RPSEA R&D Plan

2018
“Keeping it going for the long haul”
The Easy Stuff is Gone

www.rpsea.org

Tom Williams,
President
This document is the Research Partnership to Secure Energy for America (RPSEA) R&D plan (PLAN). This will allow us and our key stakeholders to prioritize our focus, as well as provide a roadmap for industry and policymakers to work together to address oil and gas challenges through research and technology transfer. RPSEA has been a focal point for the industry to address technical challenges over the past decade in a collaborative manner. This PLAN takes advantage of this network of the leading subject matter experts, looking at challenges best addressed through investments in R&D, providing value in terms of energy security, jobs and the economy while improving safety and environmental performance for the next decade. No one knows what the energy industry will look like in the next ten years, but we do know in order to maintain our leadership position, the United States must compete on a global basis, take full advantage of rapidly evolving technology and address the variety of challenges we will face. It is not sustainable to compete and be profitable offshore if new technologies and equipment are just bigger and more expensive; if the time from discovery to production is not reduced; and if advances are not made to better assure safety and environmental performance. We know we must improve efficiencies for onshore operations, while increasing the recovery of each well drilled, and investments are needed to assure operations are conducted in the safest and most environmentally responsible manner possible. It can be done!

The title: “Keeping it going for the long haul – the easy stuff is gone” is the reason we must prioritize our research investments on the key targets including:

- Technologies that will improve safety and environmental performance;
- Onshore emerging and developing shale plays;
- Offshore satellite fields; and
- Improved recovery for onshore and offshore reservoirs.

This PLAN is evolutionary and builds upon the foundation of the successful program described in the Final Report for the Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Resources Research and Development Program (Program) established pursuant to Title IX, Subtitle J, Section 999 (Section 999), of the Energy Policy Act of 2005 (EPAct). The U.S. Department of Energy (DOE), through its National Energy Technology Laboratory (NETL), provided program oversight. That report covers the period from 2007, when research began, through 2016, when the “999 program” funding ended, and builds a foundation for work that can be conducted in the future.

RPSEA, working with the U.S. Department of Energy NETL, successfully managed over 170 projects utilizing $350 million including cost share. The projects, several of which
are already commercial, have resulted in improved safety, reduced environmental risk and increased energy security. The research generated over $150 billion in direct economic value from jobs, royalties and revenue. It yielded over $40 billion in environmental damage mitigation. As evidence of its successful technology transfer program, over 5,000 articles were published documenting their results.

The Final Report describes each of the program elements and includes descriptions of specific projects that illustrate successful technology development efforts funded through the program. The report also includes a summary of technology transfer efforts, which have reached a worldwide audience, resulting in accelerated and highly successful implementations of newly developed technologies. The Final Report documents the most successful public private partnership for oil and gas R&D in the U.S. and lays the foundation for future research endeavors. Section 999 funded investments in R&D from the Federal royalty trust fund, which provided certainty, stability and continuity to research efforts. RPSEA’s successes are also due to its members providing hundreds of subject matter experts, contributing thousands of hours in directing the program. Future programs should follow the same processes and funding mechanisms and build upon the lessons learned described in the report. The result is increased success rates, shortened cycle time from concept to application, and maximum return on investment.

While the original intent of the Section 999 was to “maximize the value of natural gas and other petroleum resources of the United States” none of that value will be fully realized if the targeted resources cannot be developed in a safe and environmentally sensitive manner. The Deepwater Horizon incident prompted industry to reevaluate its approach to risk management as applied to all exploration and development operations. An important component of RPSEA’s PLAN is to ensure that the risks associated with the development of offshore and onshore resources are fully understood, and that the means are available to fully mitigate those risks with respect to both prevention and recovery.

The model RPSEA has developed involves the active engagement of stakeholders across the entire community of energy producers, researchers, technology providers, regulators, and environmental groups. The best efforts of the research community are required to identify challenges and develop the technology necessary to safely deliver hydrocarbons from the targeted resources. However, the knowledge residing with producers and service companies is crucial in providing effective direction for the needed research. Effective Technology Transfer is essential. Further, the rapid transfer and application of new ideas and results will be facilitated by the continuing involvement of producers and service companies in the planning and execution of the research program. The emphasis on safety and environmental sensitivity reflected in this PLAN will require more direct involvement and communication with the regulatory agencies and the environmental community.
The safe and environmentally sensitive delivery of secure domestic hydrocarbon resources to the citizens of the United States is not the only outcome of the research conducted under this program. While the U.S. is currently a leader in terms of the development of oil and gas (in particular, the onshore unconventional shale resources), other nations are beginning to see these resources as an important component of a plan to move toward a lower-carbon, sustainable energy mix. While development of these resources in the U.S. directly yields thousands of high-paying domestic jobs, research efforts funded by RPSEA’s program are helping to keep U.S. companies and universities in the forefront of energy technology worldwide.

This PLAN was developed through member and key stakeholder involvement, RPSEA conducted surveys, focused program advisory meetings, and meetings with industry leaders. RPSEA also asked leaders to identify the grand technical challenges, then identifying target enabling technology needs, and the R&D required to develop technologies. The PLAN also incorporates information from publications, presentations and reports from technical organizations, government, science and industry associations.

This plan has identified the need for R&D funding that in most part does not exist today. Feedback from our survey also includes the need for big challenges that will be a priority, an example is:

We have over a million wells in the US onshore and offshore, in deep and shallow water and in areas of the Arctic. In all these areas, there is significant opportunity to increase the recovery factor per well. The big challenge is how to increase production from existing wells and known discoveries in a cost-effective manner without drilling a number of new wells. This challenge requires cooperative efforts from the geoscience, reservoir engineering, mechanical and chemical engineering and production fields. A related challenge is to extend the life of a well, with aging infrastructure above and below the ground, beyond its intended life design, addressing economic, safety and environmental challenges.

RPSEA manages an onshore and offshore program. Elements of the offshore program will include addressing harsh environment challenges such as operations in the arctic, deep water and reservoirs with extreme high pressure and high temperature. Our onshore program addresses efficiencies that can be gained through new technology, that will provide a positive long-term improvement on production, environmental performance and jobs. RPSEA also strives to work with and support Federals agencies at the Department of Interior and Energy and with energy producing States. The RPSEA R&D plan focuses on all these areas and provides new technology and processes to industry and regulators, to address the big challenges the oil and gas industry faces today and will face into the future.
Founded in 2002, RPSEA is a unique 501(c)(3) non-profit, national consortium that provides focused research and development to deploy safe and environmentally sensitive technology that can deliver hydrocarbons from domestic resources to the citizens of the United States. Its membership consists of nine of the nation’s premier research universities, five national laboratories, other major research institutions, large and small energy producers, and energy consumers. www.rpsea.org
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**RPSEA R&D PLAN**

**Objectives**

The oil and gas industry’s challenges today are driven by operating profitably during a time of low commodity prices and the need to meet expectations in safety and environmental performance. Prices will always be volatile, as will the cost to drill, complete and produce. When prices are low, and the profit is “razor thin” funding for research is significantly reduced – the time when it is needed the most. This is one of the primary reasons a long-term program is needed. This is one of the fundamental reasons the Energy Policy Act Section 999 helped establish the funding for RPSEA. As part of the requirement for the funding RPSEA was required to develop an annual Research Plan. This was submitted to the DOE and who provided it to Congress. During the Sunset process of the Section 999 program and RPSEA this process stopped, with the last plan developed in 2011. The DOE and Congress did not have the value of the hundreds of subject matter experts, spending thousands of hours developing an R&D plan. Just think about how much has changed since 2011 US production was still decreasing and the “Shale Revolution” was still in its infancy, the commodity prices increased, activity took off, new technologies advanced; and then prices and activity dropped precipitously.

