readiness levels (TRL) in order to further ensure safe and environmentally sustainable oil and gas resource development. The DOE will accomplish this mission in cooperation with the private sector, academia, and other stakeholders.

DESCRIPTION: This RFI seeks input on research needs in five broad areas: unconventional oil and natural gas resource development; beneficial reuse of water produced from oil and natural gas wells; offshore spill prevention; natural gas conversion; and, carbon dioxide storage and enhanced oil recovery (CO_2 EOR). Within these five areas, there are multiple individual categories where specific information is sought.

With regard to unconventional oil and natural gas resource development, the categories are:

1. Mitigate Environmental Impacts of Unconventional Oil and Gas Development via Dedicated Unconventional Oil and Gas Field Laboratories
2. Prevent the Disposal of Large Volumes of Produced Water
3. Technologies for Improving Hydraulic Fracture Diagnostics
4. Understanding and Avoiding Induced Seismicity

With regard to beneficial reuse of produced water, there is a single category with questions related to water treatment cost reduction, water and production systems integration, and market penetration.

5. Beneficial Reuse of Water Produced from Unconventional Oil and Natural Gas Wells

With regard to offshore spill prevention, the categories are:

6. Reduce and Mitigate the Risk of Oil Spills due to Geological Uncertainty
7. Reduce and Mitigate Risk of Oil Spills during Well Operations
8. Reduce and Mitigate the Risk of Oil Spills from Surface/Subsurface Systems and Deepwater Infrastructure

With regard to natural gas conversion, the categories are:

9. Approaches for Eliminating Flaring and Direct Venting of Natural Gas Prior to, During and After Production
10. Approaches for Eliminating the Venting of Process CO_2 During Natural Gas Processing and Reducing CO_2 Emissions Associated with Flue Gas and Other Engine Exhaust Streams
11. Developing Scalable Technologies for In-field Conversion of Methane-rich Gas to Fungible Products
12. Improving Supply-Chain Options for Distributed Processing of Natural Gas and CO_2

With regard to offshore CO_2 storage/EOR, the categories are:

13. Technical and Economic Feasibility of Offshore CO_2 Transport, Handling and Injection
14. Systems Integration for Offshore CO_2 Injection Projects
15. Technically Recoverable CO_2 EOR Resources

BACKGROUND: The United States will, for the foreseeable future, continue to rely heavily upon domestically produced oil and natural gas for our national energy supply. Additionally, contributions to the national energy supply from what have become known as U.S. "unconventional" oil and gas (UOG) resources, i.e., primarily oil and natural gas from shale source rocks, continue to increase. Optimizing use of the nation's UOG supply will require safe, efficient, and environmentally responsible UOG exploration and production technologies and processes. In addition, U.S. offshore producing areas, including prospective areas in the deepwater and ultra-deepwater sectors of the Gulf of Mexico, are expected to continue to provide a significant share of our domestic oil production well into the future.

UOG reservoirs commonly extend across large regions and therefore represent extremely large "in-place" hydrocarbon volumes. However, even with the application of advanced technologies, UOG reservoirs typically exhibit low recovery factors relative to higher permeability "conventional" reservoirs; ultimate recovery values of 10% or less are cited for liquid-rich shales and only 25 to 35% for gas-rich shales. Improving these factors is an important objective if we are to avoid wasting this valuable natural resource and reduce the environmental impact per unit of energy produced.

While science-based regulation and adherence to best practices can help achieve the goal of safe, environmentally sustainable and efficient development of both onshore and offshore resources, rapid technology advancements will be required to maximize the national energy, security, and economic benefits of UOG and offshore exploration and production activities while minimizing any negative environmental impacts.

Development of unconventional natural gas resources is an important element of our national effort to reduce carbon emissions from fossil fuels used for power generation. However, it is critical that emissions of methane (a potent greenhouse gas) associated with natural gas resource development and use be minimized in order to maximize any greenhouse gas (GHG) reduction benefit. Cost effective technologies to facilitate the capture and conversion of methane that would otherwise be flared or vented are needed.

In many areas of the country, the oil and gas production process requires the simultaneous production, handling and disposal of large volumes of salt water. Oil and gas wells that have been hydraulically fractured with large volumes of fresh water will flow back a portion of this water loaded with dissolved solids, requiring it to be safely disposed of or reused. Cost effective technologies for cleaning this water to the degree necessary for its beneficial reuse are needed, particularly in those areas of the country where supplies of fresh water are low or decreasing.

Future large-scale capture and storage of CO_2 could be an important element of efforts to reduce GHG emissions and potentially reduce the impacts of climate change. One place where captured anthropogenic CO_2 could be stored is in depleted oil and gas reservoirs offshore in the Gulf of Mexico. Injecting CO_2 into these reservoirs could also result in enhanced recovery of residual oil. The technologies and procedures for offshore CO_2 EOR need to be further developed and refined before this approach can be implemented.

Deepwater oil reservoirs will continue to provide a significant portion of the nation's oil supply for years to come. In some of these Paleogene reservoirs, especially where over-pressured, unconsolidated sands have limited aquifer support, waterflooding is being used to improve recoveries from as low as 20 percent to as much as 65 percent (Li, *et al*, 2013). But waterflooding in deepwater fields presents unique challenges (e.g., permeability impairment of injectors, hydraulic fracturing of unconsolidated reservoir sands, reservoir souring from seawater injection, and limited surface space and reservoir monitoring options). Advanced technologies are needed to help minimize the safety hazards from deepwater reservoirs where waterflooding is a good option.

PURPOSE: The purpose of this RFI is to solicit feedback from oil and natural gas exploration and production companies, academia, research laboratories, government agencies, and other stakeholders. This is solely a request for information and not a Funding Opportunity Announcement (FOA). Based on the input provided to this RFI, and other considerations, DOE may decide to issue a formal FOA for topics identified in this RFI. If a formal FOA is issued, it may be issued under a new FOA number. No FOA exists at this time. DOE reserves the right to never issue a FOA in any of these topic areas.

Respondents shall not include any information in the response to this RFI that might be considered proprietary or confidential.

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

Any information obtained as a result of this RFI is intended to be used by the Government on a non-attribution basis for planning and strategy development; this RFI does not constitute a formal solicitation for proposals or abstracts. In accordance with the Federal Acquisition Regulations, 48 C.F.R. 15.201(e), responses to this RFI are not offers and cannot be accepted by DOE to form a binding award. Your response to this notice will be treated as information only. DOE will review and consider all responses in its formulation of program strategies for the identified materials of interest that are the subject of this request. DOE will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that DOE is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind DOE to any further actions related to this topic.

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

Responses containing confidential, proprietary, or privileged information must be conspicuously marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Federal Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

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

> **Notice of Restriction on Disclosure and Use of Data**:
> Pages [list applicable pages] of this response may contain confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for the purposes described in this RFI, DE-FOA-0001693. The Government may use or disclose any information that is not appropriately marked or otherwise restricted, regardless of source.

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

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

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

CATEGORY 1: Mitigate Environmental Impacts of Unconventional Oil and Gas Development via Dedicated Unconventional Oil and Gas Field Laboratories. DOE's current research program includes field sites in three different unconventional plays (Permian Basin Wolfcamp, Eastern Ohio Utica-Pt. Pleasant, and Pennsylvanian Marcellus Shale). At these locations DOE is partnering with multiple partners to carry out research programs focused on quantifying the impacts to air, water and surface ecology of development, and also on advancing understanding of the hydraulic fracturing process, the effectiveness of different well completion approaches, and the characterization of unconventional reservoirs. Information on these three field sites is available on the NETL web site (http://www.netl.doe.gov/research/oil-and-gas/project-summaries/unconventional-resources). DOE is seeking additional input with regard to the following questions in this area.

1. Should DOE expand the number of field laboratory well sites and if so, which plays and or formations should be targeted?
2. Should additional experiments be carried out at these sites and what are the research needs that should be addressed?
3. What experiments could be carried out, using wells at existing or yet-to-be-created field laboratory locations, which would shed light on ways to locate, drill, stimulate and complete wells in ways that will optimize recovery of natural gas or oil from unconventional plays?
4. What experiments should be carried out to further assess and characterize any environmental impacts to the air, surface/subsurface water or surface ecology resulting from development?
5. Should a field laboratory be implemented that can test the potential for residual oil zone production (ROZ)? What should such a test include?
6. Should a field laboratory well(s) be implemented to de-risk an emerging or smaller (<50,000 Bopde) play (or sub-plays) through research focused on: resource/reservoir characterization; completion optimization (e.g. quantifying impact of lateral length; options for stacked play development, etc.); quantifying and mitigating environmental impacts; or quantifying and mitigating impacts on local infrastructure (e.g., roads)?
7. Should a field laboratory be implemented to test the potential of enhanced recovery of tight oil/shale oil or the environmental impacts of shale oil recovery? Where should such a field laboratory be established, and what should such tests include?
8. Should a field laboratory be implemented to test the use of alternative fluids (non-aqueous) in large volume fracturing treatments (e.g., natural gas)? What should such a test include?
9. Should a field laboratory be implemented to test the potential of improved fracture diagnostic tools? What should such a test include?
10. Should a field laboratory be dedicated to field testing and demonstration of produced water or flowback water treatment technologies, either as an independent project or in combination with another field laboratory identified above?