This PLAN has identified many of challenges facing the industry that can be addressed through investments in R&D, utilizing the strength of our membership and partners. RPSEA’s public private partnership model has demonstrated the unique capability to provide a platform of industry technical practitioners, academic experts, institutions and government labs with a combination of world class capabilities and resources. This PLAN describes the foundation for how RPSEA will continue to provide highly leveraged, high returns on R&D investments.

In its report “Prudent Development: Realizing the Potential of North America’s Abundant Natural Gas and Oil Resources”, released on September 15, 2011, the National Petroleum Council (NPC) stated that “In a competitive global business environment, where companies have the ability to move capital around the world, a dependable and affordable supply of natural gas and oil is important for creating economic growth, investment, and jobs in the United States.” It is the goal of the program described in this PLAN to ensure that the technologies necessary to provide that “dependable and affordable supply” in a safe and environmentally responsible fashion are available to domestic producers, while developing the skilled workforce that will maintain the United States in a global leadership position with regard to critical energy technology.
It is important to understand that the Program mission cannot be achieved without a vibrant and diverse technical workforce of scientists and engineers. This entails a strong organizational commitment to the engagement of the academic and research community, and a Program structure that specifically enables their unique problem-solving and innovation capabilities. The active engagement of the research community ensures that the program is able to look-ahead toward future challenges as well as respond effectively to current needs. This robust R&D emphasis also supports the nation’s intellectual capital, helping to maintain America’s global technological leadership position, as the universities are the training ground and consequently the source for this skilled workforce.

RPSEA works to educate both the professionals in the oil and gas industry and the general public on the issues surrounding technology development and deployment and the corresponding public benefits.

As such, RPSEA:

- Works with universities and other researchers to ensure that new technical advances are directed and applied toward the key challenges associated oil and gas resource development in the U.S.
- Works with industry to enhance technology transfer and deployment, demonstrating technology utilization as technologies are developed
- Coordinates outreach efforts to ensure that the results of successful trials and experiments are made widely available

While RPSEA does not advocate, we provide information that encourages public to better understand how of the natural gas and oil industry is both an innovator and consumer of technology solutions and our commitment to the environment and safety.

It is also critical to acknowledge the importance of a collaborative partnership with industry to the success of the mission. Academic research, while absolutely necessary, is clearly not sufficient. Industry, as the ultimate end user investing in the application of the technologies developed in this Program, must play a key, and in many instances, lead role in technology development. This is particularly true as projects move to the development and demonstration phase.

**The Development of this PLAN with an assurance the investments and results are documented**

RPSEA conducted surveys, workshops and one-on-one member meetings. We asked members to review a prior list of objectives in the R&D process that would best assure that R&D is applied. They include:

1. Identify Technology Needs
2. Technology Research & Development, and Applied Science
3. Project Champion and Cost Share is required
4. Technical Development and Field Qualified
5. Environmental and Safety Technology Development and Deployment
6. Technology Demonstration

Feedback noted that this list needs to include a way to better assure projects funded require a quantifiable or measurable goal. This may be requiring a commercial plan or to identify the measure of success.

Potential metrics might include jobs creation, increased production, energy security, and ensuring public confidence in regulatory decision-making through science-based assessments and risk prediction. In addition to a commercial success, jobs, barrels produced, it includes results from study for policy or open source data used by others.

Another recommendation was to prioritize the Technical Readiness Level (TRL) level for funding. In other words, RPSEA needs to work with organizations that can provide early development, or basic R&D that could feed RPSEA. On the other end, there was a discussion on the high TRL levels. Even though the RPSEA process requires an end user, without funding for testing and demonstration, many projects/technologies will never be applied. This has been a flaw in DOE funding in the past, as many good ideas and potentially valuable technologies were never commercialized.

The surveys also asked to identify priority enhancing technology topics coupled with a list of enabling technologies that allow the priority need to be achieved. The PLAN defines a challenge and the enhancing technologies provide the means to “get there”.

Well defined challenges and issues facing the onshore oil and gas industry in the U.S. challenge universities, oil and gas producers and service companies to work together on solution goals. Feedback provided emphasis on the value that end users provide in being involved in the research. This supports the processes RPSEA has developed to assure project accountability and relevance. The objective in this PLAN is to identify the areas where we should focus R&D investments in the future. These are our program goals.

RPSEA also conducted literature searchers from trade publications and technical papers, conducted workshops with industry associations and stakeholders who were not RPSEA members, and surveys of state regulators, who RPSEA believes are also key stakeholders.

The RPSEA final Report found on at [www.rpsea.org](http://www.rpsea.org) Reports documents the roles of a successful Public/Private Partnership. The sections on lessons learned and recommendations are an excellent model for future endeavors.

**Project Identification Process**

One of the primary differences from oil and gas research proposals initiated from the Federal Government is the Agency (DOE or DOI) is provided appropriated funds from
Congress. They use their best judgment to identify areas for research and the amount of funding needed to carry out projects. Congress may get some guidance from DOE, associations, academia or groups seeking funds. Based on the funds and topics the Agency draft a request for proposals based on their understanding of the challenges and objectives appropriated and then following Federal Acquisition Regulation guidelines solicit proposals, make and manage awards.

The RPSEA program on the other hand to identify projects has had funding authority oversight from the DOE on general topics and challenges developed through the RPSEA annual research plan. The RPSEA request for proposals are developed with input from subject matter experts in the technical advisory committees. The process uses a Cost Time Resource (CTR) Sheet. The CTR sheet has been used by years by industry when developed research proposal solicitations and is also used by researchers when they have an idea they want to be considered for future funding. This is a proven process that includes:

- Current Technology Gaps
- Objective: & Value Targets
- Deliverables by Gate/ Go-No go decision point (development building block, end point, prerequisites, etc.)
- Quality expectations (key metrics to measure deliverable success)
- What gaps will the project close with a successful completion?
- Estimated Budget and Timing

**Project Selection Process**

When government funds are available RPSEA solicits proposals with a good idea on the scope, cost and timing because of the proposal identification process and CTR’s. The requests are also divided into functional areas that are closely aligned to the recommendations from the Technical Advisory Committees. Non-conflicted evaluators are chosen from the RPSEA members and industry based on the particular subject matter expertise on content of the proposals. Three or more reviewers provide technical evaluations of the proposals within each topic area. To the greatest extent possible, all of the proposals within a topic area are evaluated by the same set of reviewers.

The Program Advisory Committee (PAC) recommends proposals for funding based on the technical evaluations and the priorities associated with the various topic areas and targeted resources. The highest priority topic area proposals that address the most compelling or critical needs associated with the portfolio and that meet the objectives outlined in the Annual Plan are given the most weight in project selection, although all proposals with competitive technical review scores are considered for funding. The PAC considers factors such as balance among the time scales associated with technology, leveraging or other association with other competitive or complementary R&D, diversity of technical approach, and offshore program future funding levels when developing a
portfolio of projects intended to maximize the probability of meeting program goals. Safety and Environmental considerations and benefits are also considered.

The evaluation criteria for funding was designed to encourage partnerships between oil and gas producers and research organizations. Partnerships were encouraged in order to facilitate the transition from research to application. In addition, the solicitations encouraged oil and gas producers, who may not be familiar or have expertise in proposal submissions, to partner with universities, research organizations and service companies, who are familiar with this process. This process is a significant improvement on funding solicitations from the Department of Energy or Interior, and encouraged more qualified proposal teams with less wasted investments in unsuccessful proposals.

Awards are made with a defined technology and resource development plan, diversity of technical approach, and the geographic distribution of targeted resources when developing a portfolio of projects intended to maximize the probability of meeting program goals.