CATEGORY 2: Prevent the Disposal of Large Volumes of Produced Water. The shale plays being developed across the U.S. currently rely on a combination of horizontal well drilling and high-volume water-based hydraulic fracturing treatments to enable commercial production. Procedures have evolved to develop acreage in an "industrial" fashion with integrated systems to supply water, treat the water with high total dissolved solids (TDS) content that initially flows back after hydraulic fracturing (termed "flowback") for reuse, and dispose of the unusable portion of this flowback as well as other water that is produced from these wells over a longer period of time (termed "produced water"). (NOTE: Definitions for various water categories are at the end of this document.) This approach leads to the permanent loss of large volumes of fresh water and an increased risk of induced seismic activity associated with water disposal wells. Both of these environmental impacts can be mitigated through the development and application of non-aqueous fracturing fluid alternatives. The development of an effective non-aqueous alternative fracturing fluid could potentially enable wells to be as (or more) productive with significantly less fresh water use and brine disposal. DOE is seeking additional input with regard to the following questions in this area.

1. What are the primary barriers to duplicating the well performance possible in shale gas and shale oil plays using natural gas (liquefied or gaseous) as a complete or partial alternative to water? Are the primary barriers equipment limitations, well pad size limits, scale/logistics issues, safety, or cost?
2. What testing or research efforts could help to demonstrate the potential (or lack of potential) for this natural gas approach? If the barriers are equipment limitations, what research needs to be done to design and validate new blending and pumping systems?
3. Is there a need for further research into the impact on productivity, positive or negative, from using water as a hydraulic fracturing fluid in various shale formations? Do we understand the impact on formation permeability of the choice of water as a fracturing fluid? What research needs to be done to answer any unknowns?
4. Do we need fundamental laboratory research to document the rheological properties of non-aqueous fluid and proppant mixtures over a wider range of temperature, pressure and pumping rate values? If so, what would be the range of specifications to investigate?

(Note: DOE is not seeking information related to microwave, radio frequency, propellant-based or other explosive approaches to fracture stimulation that do not create propped fractures that extend at least as far into the reservoir as those created via high volume water-based hydraulic fracturing treatments.)

CATEGORY 3: Technologies for Improving Hydraulic Fracture Diagnostics. Accurately estimating the dimensions and other characteristics of created hydraulic fractures has long been a goal of well completion engineers. Improved fracture diagnostics leads to increased recovery efficiency per well and ultimately reduced environmental impact per unit of energy produced. Micro-seismic fracture mapping is currently seen as the only way to obtain an independent characterization of a hydraulic fracture's length and height, but this option is expensive and remains less than completely accurate in all situations. New approaches to independently measuring fracture height, length and (potentially) conductivity are needed. DOE is seeking additional input with regard to the following questions in this area.

1. DOE has funded three recent research projects focused on fracture diagnostics: electromagnetic induction using conductive proppants, injection and tracking of micro-seismic emitters, and deep subsurface resistivity imaging. These projects are summarized here (http://www.netl.doe.gov/research/oil-and-gas/project-summaries/unconventional-resources). Are there other approaches, including applications of high-performance computing (HPC), to enhancing our understanding of fracture dimensions and characteristics and if so, what are they and how might they be investigated?
2. What are the technical and economic barriers, if any, to wider use of micro-seismic fracture mapping as a method for characterizing hydraulic fractures?
3. What subsurface experiments might be carried out at a field laboratory (see Category 1 above) that would significantly enhance our understanding of fracture diagnostic methods?
4. What laboratory experiments might be carried out to significantly improve the accuracy of fracture diagnostics using current methods?