This PLAN recommends that future research funding allows portfolios designed to be balanced in order to include projects that focus on near- mid- and longer-term metrics; as successful and promising projects progress. A successful program must be committed to assuring these promising technologies are applied and commercialized. Recommendations for a portfolio of projects specifically should:

- Create leverage wherever possible on funding, personnel, equipment, operations, and other resources;
- Create synergies through integration or investments in cross-cutting and enabling technologies, allowing the whole to be greater than the sum of its parts;
- Allow for investment in high-risk, high-reward activities and ensure that good project management derives maximum learning benefit from failures that are expected from a portfolio with an appropriate risk profile;
- Avoid the funding of many disparate small and/or one time, single-use projects, which generally minimize the potential for high-impact results;
- Focus, as the portfolio matures, on a relatively fewer number of larger and/or higher potential impact projects, which create legacy opportunities with appropriate provisions for follow-on funding and resources;
- Identify expertise and technologies outside of the natural gas and oil industry that may have application to help achieve the mission of the Program; and
- Assure safety and environmental protection goals are addressed and documented – this also assures new technologies will achieve faster regulatory approval.
Successful research in many cases requires demonstration in real-word field site laboratories prior to field implementation. This testing will help in operator acceptance, regulatory approvals and the uptake of commercialization. There are a number of these facilities with mission specific functions. The use of these type of resources should be a prerequisite in funding for some high risk potentially high reward R&D.

The majority of research aimed to develop new technologies requires a process of testing, small scale demonstration, certification (particularly offshore), large scale demonstration to early commercialization. Third party documentation assist in this process. RPSEA has developed a list of companies and sites that provide these services. The research project process encourages teaming early on so that the researcher is aware of these sites and services. Many of the large and mid-size service providers have internal testing and demonstration facilities. Universities and service providers provide laboratory and small-scale testing. National Labs are also a resource in the research to commercialization process. Developing the right team is part of the technical advisory committee function.

![Average Price of Crude Oil from 2002-2017](image-url)

*Figure 1: Average U.S. price of crude oil from 2002-2017 based on EIA data*
ONSHORE

U.S. dry natural gas production
trillion cubic feet

Source: U.S. Energy Information Administration, Annual Energy Outlook 2013 Early Release

Figure 2: U.S. Gas Production – Historical and Projected - Research from the 1980’s is providing for today’s gas supply. Research today is adding to our current resource base providing for tomorrow’s gas production.

RPSEA program advisory committee (PAC) meetings and surveys provided input that is included in this R&D Plan & Strategy. RPSEA’s Final Report to DOE in January 2017 showcased the most successful public private partnership for oil and gas R&D in the US and lays the foundation for future endeavors we will be pursuing. These projects were reviewed and specific projects that were not completed due to lack of funding caused by the downturn were reviewed by the PAC members.

Reliable and reasonably priced natural gas and oil supplies will be a critical component of a future energy mix that combines near-term use of traditional sources and long-term development of alternatives with conservation and energy efficiency. In order to achieve this mix, an effective Program must balance incremental technology developments with breakthrough technologies, such as grand challenges that will have fundamental and lasting impact for energy consumers through increased supplies leading to lower and more affordable commodity prices. Innovative and cost-effective technologies will be required to realize the promise of large emerging energy supplies. This necessarily entails multiple perspectives to identify problems, as well as solutions. This PLAN must encourage and make provisions for “out-of-the-box” approaches and applications to enable powerful entrepreneurial enterprise and innovation. Further,
RPSEA must provide safeguards against “development by committee” and promote a commitment to technology transfer, as well as commercialization.

Over the past decade, it has become increasingly clear that natural gas produced from shale formations (shale gas)—has the potential to add hundreds of trillions of cubic feet (TCF) of gas resource previously considered technically unavailable to the domestic energy supply. Advances in horizontal drilling and hydraulic fracturing are largely responsible for this evolution.

**Technologies related to regulations**
Identified challenges have some geographic variability. Common to all regions are the need for technologies to enable operators to remain economically viable in low commodity prices, especially those hit through active opposition from NGOs, community organizations, local referendums, and added cost of Federal, State and Local Regulatory compliance (dealing with a moving target). There were recommendations that RPSEA could play a role in using technology to improve the permitting process, particularly on public lands. Efficiency cost is addressed in this PLAN, however efficiency in regulatory compliance can also be addressed through improved technologies and processes. *These recommendations apply to both onshore and offshore*, where RPSEA’s experience and objectivity was one of the factors in these recommendations. New regulations are making it cost prohibitive to produce many wells today. Some of the regulations are based on bad data, trying the achieve a “worth goal” while others are reactive and are not based on practical or sound science reasons. In both cases, they adversely impact the mineral owner, producer, States and consumer. Solution-based technology can play an important role in providing good data and addressing compliance costs to assure energy is produced efficiently while protecting safety and the environment.

Responses in developing this PLAN documented the need for investments in research to develop cost effective technologies that will improve safety and environmental performance. Two examples supporting these recommendations are found in a June 2017 report from The Academy of Medicine, Engineering and Science of Texas. The report, “*Environmental and Community Impacts of Shale Development in Texas*¹,” was chaired by RPSEA Board member Christine Ehlig-Economides from the University of Houston. The report included findings and recommendations in six topic areas: Geology and Earthquake Activity; Land Resources; Air Quality; Water Quantity and Quality; Transportation; Economic and Social Impacts; as well as a chapter on Transdisciplinary Connections, Trade-Offs, and Decision Making. Another Report was released in January 2013 by DNV-GL, titled, “*Risk Management of Shale Gas Developments and Operations*.”

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**Recommended Practice DNV-RP-U301.**

This report provides an analysis on broad areas of shale development risks, internal and external factors effecting risk management.

RPSEA was involved in a survey of state regulators to identify their challenges that could be addressed through technology transfer. This list went to technical and industry organizations.

The six issues that follow were selected from a state needs survey, as well as from IOGCC proceedings where states discuss the major issues they currently face. The issues are:

**Air**

1) Methane Quantification / Monitoring (how methane emissions from upstream and related facilities can be monitored and quantified)

2) Flaring reduction through gas injection / gas capture (exploring ways that flaring can be reduced, with underground injection and capture for beneficial use among the leading topics of interest)

**Plugging**

3) Plugging to ensure long-term integrity (how to ensure that wells are plugged in a manner that does not leak gas or other fluids to the environment over very long timeframes)

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Well Operations
4) Hydraulic fracturing monitoring (latest techniques in monitoring various factors during hydraulic fracturing, including hydraulic fracturing-induced seismicity)
5) Simultaneous drilling/hydraulic fracturing: frac hits; anti-collision (surface and subsurface safety issues including subsurface interference related to drilling and completing wells in close proximity to each other)
6) Techniques and procedures for safely with an added focus on servicing high-pressure, high-volume wells

The survey was also insightful in identifying supporting R&D.

The PLAN surveys to industry and academia included a few similar topics:

Air quality and Emissions
Generally, strategies do not exist for small operators to meet methane reduction goals. Universally, all operators want to monetize all their oil and natural gas produced. Operators, regardless of their size, have stated technologies must be cost effective,
reliable, and be able to retrofit existing equipment, as the cost to replace expensive sunk-cost equipment may be cost-prohibitive. Methane sensor detection and monitoring technologies are evolving, but added improvements and demonstrations are needed. Emission reductions can also come from advancing and demonstrating technologies using power from stranded and flared natural gas. Supporting these reductions can also come from improvements in reciprocating engines, turbines, microturbines, fuel cell systems, improved combustion systems and incorporating power in operations from alternative sources like wasted heat, solar or wind. Opportunities were identified for RPSEA to lead an effort to develop technologies and systems to help industry address and comply with issues and regulations such as venting and flaring and emissions from completions/hydraulic fracturing.

A recommended R&D topic was: Documenting the impacts of development and production of shale gas on regional air and water quality (including major projects on environmental baseline monitoring, fugitive methane emissions, and fracturing flow back water characterization). It was recommended to fund a complementary effort to identify, mitigate and monetize energy produced from drilling and production operations.

**Water**

There is a common need for R&D investments in reducing the cost of water treatment technologies and applicable management strategies, including the transportation cost; however, issues on water management are regional. For example, in arid regions the highest R&D challenge is need for a comprehensive study to research sourcing of water and on the beneficial use of produced water. The recommendations for an R&D topic include: basic research, and a program that involves producers, end users of the water, states and municipalities, as well as a program that would also address public concerns about the efficacy of the water, and include demonstrations on the long-term impacts.

Water management is a universal issue, with the cost of recycling being a primary driver; but also, it was noted that advances are somewhat restricted by regulations, liability, risks, transportation, sourcing and disposal. It was recommended a solution should include: *Cost-Effective Treatment of Produced Water Using Co-Produced Energy Sources*. Related were recommendations that more research and better technologies are needed to monitor and manage water disposal related to induced seismicity. Recommendation were also made for RPSEA to quantify the potential for hydraulic fracturing activities to induced seismicity activity and/or effect on underground water sources.

**Recommended R&D Topic**

(a) Quantifying the potential for hydraulic fracturing activities to induce seismic activity and/or affect underground sources of drinking water (including projects that modeled fracture propagation and induced seismicity); and
(b) Ensuring public confidence in regulatory decision-making through science-based assessments and risk prediction.

**Low recovery factor from unconventional wells**

The current average recovery of from shales in the US is less than 10% for oil production and 15% from gas wells as reported by multiple sources. A recent report from World Oil (2017 North American Shales: Break-Even Prices 1st Edition), highlighted the breakeven prices for 45 different active U.S. shale plays and sections in these plays. The economics, even within those regions of the play considered “sweet spots” vary significantly. For example, in the Eagle Ford the breakeven price for oil production is $26.67 in DeWitt to $59.62 in Giddings. In the Marcellus, the breakeven gas price is $2.20 in Appalachian Pennsylvania West to $3.60 Appalachian Pennsylvania South. These are general and average prices. The variability in these prices can be due to a lot of cost factors, as well as the quality of the reservoir, the operator’s stage in the learning curve and access to sales. There are many non-technical factors that also increase the break-even price, including the State-to-State and State-to-Federal variability. Regulatory compliance costs also range significantly from State to State and State vs. Federal (BLM). Understanding all the variabilities and determine how each may be applied in other regions should of this program.

The topic of marginal wells is a proposed priority in terms of how to prevent unconventional wells, with their low recovery factors, from becoming prematurely “marginal.” This led to a proposed R&D program: Develop, demonstrate and transfer technologies, through research, to improve the recovery factors and extend the life of unconventional/shale wells beyond primary pressure depletion. Out of this program initiative we can develop a series of complementary enhancing technologies. This program will also lead to improvements in new well construction and extended life of the well designs.3

Additionally, recommendation included a focus in reservoir characterization necessary to improve completion and recompletion improvements, well design, and placement. Characterization technologies may include mapping fracture propagation, high-resolution rock imaging and a host of diagnostic monitoring and testing technologies during fracturing. Ongoing research by service providers and government needs to be identified so ensure future efforts complement and not duplicate this research.

Issues surrounding flow lines, pipelines, stray gas and safety were recommended, as this is a recent topic because of the recent Firestone incident in the DJ Basin; this issue has become an issue in part by recent development and population growth where old and sometimes abandoned flowlines were not mapped or identified. Cost effective solutions are needed as this could evolve into a larger national issue.

Safety
The domestic unconventional gas resource has dramatically altered the energy picture in the U.S., in part from the contributions from the technology being developed by the RPSEA Unconventional Resources Program. As attention turns toward shale gas resources around the world, the technologies developed through this program and applied to environmentally responsible development of domestic resources will keep U.S. companies and universities in the forefront of global unconventional resource development.

Recommended R&D focus: While safety and environmental impact have been key elements of the program since its inception, specific efforts should be made to more fully define the risks associated with oil and gas development and ensure that appropriate technologies are available to mitigate those risks. Advances in the offshore could be considered as part of an onshore safety R&D focus and includes: automation, monitoring of equipment reliability, application for of downhole early detection of kicks, abnormal pore pressures, and well control. Safety is also compromised from gas migration behind the pipe and sustained casing pressure.

Environment
Proactively embedded in future efforts must include cross-cutting all elements of the Program with a focus on the environment, including projects that minimize or mitigate environmental impact or risk, mitigate water usage, reduce the “footprint,” and lower emissions. R&D recommendations noted a need to identify elements that focus specifically on understanding the risks associated with oil and gas development operations and developing technologies to mitigate those risks. An R&D program going forward must go well beyond crosscutting and have a strong focus on developing technology to improve environmental performance. Larger companies measure performance through annual their annual sustainability reports and risk assessments. This type of assessment is out of the ability and financial range of medium and smaller companies, yet the industry as whole is perceived collectively on safety and environmental performance. It is in the interest of the larger companies, the government and industry as a whole to identify, quantify and manage to an incident free industry. The government, industry and stakeholders must be a part of these type of research projects. All projects need to include potential and ongoing environmental impacts as applicable, both positive and negative, to ensure that these impacts are fully understood during project selection and management.

There is a need to demonstrate that the controls, safeguards, and environmental impact mitigation procedures put in place during drilling and production operations to protect America’s communities and the environment are commensurate with the risks of potential environmental damage that oil and natural gas development entails.
A related research program was recommended on the quantification of methane emissions during shale gas development, to include life of well emissions, and development of technologies and best practices to reduce the emissions.

Since one of the greatest barriers to full development of domestic shale gas resources is public concern over the impact and safety of that development, the program will be focused on the development of cost-effective technologies that will enable and ensure safe and environmentally responsible exploration for and production of shale gas resources.

The onshore program should include a focus on independent and small producers, who are quick to adopt new technology that has been shown to have an economic benefit in their operating environment. This element of the program holds a crucial role in ensuring that leading edge exploration and production technology is made available to small producers, allowing them to maximize their important contribution to the nation’s secure energy supply. Support provided through the program will help mitigate the economic risk normally associated with the application of new technologies. The information acquired as a result of projects funded through the program will serve as the basis for technology transfer efforts that will promote appropriate technology applications throughout the independent and small producer community. Most of these are near to mid-term program themes:

- **Reduce Cost and Improve Efficacy of Well Interventions and Drilling**
  
  Develop and demonstrate technologies to reduce the cost of, reduce the environmental impact of, and/or improve the efficacy of well interventions or drilling. Recompletion of unconventional wells will extend the recovery and life.

- **Extend Economic Life of Mature Fields Through Environmentally Safe Efficiency Improvements**
  
  Develop and demonstrate technologies to improve oil and gas recovery from mature fields (including conventional and unconventional reservoirs).

  This research and demonstration may include better understanding of the reservoirs in order to drill field extensions, better understand how to produce residual oil zones, and new applications for horizontal drilling for infield development.

  Develop and demonstrate technologies for mitigating environmental impacts from past or current operations in mature producing areas, including development drilling and completion operations.
Development of cost-effective, intelligent well monitoring and reservoir modeling methods that will provide operators with the information required for efficient, safe, and environmentally responsible field operations.

- **Reduce Operating Costs Through More Effective and Efficient Compliance with Operating Regulations**
  Carry out research that will assist in operators in regulatory compliance and demonstration of regulatory compliance, working with regulators.

- **Minimize surface disruption associated with shale development.**
  This includes not only well site construction, but includes air emissions, noise, visual impact and impact on surface water resources.

- **Maximize the efficiency of hydraulic fracturing operations**
  The objective is to ensure that the minimum amount of fluid is used to completely stimulate the reservoir zone and the need to minimize refracture treatments. This may include waterless fracturing.

  Develop practices for managing the fluid use associated with development. Develop alternatives to or the reduction of water. This includes a better understanding and minimizing the impact on regional water resources, including the development of “green” drilling and fracturing fluids that minimize contamination concerns, the development of improved treatment and re-use options and the minimization of fluid waste streams.

  Develop technologies to improve fracturing water sourcing, handling, transportation, treatment, and disposal. Make the data from these research activities available for regulatory agencies in making informed decisions on promulgating sound science-based regulations.