CATEGORY 4: Understanding and Avoiding Induced Seismicity. Research carried out over the past five years by DOE, U.S. Geological Survey and others has begun to shed light on the relationship between wastewater injection and seismicity. This is particularly important due to the need for disposal of increased volumes of high TDS flowback water produced during the hydraulic fracturing of shale oil and gas wells and subsequently required to be disposed of in wastewater injection wells. While we have learned some important facts (e.g., triggering of induced seismic events is statistically linked to injection rate, maximum magnitudes appear to be related to volumes injected, seismicity dies down quickly when injections are halted, not all wastewater wells produce quakes) some questions remain. DOE is seeking additional input with regard to the following questions in this area.

1. What would be the best approach for carrying out field experiments that include detailed characterization of the subsurface, controlled injections, and combined sensing/imaging and monitoring operations, in a manner that minimizes risks of damage but maximizes scientific impact?
2. What locations and/or partnering relationships would best suite these experiments?
3. What are the key unknowns that limit our ability to effectively regulate wastewater injection volumes/rates/locations in a manner that significantly reduces the risks of damage from induced seismicity?
4. What research is needed to eliminate these unknowns?

CATEGORY 5: Beneficial Reuse of Water Produced from Unconventional Oil and Natural Gas Wells. High volume hydraulic fracturing of shale oil and shale gas wells requires the use of large volumes of fresh water. While much of this water remains underground, as much as 30% returns to the surface containing significant amounts of dissolved solids. Much of this flowback water is treated as wastewater and pumped into deep disposal wells. The economics of cleaning and reuse vary from play to play and depend on the chemical makeup of the flowback water, the relative costs of disposal versus treatment and reuse, and both supply and demand for fresh water within the region.

Many companies and organizations, including DOE, have made significant R and D investments over the past decade or more in an attempt to lower the cost of treating this water to a point where it can economically be reused for both oilfield and non-oilfield purposes. However, the treating costs rise rapidly with the level of cleanliness achieved, and more often than not treatment technologies cannot compete with the option of disposal, except in a few niche markets.

Developing technologies that can lower the cost of water treatment still further would be of significant value in reducing the cost of unconventional resource production and in reducing the demand for freshwater in water stressed areas. In order to decide what efforts deserve additional focus and funding, DOE is seeking additional input with regard to the following questions.

1. What specific basic science or technology development challenges must be solved to achieve a treating cost of $0.08 per barrel ($0.50 per cubic meter) for an output with total dissolved solids (TDS) levels suitable for both hydraulic fracturing and agricultural use?
2. Are there treatment technologies that are “market ready” or very near market ready that can compete with transport and disposal in specific plays or basins? If so, could a demonstration pilot test or a specific research finding move a technology into the marketplace?
3. What system integration advances are needed to most effectively employ new breakthrough technology/systems (including sensors, controls, and computation/data/artificial intelligence capabilities)?
4. What challenges are there for market penetration by such technologies, including water treatment technologies currently being implemented in offshore operations (e.g., resistance to disruptive technologies, regulatory policies, capital investment requirements, or other perceived risks)?

CATEGORY 6: Reduce and Mitigate the Risk of Oil Spills due to Geological Uncertainty. Improving our understanding of subsurface hazards and minimizing safety risks associated with drilling through unknown pressures and fluids, and deepwater hydraulic fracturing is important in reducing the risks of an offshore release of hydrocarbons and other fluids. Waterflooding in deepwater fields presents unique challenges (e.g., hydraulic fracturing of unconsolidated reservoir sands, shale instability, and reservoir monitoring options). Advanced technologies are needed to help minimize the safety hazards from deepwater reservoirs where waterflooding is a good option. New data acquisition and remote sensing capabilities can provide higher resolution of subsurface detail prior to drilling and ahead of the bit during drilling, and during operations. DOE is seeking additional input with regard to the following questions related to deepwater reservoirs:

1. Is there a need for additional research for hydraulic fracturing models and/or techniques for these very deep and/or unconsolidated GOM reservoirs?
2. What other completion/stimulation research or best practices studies would be appropriate for Federal funding support?
3. Is there a need to improve our ability to predict the occurrence of thin sandstone intervals or unstable shales that could represent over-pressured zones ahead of the bit, or wellbore stability issues? If so, what are the potential solutions to this challenge and the key research needs associated with meeting those challenges?
4. Is there is a need for improved technologies for passive acoustic monitoring that would acquire high-quality seismic data while remaining compliant with the Marine Mammals Protection Act? If so, what are the highest priority research needs?
5. Is there an opportunity to adapt information from other domains (communications, navigation, radar, etc.) where relatively mature techniques are used to handle stochastic information and extract information from low resolution data, in order to achieve high resolution interpretations? Could such an approach enable a significant technology leap forward by allowing reservoir dynamics interpretation using remote sensing? What might be the research objectives of an effort in this area?
6. Is there a need to improve our ability to map and model sub-salt sediments to assist in determining if some areas are more prone than others to overpressure? Similarly, is there a need for improved overburden characterization? What would be a good example of a federal role in carrying out research to better predict the potential for an event that could negatively impact safe operations?
7. Is there a need for additional research into methods and technologies for improving knowledge of the seafloor prior to drilling, including the use of autonomous utility vehicles to record seeps and other ocean bottom activity? If so, what are the key research needs?
8. Is there a need for improved logging technologies that can accurately and reliably represent the *in-situ* stress state of the rock? If so, what are the key research needs?
9. Is there a need to improve our understanding of rock (sand, shale) interactions with oilfield mud, injection waters, and chemicals under various pressure and temperature conditions, at the microscopic and submicroscopic level, over time?
10. Are there research and testing efforts that could accelerate development of the next generation of geochemical sensors with the potential for detailed geologic characterization of both formation and *in-situ* fluids downhole in real time?

CATEGORY 7: Reduce and Mitigate Risk of Oil Spills during Well Operations. DOE has previously funded research that focused on reducing risks during the drilling, completion, and intervention/workover phases of offshore wells. Deepwater water injector well failures, out of zone injection and reservoir souring from deepwater seawater injection have also been identified as challenges. Improved hydraulic fracturing diagnostics and accurate fracture modeling is seen as areas that could help in the containment of hydrocarbons and other contaminants within injected zones. Seawater contains anaerobic organisms leading to increased concentrations of H2S which is toxic and corrosive, leading to corrosion of steel in well tubulars, pipelines, and process facilities. Accurate predictions of souring and proper selection of materials can ensure the long-term integrity of casing and facilities. While much is known, additional research could help identify ways to prevent or mitigate souring in deepwater waterfloods. In order to decide which of these efforts deserve additional focus and funding, DOE is seeking additional input with regard to the following questions.

1. Is there a need for improved technologies for the re-entry of wells, particularly in deep water locations, in order to carry out repair, maintenance or abandonment operations? If so, what are key research needs associated with the development of such technologies?
2. Is there a need to develop improved technologies that can reduce the need for re-entry during a well's producing life (e.g., sand control, cement job integrity, downhole flow control hardware)? If so, what are key research needs associated with the development of such technologies?
3. There are thousands of offshore wells that need to be plugged, particularly in shallow water, but this is difficult to accomplish cost-effectively and safely. In the past, wells were not designed with future plugging in mind. In addition, some of the records of shallow water wells are inadequate, and it can be difficult to even locate these wells. What new approaches are needed to address this problem and what are key research needs associated with such approaches?
4. Maintaining wellbore integrity is an important issue for all wells but particularly for wells where high temperature, high pressure, H_2S, and CO_2 are present. What are the critical research needs associated with improving wellbore integrity: materials development (e.g., elastomer seals, alloys), cement formulation and testing, cement quality control, or other needs?
5. Is there a consensus on "best practices" for deepwater waterflooding or does the variation in reservoir conditions, infrastructure and operations differences make this unlikely? Would an effort to develop such guidelines be useful?
6. Is there a need for improved modeling capabilities or other research and development (R and D) to better predict the tendency for out-of-zone injection and well impairment under a variety of conditions?
7. Is there a need for improved sensors to enable advancements in surveillance of downhole pressures? What research needs to be done to move such capabilities forward?

CATEGORY 8: Reduce and Mitigate the Risk of Oil Spills from Surface/Subsurface Systems and Deepwater Infrastructure. DOE has funded research focused on improving the safety and effectiveness of surface and subsurface facilities in deepwater. In order to decide which efforts deserve additional focus and funding, DOE is seeking additional input with regard to the following questions.

1. All-electric subsea systems could be more reliable and environmentally safer than existing hydraulic systems. What are the key challenges to developing safe and cost-effective alternating current (AC) and direct current (DC) systems that can meet the power needs of subsea equipment? What research, testing and demonstration projects would be best for catalyzing development of such systems? Is there an opportunity to transfer technology from

onshore to offshore in areas such as power generation, power transfer and distribution systems, and switching and control systems?

2. Are there opportunities for DOE to integrate the federal network of satellites and ocean based sensor systems with data from the maritime industry and Department of Defense assets, to develop and analyze metocean data in ways that would be useful for improving the design criteria for large-scale deep water production systems? If so, what should be the primary objectives of such an effort?
3. There is a need for new materials, including lighter weight composites and advanced alloys with improved safety and long-term durability characteristics, for use in manufacturing of critical elements of offshore systems. In particular, such materials could be useful in the creation of "next generation" umbilicals, light-weight risers, and components capable of achieving long-term reliability under HTHP/HTLT and corrosive environmental conditions. What are the key research needs in this area? Federal laboratories have expertise in specialty steels and ceramic composites. Are there important contributions that could be made by these labs to advance knowledge in these areas?
4. What are the primary challenges to developing the improved sensing and automation technologies necessary to enable safe and highly reliable remote operation of unmanned surface production facilities? Are there critical testing and demonstration programs that could catalyze or accelerate development of such systems?
5. Initial findings for preventing excessive surface facility congestion to reduce deflagration to detonation risk have provided new insights to facility design. Is more work needed in this area of research?
6. What priority would you attach to research into advancing any of the following technologies: dry tree systems, seafloor drilling systems, and enhanced subsea sensors and measurement tools?
7. Is there a need for improved enhanced protective measures against cyber-terrorism and/or cyber failure given the extensive deployment and networking of offshore IT? If so, what are the priority research needs associated with this area?
8. Is there a need for enhanced blow out prevention (BOP) systems? If so, what are the research needs for improving BOP design, instrumentation, and testing?
9. Is there a consensus on "best practices" for reducing the potential for reservoir souring in deepwater waterflooding? Would an effort to develop such guidelines be useful?
10. Is there a need for improved modeling capabilities to predict the likelihood of reservoir souring under a variety of conditions?
11. Is there a need for improved sensors to enable advancements in detection of souring in situ? What research needs to be done to move such capabilities forward?
12. What research is needed to develop methods (e.g., scavengers) for mitigating souring once it has occurred?
13. Are there any other issues associated with reservoir souring for which there is a Federal role?

CATEGORY 9: Approaches for Eliminating Flaring and Direct Venting of Natural Gas Prior to, During and After Production. Venting and flaring contribute significantly to the oil and gas industry's greenhouse-gas emissions of methane and CO_2, respectively. The U.S. DOE Energy Information Administration reports that since the early 1990's, venting and flaring of natural gas in the U.S. has ranged between 100 and 300 Bcf per year. In 2013, gas flaring contributed 15.9 million tonnes of the greenhouse gas CO_2 to the atmosphere. While venting and flaring is currently controlled by a patchwork of state and federal regulations, DOE is seeking information on cost-effective methods and technologies that can radically reduce these emissions:

1. What options are currently available to reduce flaring and venting of natural gas from oil and gas operations?
    a. How widely employed are these options in the U.S. and globally?
    b. Are these options currently underutilized, and if so why?
    c. What are the emissions reduction potential and cost limitations of these options?

    Where possible, please address answers to the questions above, to specific categories of flaring and venting.[1]
2. What level of reduction in venting and flaring do you believe is achievable with and without advanced technology development over the next five, ten or fifteen years?
3. What technology advances do you believe could significantly reduce production-related flaring and venting? Please consider technologies for:
    a. *Reducing* the generation of these waste streams (*e.g.*, temporary storage or early pipeline construction),
    b. *Reusing* methane (*e.g.*, re-injection),
    c. *Energy Recovery* for on-site or local use (*e.g.*, combined heat and power, LNG, CNG),
    d. *Carbon Recycle* to convert methane and other light hydrocarbons found in natural gas to liquid fuels and chemicals (*e.g.*, methanol).
4. Are there other approaches to reducing flaring and venting that you would like to bring to DOE's attention?