- **Develop improved approaches for managing waste streams associated with shale gas development.**
  Develop additional options for treatment, re-use and disposal of liquid and solid waste streams associated with shale gas development, including naturally occurring radioactive material (NORM) and drill cuttings.

  Develop drilling and production approaches that reduce the total volume and/or the proportion of harmful constituents in waste streams.

  Develop technologies and methodologies for handling and disposal of large volumes of flowback water, as well as water that is produced during the longer-term production phase.
Emerging and Developing Plays

Technology funded through RPSEA helped unlocked millions of barrels of crude oil and natural gas from shale formations across the country, especially in the Permian Basin. That technology, combined with established enhanced oil recovery technology, promises to unlock billions more currently held in residual oil zones (ROZs), according to research being conducted in the region. This success easily justifies additional research in other formations and other regions. As comments on the development of this PLAN pointed out, the return on this ROZ research alone more than paid for the entire RPSEA program. The identification of ROZ opportunities should be a focus of future R&D.

Emerging and Developing Shale Plays – throughout the development of this PLAN the industry has stressed the need for a focus on many of the developing shale plays that have that are not economical today. We will soon reach the point where most of the lower-cost oil and gas will be exhausted and technological advances and other learning will have progressed to the point that operators will turn their attention to new shale plays that have either been recently identified and/or have been tested in the past, but have not proven economic using older technologies.

The U.S. Shale Plays identified by the U.S. Energy Information Agency includes prospective, or emerging shale plays such as the Tuscaloosa Marine Shale, the Bend, the Cody, the Heath, the Chattanooga, the Floyd-Neal and the Floyd-Chattanooga. Other resources, for example NGI’s North American Shale & Resource Plays Factbook, contain information about emerging shales as well, such as the Rogersville Shale located in Kentucky and West Virginia. RPSEA has managed emerging shale play studies including: New Albany Gas Shale Project 07122-16, Black Warrior Shales Project 07122-17, Mancos Shale Uinta Basin Project 09122-17 and Paleozoic Shale Gas Resources of the Colorado

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Plateau Eastern and Great Basin, Utah Project 07122-45. Some of the research projects were conducted to identify and quantify reserves through “basin study” resource assessments. Examples of some of the regions that have been analyzed through RPSEA research where increased reserves were recognized include the Mancos shale, the New Albany shale, Alabama shales in the Black Warrior Basin and the Appalachian Thrust Belt, and Paleozoic shale resources residing in the Colorado Plateau and the Eastern Great Basin in Utah. By focusing on these frontier regions, the program has increased public knowledge of this resource and spurred industry interest, leading to accelerated exploration and development, thereby helping to increase national reserves.

All of these shale plays have common, core information within the specific play. If this core information is better refined and made available where an applied research program working with operators develop the best technologies to improve drilling efficiencies and develop effective completion, production, recompletion and abandonment strategies then productivity and long term well integrity can be optimized. This will accelerate the commercial development, provide environmental protection, create local employment opportunities and improve economic development for the areas. This project will build upon the prior research and extensive knowledge provided by the project team. As with any developing and emerging shale development emphasis needs to include infrastructure necessary to allow these plays to be fully and economically developed. The investment however will not be made unless sufficient reserves can be proven to justify these investments.
Offshore exploration and production are vital to our energy mix. In 2016, the Gulf of Mexico produced a record breaking 1.6 million barrels of crude oil per day. The offshore, particularly the deepwater GOM, will remain a key contributor to America’s supply of oil for the foreseeable future. Worldwide, deepwater oil and gas production is becoming an increasingly important element of the global energy portfolio. The US needs to remain the technical leader, however increasing R&D investments in the North Sea countries and Brazil coupled with decreasing R&D investments in the US are causing the balance to shift.

Secretary Zinke recently released a draft proposed plan for the Outer Continental Shelf Oil and Gas Leasing Program that would greatly expand the offshore program to areas that have not been available for decades. A great deal of environmental, safety and technical research will be needed in order to support the implementation of this plan.

RPSEA offshore program advisory committee (PAC) members provided valuable input in the development this R&D Plan & Strategy.

The mission of the offshore program is to identify and develop technologies, architectures, and methods that ensure safe and environmentally responsible exploration and production of hydrocarbons from the Outer Continental Shelf (OCS) in

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5 EIA Gulf of Mexico crude oil production, already at an annual high, expected to keep increasing.
https://www.eia.gov/todayinenergy/detail.php?id=30752
an economically viable (full life cycle) manner. This mission will also add a focus on harsh environments like the arctic.

The importance of this mission is illustrated by the difficulty the oil and gas industry has had in converting discovered resources into proven reserves (producing developments). Proven reserves add value to royalty revenues, consumers, and the oil and gas industry. Identified non-producing resources do not contribute to the supply base or generate royalties.

Small fields, regardless of the size, are discoveries that are not economic to produce. They may be small, but the large number of small fields can contribute significantly to the overall resource base if they can be economically developed. The majority of future discoveries that will be developed are likely to be these smaller fields, developed with extended subsea tiebacks, utilizing a ‘hub and spoke’ methodology with multiple small fields tied to single surface hosts. Because each of these fields has different characteristics (pressure, temperature, fluids, flow rates, etc.) and life cycles, this complex system within the overall GOM facilities and pipelines complex will be unique to each small field. The interaction, safety mechanisms, and overall mix relating to each hub is akin to management of a traffic circle, only that many of the working parts and “nodes” will be below the surface of the water, and even at the individual wells’ reservoirs. Critical to producing many offshore discoveries requires using existing infrastructure through and subsea production facilities.

Providing a means for reliability and assurance of these existing infrastructure lines and facilities was identified for research investment needs and additional technology development. RPSEA’s prior investments in funding new AUV and LDAR technologies is a step in the right direction. Additional funding is required as an enabling means for producing many of these smaller fields. This includes subsea pipeline assessments and inspections.

The Department of Interior and BOEM have funded studies on mapping existing oil and gas infrastructure including issues regarding aging infrastructure. Many of these studies are out of date and incomplete. It is recommended that a comprehensive study on the Gulf of Mexico to identify needs for evaluation, certification, risk, and upgrades should to be conducted.

In addition, there are somewhat competing forces evident in studies and regulatory initiatives by DOI and GAO recommending adding additional financial costs and bonds to operators in order to avoid the risk for abandonment. The justification was a risk of inadequate funding the government will be liable for completing. These studies and initiatives lack a proper assessment of the value of infrastructure potentially lost this would cause. They may have unintended consequences. They also lack assessment of risk to future production. Existing infrastructure may also be of value for carbon storage and utilization, particularly on shelf wells in the GoM. A systematic and objective
assessment should be conducted. Research on reliable assessment technologies should also be initiated.

RPSEA offshore program utilizes an offshore Technology Advisory Committees (TACs) with industry representation from subject matter experts, identify current technology gaps and define the specific R&D efforts needed to address these gaps.

The focus areas of the TACs through 2016 have been:

- Flow Assurance
- Subsea Systems
- Floating Facilities and Risers & Systems Engineering
- Geosciences & Reservoir Engineering
- Drilling, Completions and Interventions
- Environmental, Safety and Regulatory & Metocean

Operator engagement in the process is critical because:

- The operators will be the organizations called upon to actually deploy and operate the new technologies developed under the program;
- The service, supply, and manufacturing industry representatives provide a unique perspective concerning development issues related to novel technologies;
- The safety and environmental concerns are fully aware of new developments and specific technological gaps and needs within their areas of expertise; and
- Academic researchers provide an additional link between fundamental and applied research that can shed light on newer, promising, beyond the horizon technologies.

R&D Topics from the RPSEA 999 Program

The RPSEA Offshore Program focused on risk assessment and prevention, safety and the environmental aspects through drilling, completions, operations, reservoir, and metocean functionalities. This research that did not have adequate funds to initiate or projects that were not commercialized included:

1. **Improved well design and construction to reduce risks for ultra-deepwater wells.**

   RPSEA research to include evaluation, risk assessment, and potential development of the following, as long as work is not already being performed by others:

   - Novel casing design or repair alternatives
   - Alternatives that comprise competent cement barriers to flow
   - Investigate, characterize, and describe the physical and chemical behavior of typical cements that are used in completions and verify the performance
characteristics of these cement formulations during setting and post-setting, with an emphasis on potential failure pathway identification.

2. **Improved subsea ultra-deepwater measurement and monitoring instrumentation.**

Perform work that may include the following:

- Identify and characterize the need for and role of remote sensing and surveillance equipment and vehicles under various operating scenarios that include failure scenarios, including technology specifications leading to the development of autonomous underwater vehicles (AUVs) or other technologies that can independently access seafloor information and transmit it to the surface uninterrupted, twenty-four hours per day, seven days a week, whether or not the original surface equipment is present.
- Identify and characterize the optimum capabilities of high resolution imaging technologies that can be used to observe subsea installations via long range, high resolution range-finders, detectors and sensors that lead to the development of devices that can be packaged onto an AUV.

3. **Improvement of flow assurance, expediting the completion of well control efforts, and reducing the risk of environmental impacts from potential hydrate plugging related ruptures during producing operations.**

- Develop detailed descriptions and models of ultra-deepwater conditions that can result in hydrate formation and blockage phenomena during production operations
- Improve the ability to predict hydrate behavior based on advanced modeling of hydrate plug formation and dissociation in natural gas dominated systems
- Continue to modify and validate existing models as needed by carrying out flow loop and other experiments to support model validations
- Use the improved models to predict behavior of two-, three-, and four-phased systems under a wide range of extreme UDW pressure, temperature, and equipment architecture conditions

4. **Increased understanding of complex fluid phase behaviors that occur under conditions of extreme pressure and temperature, and develop advanced models of hydrocarbon behavior.**

- Develop an improved understanding of complex pressure-volume-temperature (PVT) relationships for mixtures of flowing fluids (water, gas, and oil) under extreme temperatures and pressures (>19,000 psia bottomhole pressures and >250° F)
- Study variations in behavior when these fluids include brine, hydrogen sulfide, and/or carbon dioxide
• Conduct experimental and theoretical studies to predict the behavior of petroleum fluids under UDW pressure and temperature, including extreme high pressure – high temperature (xHPHT), conditions

• Develop and validate advanced models for extreme high pressure – high temperature (xHPHT) well and reservoir conditions for complex fluid mixtures

5. Research on sensors, instrumentation, command electronics, and advanced data interpretation technologies.

• Develop improved failsafe systems, and controls for UDW subsea production equipment

• Address risks associated with installation and operations of long flowline tie-backs and develop tools and equipment to reduce or mitigate such risks

• Develop long flowline tie-backs that incorporate a high integrity pressure protection system (HIPPS) with isolation valves that are capable of operation with a failsafe position and with multiple sensors that can be employed with the hardware to make shutdown decisions from topside locations.

• Verify the limits under which the above system can be maintained in optimum modes

• Identify, characterize, and quantify the limits under which currently existing subsea electrical connection technologies can be maintained in optimum operating modes

• Develop technologies that will improve both the failsafe integrity and reliability of electrical connectors and penetrators in ultra-deepwater architecture and technology

6. Improved reservoir characterization, simulation, and recovery methods which result in lower dependence on new field developments and new wells, thus reducing the physical and environmental footprint, as well as dependency on foreign sources of oil.

• Improved subsurface imaging through seismic reduces the need for appraising and characterization through drilling of wells

• The development of low environmental impact, testing techniques for characterization

• Improved reserve recovery methods and technologies that are specific to the deepwater Gulf of Mexico reservoirs

• Technologies to increase the recovery of existing UDW reservoirs
7. **Continued research and technology development and demonstration of certain previously identified concepts and needs include:**

- Development of safe, reliable dry tree floating facilities systems capable of drilling and producing in up to 10,000-foot water depths
- Full qualification of specialized drilling and/or production risers and riser materials to improve environmental integrity and safety
- Novel and reliable well completion and intervention systems and tools that reduce the need for personnel, equipment, and/or time on station
- Improved corrosion control technologies for subsurface and/or subsea equipment to prolong equipment life and reduce the possibility of spills
- Improvements in providing power and step-changes in developing power efficiencies for subsea and subsurface, resulting in more reliable transmission, controls and measurement

Technology improvements have been made, as documented in the RPSEA report to DOE but with a dramatic drop in drilling activity, and the associated drop in R&D investments, many of the prior research did not received industry funding to get the technologies demonstrated. As a result, these topics remain a priority of the Program.

**Safety and Environmental Awareness**

A key goal for RPSEA is “improving safety and minimizing environmental impacts”. Access to additional energy resources cannot be realized unless those resources can be
reliably produced with minimal risk to the public, oil and gas development personnel, and the environment. This is a tenet that industry must embrace in order to maintain a license to operate with the required access to our resources. Additionally, the risks associated with oil and gas development in the targeted resources must be transparent and understood not just by industry, but by the public and the regulatory bodies charged with ensuring the safety of the public and the environment. Recommendations from our members reflect R&D effort and funds are directed toward addressing and evaluating the risks associated with oil and gas development offshore and technology development to mitigate those risks. Working with industry associations like API, IADC and the Center for Offshore Safety (COS) and organization like SPE, SEG, AAPG to prioritize safety technologies needs will assist in collaboration instead of duplication and facilitate technology transfer. The status of RPSEA as a public-benefit organization with active engagement of industry, universities and other stakeholders provides a unique opportunity for making a significant near-term impact on the safety and reducing the potential environmental impact of oil and gas development operations.

The goal of Offshore Program is to develop environmentally sensitive, cost-effective technologies to identify and develop resources in increasingly challenging conditions and ensure that the understanding of the risks associated with deepwater operations keeps pace with the technologies that industry has developed. RPSEA will assess and mitigate the risk in offshore production activities related to controls, safeguards, and environmental impact mitigation procedures in place during drilling, completion, and production operations.

As most research and focus has included advancing technologies that will improve safety, it was recommended RPSEA stay in the forefront on advancing technologies that will be applied take a in the near term. It was also recommended RPSEA take a longer view of what is possible through safety innovation. A program should determine how drilling and production systems could be developed by utilizing adaptive machine learning, condition based monitoring and real-time diagnostics, better equipment reliability with longer life designs, reliable sea floor systems that replace surface facilities and can be maintained, autonomous inspection systems, and others.

Recommended Safety Research topics from PAC meetings include:

- Development of improved well control and wild well intervention techniques; expediting the completion of relief wells
- Next generation well control and BOPs
- Early/real time pore pressure detection
- Real time downhole detection of hydrocarbons during drilling operations
- Improvements in life of the well integrity, cementing and casing
- Innovative identification and repair of sustained casing pressure and gas migration
- Evaluation of instrumentation and monitoring
As advances are made, the RPSEA regulatory committee is a resource that should be utilized to address any hurdles to adaptation of new technologies, best practices or other improvements. The committee mission is to:

- Engage and inform the regulatory community
- Identify potential and future regulations that may need technology solutions
- Identify regulatory barriers to the application of new technologies
- Provides an objective platform for a dialogue between regulators and RPSEA members and other interested parties over technological solutions to industry challenges and regulatory compliance
- Collaborate with industry trade associations and societies on technologies and regulatory interface

**Technological advances related to preventing and mitigating environmental impacts**

Industry has had impressive success in innovating new technologies to find, develop and commercialize oil and gas in deepwater, but additional work remains to be done to increase certainty and confidence that shoreline communities are protected, offshore workers are safe, and the integrity of the environment is maintained. The National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling report to the President highlighted the degree to which technological advances in the prevention and mitigation of environmental impacts have not kept pace with advances that have focused on commercializing oil and natural gas offshore. The report recommended that this research program be refocused on safety. Continued development of offshore resources will require the assessment of risks, the evaluation of technologies and processes to anticipate and mitigate accidents, and the ongoing evaluation of new innovations pursued by operators. Applicable research from the Restore Act through the coastal states including the centers of excellence established in each state needs to be identified so that research can be complements and not duplicated.