CATEGORY 10: Approaches for Eliminating the Venting of Process CO_2 during Natural Gas Processing and Reducing CO_2. DOE currently has on-going R and D efforts related to carbon capture, utilization, and storage. However, these efforts are primarily focused on the reduction of CO_2 emissions from large, coal-fired power plants. Achieving net-zero carbon emissions to the atmosphere will require emissions from smaller point and mobile sources to be mitigated. DOE is seeking information on methods and technologies that can radically reduce these emissions, which are of specific interest to the oil and gas upstream sector and are not currently being adequately explored by the DOE:

1. What technology options (absorption, adsorption, membranes, cryogenic fractionation, other) are currently preferred for the removal of CO_2 from wet natural gas?
    a. How much is currently being vented versus injected?
    b. What are current uses for this gas?
    c. Does the CO_2 require further treatment for these or other uses?
    d. Are there other CO_2 removal technologies specific to gas processing that are not currently being addressed as part of DOE's Carbon Capture and Storage R and D Program?
2. What are other possible uses for CO_2 removed during gas processing (*e.g.*, hydraulic fracturing, enhanced oil or gas production, waste water treatment, geothermal energy production, saline water extraction and purification)?
3. What technology advances do you believe could significantly reduce fuel combustion-related CO_2 emissions? Please consider technologies for:

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[1] Routine venting or flaring is continuous or intermittent and occurs on a regular basis during normal process operation. Non-routine venting or flaring can be unplanned or planned. Unplanned venting or flaring of gas occurs automatically in response to an emergency or operational upset and is necessary to prevent damage to equipment and provide for personnel safety. Planned venting or flaring is done intentionally and is associated with well testing, well unloading, and operation start-ups and shut-downs. Typically, planned events are of short duration; however, in cases where the gas is stranded, events can last for a significant duration, on the order of years or even longer if unregulated.

   a. *Reducing* these emissions through *efficiency improvements* to boilers, combustion turbines, and engines, or *fuel switching*, the substitution of low-carbon energy sources (e.g., compressed natural gas/liquefied natural gas for diesel fuel, solar heating),
   b. *Carbon Recycle* to convert CO_2 (possibly along with methane and other light hydrocarbons) to liquid fuels and chemicals (*e.g.*, methanol).
4. Are there other approaches to significantly reducing CO_2 emissions from oil and gas production, and natural gas processing that you would like to bring to DOE's attention?

CATEGORY 11: Developing Scalable Technologies for In-field Conversion of Methane-rich Gas to Fungible Products. Such technologies could have an immediate and significant impact on reducing associated natural gas flaring and related emissions. DOE is seeking information on the current state-of-the-art with respect to development and demonstration of technologies for use in small-scale gas-to-liquids or chemicals conversion processes. Specifically, what development challenges exist and what might be appropriate R and D needs with respect to:

1. Novel process equipment that are modular, compact, integrated, and mobile for use in conversion processes (*e.g.*, membrane-based syngas generation reactors, compact three-phase reactors, and advanced bioreactors),
2. Modular design, manufacturing and deployment of standard components of these processes (*e.g.*, existing modular design and design for assembly methods, along with emerging 3-d and 4-d printing technologies), and
3. Nanotechnology and biotechnology applicable to small-scale process technology (*e.g.*, new materials, including: ultra-selective and multifunctional catalysts and organisms for synthesis and upgrading, atomically-thin membrane materials for gas separations, organic framework-based sorbents for intermittent gas storage)?

CATEGORY 12: Improving Supply-Chain Options for Distributed Processing of Natural Gas and CO_2. The options identified in Categories 8-10 above, for the utilization of unconventional and underutilized natural gas resources, will also require improving the economics of transporting small and possibly intermittent quantities of natural gas, CO_2, and various conversion products from the field to markets. DOE is seeking new concepts that can be translated into low-cost solutions to this transportation problem. Specifically, what development challenges exist and what might be appropriate R and D needs with respect to:

1. Novel supply-chain management strategies (*e.g.*, spoke-and-hub supply configurations) addressing the logistics of operations in remote, not easily accessible locations,
2. Novel technologies for densifying gases for storage and transport, and
3. Low-cost, high-strength materials for holding and transporting small quantities of liquids and high-pressure gases?

CATEGORY 13: Technical and Economic Feasibility of Offshore CO_2 Transport, Handling and Injection. The extension of CO_2 injection to offshore reservoirs for either sequestration or EOR purposes will require transport, handling and injection equipment and methods to be adapted for offshore conditions. These include subsea location of pipelines, space limitations, and corrosive environments. DOE is seeking additional input with regard to the following questions:

1. What are the primary technological limitations, including new materials-based technology, on transporting and injecting supercritical CO_2 at offshore locations?
2. What research is needed to advance the technical feasibility of offshore CO_2 injection and recycling of produced CO_2 in the case of EOR applications?
3. Are there challenges unique to the offshore environment that preclude or complicate the application of established best practices for CO_2 EOR based on onshore industry experience?

CATEGORY 14: System Integration for Offshore CO_2 Injection Projects. The extension of CO_2 injection offshore may require entirely new approaches and tools for monitoring subsea and subsurface activities. Future CO_2 storage projects will need to adhere to very high safety standards to reduce the long-term risk of leakage. This could require new sensors, data acquisition systems, and models. DOE is seeking additional input with regard to the following questions:

1. Are there ways to leverage existing infrastructure and/or field test advances in subsea technology that can reduce the need for platform modifications to enable offshore CO_2 EOR?
2. What needs to be done to adapt established oil and gas industry reservoir monitoring tools, especially with regard to data processing and interpretation, for CO_2 storage or EOR?
3. Is there a need for new marine sensors or underwater platform technologies (e.g., automated underwater vehicles or mini-remote-operated-vehicles) to support offshore CO_2 storage or EOR?
4. Is there a need for advanced real-time data retrieval from integrated *in situ* sensors to monitor offshore CO_2 injection at the levels required of onshore projects?

CATEGORY 15: Technically Recoverable CO_2 EOR Resources. DOE has assessed the potential for CO_2 EOR offshore in the Gulf of Mexico and determined “next-generation” EOR technologies could enable the recovery of significant volumes of oil (Malone, *et al*, 2014). It is estimated that technologies that improve conformance, advance flood design, enhance mobility control and increase efficiency could make more than 14 billion barrels technically recoverable from offshore fields. For some time DOE has carried out R and D focused on methods for improving the sweep efficiency of injected CO_2 in EOR projects (Enick, 2012). NETL also has several recently completed or currently underway projects focused on this topic (summaries can be found here http://www.netl.doe.gov/research/oil-and-gas/project-summaries/enhanced-oil-recovery). While it is recognized that two of the most important factors in CO_2 EOR project success are the price of oil and the availability of a steady and reasonably-priced supply of CO_2, new technology advancements are also needed to improve the chances of success. DOE is seeking additional input with regard to the following questions.

1. What “next generation” technologies are needed to reduce the technical and economic risks of CO_2 EOR projects, either onshore or offshore?
2. What steps could be taken to decrease the likelihood that offshore infrastructure will be abandoned before EOR projects are considered, dramatically reducing access to reservoirs for either CO_2 storage or EOR?
3. What design modifications could be considered for new or existing platforms, wells, or other nearshore/offshore infrastructure that would facilitate the eventual implementation of CO_2 injection projects?

REQUEST FOR INFORMATION RESPONSE GUIDELINES: Responses to this RFI must be submitted electronically to RFI-UOG@netl.doe.gov, no later than 8:00 pm (ET) December 16, 2016. Responses must be provided as attachments to an email. Responses must be provided as an editable Word document or PDF file attachment to the email not larger than 10MB in size, no more than three pages in length per category addressed, single spaced, 11 point font, one inch margins. Only electronic responses will be accepted.

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

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

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

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

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DEFINITIONS

Flowback water: After the hydraulic fracturing procedure is completed and pressure is released, the direction of fluid flow reverses, and water and excess proppant flow up through the wellbore to the surface. The water that returns to the surface is commonly referred to as “flowback”

Produced water: After the drilling and fracturing of the well are completed, water is produced along with the natural gas. Some of this water is returned fracturing fluid and some may be natural formation water. These produced waters move back through the wellhead with the gas, and flow to the surface throughout the entire lifespan of the producing well. The transition point for referring to water as “produced water” versus “flowback” is not standardized.

Wastewater: Includes both flowback and produced water, and is dealt with in one of several ways, including but not limited to: disposal by underground injection, treatment followed by disposal to surface water bodies, or recycling (with or without treatment) for use in future hydraulic fracturing operations.