Given the growing importance of deepwater production worldwide, it is imperative that U.S. operating companies and technology developers maintain a focus on technologies that can help minimize environmental impacts cost effectively. Domestic oil production will continue to play an important role in our Nation’s energy security, and oil and gas operations must be performed responsibly for the safety of our workers and our environment.
ARCTIC AND HARSH ENVIRONMENTS

The RPSEA Section 999 program funding was limited to research for ultra-deep-water, shale/unconventionals and small producer programs. With the exception of a 2015 National Petroleum Council (NPC) study on the prudent development of the U.S. Arctic oil and gas resources, there has been limited effort to identify Arctic-related research needs since it has traditionally been large-producers involved in Alaska North Slope production. In the development of this PLAN it was determined that prior RPSEA research and the resulting expertise could be modified to address many of the challenges faced (in-particular) by medium and small producers as they become more active in exploration and development the Arctic. This includes risk assessment and prevention, safety and the environmental aspects through drilling, operations, reservoir, and production. Prior R&D specific for offshore in non-Arctic environments can be modified to apply to Arctic onshore and offshore; these include subsurface characterization, flow assurance, subsea completions and met-ocean functionalities.

In December, 2017 Interior Secretary Zinke released an updated resource assessment for the National Petroleum Reserve in Alaska, the Western Beaufort Sea, adjacent State and Native Lands, and State waters, which estimated the mean undiscovered, technically recoverable resource for both on and offshore to include 17.6 Bbl of oil and more than 50 Tcf of gas.

Figure 7: Doyon Drilling Rig 141 Winter- Arctic drilling operations
Why research specific to the Arctic is included in this PLAN

The NPC study considered the research and technology opportunities to enable prudent development of U.S. Arctic oil and gas resources. They also recommended policy shifts that are now starting to be either considered or are being implemented. These cause in increased interest in the Arctic for economic opportunity. The NPC study included concerns about the future of the culture of the Arctic peoples and the environment in the face of changing climate and increased human activity. These recent policy shifts will help increase exploration and development in the U.S. Arctic to enhance national, economic, and energy security, benefit the people of the North and the U.S. as a whole, and position the U.S. to exercise global leadership.

Since this NPC study was completed in 2015, the US has increased oil and gas production from shale plays across the US and advances in technologies have occurred, while production from Alaska has decreased.

The NPC recommendations were grouped into three broad themes are incorporated for consideration into this PLAN:

**Environmental Stewardship**
1. Oil spill prevention and source control
2. Oil spill response in ice
3. Increasing knowledge of arctic ecology and human environment

**Economic Viability**
4. Technologies to safely extend the drilling season
5. Lease terms appropriate to arctic conditions
6. Effective policies and regulations
7. Enabling infrastructure

**Government Leadership and Policy Coordination**
8. Domestic leadership and policy coordination
9. U.S. chairmanship of the Arctic Council

The NPC reported stated that “there have been recent technology advancements that still need assessment and demonstration to gain acceptance by regulators and key stakeholders, and opportunities for further technology and knowledge can and should be developed to improve safety, environmental, and/or cost performance.”

Access to some of Alaska’s vast oil and gas reserves previously off-limits, are finally moving forward. These include offshore areas NPRA and ANWR. DOI plans to auction all
available tracts within the 22.8-million-acre National Petroleum Reserve in Alaska (NPR-A) for oil and natural gas development. The Department of Interior's (DOI) Bureau of Land Management (BLM) said it would offer 900 tracts totaling 10.3 million acres in the lease sale, the largest in the reserve's history. These tracks provide tremendous opportunities and challenges.

The need to identify and develop emerging areas including tight sandstone, shale (source rock), methane hydrate and heavy oil plays.

Alaska North Slope annual production now averages about 525,000 BOPD, down from its peak of 2 million barrels per day in 1988. Further decline puts the viability of the Trans Alaska Pipeline System (TAPS) in jeopardy, a risk to U.S. energy security. In order to bring new oil into the TAPS, new projects will need to be identified and developed. All of these projects will have large technical and economic challenges.

**Challenges addressed through research include:**
It is recommended that the subject matter experts, including various RPSEA offshore technical advisory committee (TAC) research award members and recipients conduct workshops with Arctic-specific operation interests and regulators to identify specific technologies that can be identified, further developed and transferred. Specific areas from past RPSEA research include but are not limited to:

1. **Improved subsurface imaging and reservoir characterization to optimize exploration, field development and reservoir management**
   - Obtain more detailed structural image of the subsurface, deeper and complex reservoirs, using a wide range of novel seismic imaging technologies such as fiber optic sensing, passive seismic imaging, and azimuth ocean bottom sensing. These techniques should be able to “illuminate” target reservoirs located in challenging geological regions, such as heavily faulted areas, gas hydrate zones, or permafrost zones.

2. **Improved well design and construction to reduce risks for ultra-deep-water wells have applicability to many arctic E&P activities.**
   Research to include evaluation, risk assessment, and potential development of the following, as long as work is not already being performed by others:
   - Novel casing design or repair alternatives
   - Alternatives that comprise competent cement barriers to flow
   - Investigate, characterize, and describe the physical and chemical behavior of typical cements that are used in completions and verify the performance
characteristics of these cement formulations during setting and post-setting, with an emphasis on potential failure pathway identification.

3. **Improved subsea ultra-deep-water measurement and monitoring instrumentation.**

Perform work that may include the following:

- Identify and characterize the need for and role of remote sensing and surveillance equipment and vehicles under various operating scenarios that include failure scenarios, including technology specifications leading to the development of autonomous underwater vehicles (AUVs) or other technologies that can independently access seafloor information and transmit it to the surface uninterrupted, twenty-four hours per day, seven days a week, whether or not the original surface equipment is present.
- Identify and characterize the optimum capabilities of high resolution imaging technologies that can be used to observe subsea installations via long range, high resolution range-finders, detectors and sensors that lead to the development of devices that can be packaged onto an AUV.

4. **Improvement of flow assurance and reducing the risk of safety and environmental impacts from potential hydrate plugging related ruptures during producing operations.**

Consider the continuation or adaptation of the RPSEA project “Hydrate Characterization & Dissociation Strategies (07121-1603b).

5. **Increased understanding of complex fluid phase behaviors.**

Expanding the research “Heavy Viscous Oil Pressure – Volume – Temperature Project.”

6. **Research on sensors, instrumentation, command electronics, and advanced data interpretation technologies.**

Technology applications may include on and offshore.

7. **Improved reservoir characterization, simulation, and recovery methods which result in lower dependence on new field developments and new wells, thus reducing the physical and environmental footprint, as well as dependency on foreign sources of oil.**

8. **Reliability of Annular Pressure Buildup Mitigation Technologies (expansion of RPSEA 12121-6502-01)**

   this has onshore and offshore applicability; including R&D focus on drilling, cementing and long-term production through the permafrost.

9. **Other prior research and technology development and demonstration include:**

   - Subsea completion and reliability.
- Novel and reliable well completion and intervention systems and tools that reduce the need for personnel, equipment, and/or time on station
- Improved corrosion control technologies for subsurface and/or subsea equipment to prolong equipment life and reduce the possibility of spills
- Improvements in providing power and step-changes in developing power efficiencies for subsea and subsurface, resulting in more reliable transmission, controls and measurement
- Application for superhydrophobic and icephobic internal pipe coatings, and the effects on reducing wax and hydrate deposition. (continuation of prior R&D funded to Colorado School of Mines and Oceanit by RPSEA)
- Further development of a RPSEA deepwater project “Technologies of the Future for Pipeline Monitoring and Inspection.”

**Technological advances related to preventing and mitigating environmental impacts.**

**R&D on oil in ice**
Prior R&D focusing on oil in ice has been to develop knowledge, methods and equipment for oil spill response in Arctic and ice-covered waters. The need and research areas to prevent and response to oil in ice has been defined, but additional research in conjunction with other international organizations is recommended. Additionally, research post-Macondo related to spills, mitigation and containment may also provide some applicable technologies and findings.

The topics include:
- Detection and monitoring
- Access and containment
- Response techniques
  - Mechanical recovery
  - In-situ burning
  - Dispersants
- Oil transfer
- Ecosystem damage mitigation

**New areas of research may include:**
- Innovative ways for exploration and development in narrow operating windows. In recent years, Alaska has experienced warmer temperatures for longer periods of time during the year. Warmer temperatures reduce the amount of time energy companies can explore for onshore oil, because ice roads and drilling pads can be used only during the coldest months of the year, when the frozen land is less damaged by equipment. Once deployed, they must be certain to retreat from the drill sites before the ice roads become soft. Conversely, the
warmer temperatures reduce floating ice packs, potentially making offshore oil exploration easier

- Include some of the challenges of narrow windows for 3-D seismic acquisition and processing program, shallow hazards surveys, dealing with delays due to ice, weather, whaling, and marine mammal mitigation plans and capabilities
- Innovative ways of applying technologies from the shale development in the Lower 48 to the development of shale source rocks (there are at least 3 potential shale plays identified on the North Slope south of Prudhoe Bay). Challenges include logistics for power sources, water and sand (or alternatives) for hydraulic fracturing, disposal of flowback and produced water
- Improved oil recovery – expansion of the onshore R&D and technologies for increasing reserves coupled with applying concepts developed in the RPSEA research project “Development of a Research Report and Characterization Database of Deepwater ad Ultra-Deepwater Assets in the Gulf of Mexico, including Technical Focus Direction, Incentives, Needs Assessment Analysis and Concepts Intensification for Improved Recovery Technology = Project 07121-1701-01 and the research later continued by DeepStar

**Safety and Environmental Awareness**

Improving safety and minimizing environmental impacts to energy resources cannot be realized unless those resources can be reliably produced with minimal risk to the public, oil and gas development personnel, and the environment. These challenges are compounded with operations in environmentally sensitive areas and in harsh weather conditions. This was highlighted in the NPC Report.

Recommendations in the development of this Plan stress the need for an R&D effort directed toward addressing and evaluating the risks associated with oil and gas development and technology development to mitigate those risks. Incorporating advances in safety technologies and processes such as Safety and Environmental Management Plans (API-RP 75) provide excellent processes based on lessons learned from offshore Gulf of Mexico having applicability to operations in the arctic.

Recommended safety research topics from prior RPSEA PAC meetings for the offshore R&D program that should also be considered in arctic R&D:

- Development of improved well control and wild well intervention techniques expediting the completion of relief wells
- Next generation well control and BOPs
- Early/real time pore pressure detection
- Real time downhole detection of hydrocarbons during drilling operations.
- Improvements in life of the well integrity, cementing and casing
• Innovative identification and repair of sustained casing pressure and gas migration
• Evaluation of instrumentation and monitoring

Consider a R&D focus on natural gas resources on the North Slope
The U.S. Geological Survey (USGS) estimates reserves could be as high as 80 trillion cubic feet (TCF) that have no pipeline access and are therefore stranded. A number of pipeline proposals emerged in the 1990s and 2000s that would bring that gas to market in the lower 48, where U.S. markets for electricity were suffering from a supply shortage. The cost and added supplies from the lower 48 made these ideas uneconomic.

About three-fourths of Alaska's natural gas withdrawals are consumed at the production site. Natural gas produced in the south is either consumed domestically or exported as liquefied natural gas (LNG). China’s largest oil company, Sinopec, recently signed a deal last to explore the development of a massive $43 billion natural gas pipeline and LNG export terminal in Alaska. The project would carry natural gas from Alaska’s North Slope to its southern coast, where it would be liquefied and exported. Natural gas volumes from the North Slope far exceed local demand, and there is no pipeline to transport the natural gas to consumers in the south. Large volumes of natural gas, extracted during oil production, are reinjected into oil fields to help maintain crude oil production rates.

Recent Activities and Developments
A focus on new technologies could have a positive impact on developments in the works on the North Slope: ConocoPhillips announced the Willow discovery at NPRA, which could produce 100,000 BOPD over the next six years. Hilcorp is pursuing necessary approvals to drill and produce the Liberty Project, which the company describes as the largest undeveloped, light oil reservoir on the North Slope. It has an estimated 80 to 150 million barrels of recoverable oil with peak production of between 60,000 and 70,000 BOPD projected within two years of initial production and a life expectancy of 15 to 20 years. It is an artificial island located 15 miles east of Prudhoe Bay.
Armstrong Energy and Repsol announced the discovery of a massive field on the North Slope with an estimated 1.2 billion BOE of recoverable oil, the largest onshore conventional hydrocarbon discovery in the U.S. in the last 30 years, according to Repsol. The companies have submitted permits to develop the Pikka area of the field, anticipating first production in 2021 and a potential rate of 120,000 BOPD.

Caelus Energy is pursuing a discovery at Smith Bay, with an estimated 6 to 10 billion barrels of oil in place. It believes the development has the potential to provide 200,000 BOPD of light oil to TAPS. Caelus is also pursuing onshore development of the Nuna field, just east of the Colville River. It estimates a resource potential of 75 to 150 million BOE and peak oil production of 15,000 to 18,000 BOPD.

Earlier 2017, the U.S. Bureau of Ocean Energy Management approved a plan for Eni to drill a well in the Beaufort Sea from an artificial island. It still has permits to obtain but plans to use extended wells more than 6 miles long.

It has been reported that 88 Energy and Burgundy Xploration, which operate under Accumulate Energy Alaska, are pursuing the Icewine prospect in a potential shale play on the south side of the North Slope on state lands near TAPS. A resources appraisal firm estimated that the prospect could contain about 980 million barrels of recoverable oil and natural gas condensate liquids — about 200 million barrels of which is oil, according to 88 Energy.

As new advances are made the RPSEA regulatory committee is a resource to assure there will be a reduction to hurdles in the adaptation of new technologies, best
practices or other improvements. The committee mission will include issues specific to the Arctic in the Plan.

- Engage and inform the regulatory community
- Identify potential and future regulations that may need technology solutions;
- Identify regulatory barriers to the application of new technologies
- Provides an objective platform for a dialogue between regulators and RPSEA members and other interested parties over technological solutions to industry challenges and regulatory compliance
- Collaborate with industry trade associations and societies on technologies and regulatory interface

Seismic Hazard Assessment related to pipeline installation
There has been no published update of seismic hazard map of Alaska since 2007. As new pipelines and fiber optic cables are being installed and planned, seismic hazard assessment integrating shallow and deep subsurface information becomes necessary. A fully integrated study will be helpful to regulatory agencies, operators, service providers, and local community.

Feasibility studies of offshore carbon storage and utilization
As hydrocarbon-producing reservoirs in the Cook Inlet and North Slope basins become depleted after decades of production, they can provide an excellent opportunity for massive volume of carbon storage and enhanced hydrocarbon recovery. After WestCarb program, not many Alaska-specific carbon storage and utilization related projects have been pursued and demonstrated at field laboratory scale. In this regard, natural seismicity, induced seismicity, and time-lapse change of subsurface reservoir and geomechanical properties should also be investigated.
TECHNOLOGY TRANSFER

It is essential that technology developed under any research project be rapidly and effectively applied by operators exploring for and developing new hydrocarbon resources. The goal for technology transfer is to assure the engagement of participants all along the technology value chain, from conceptual development to commercial application, in order to maximize the impact of Program technology.

Under the RPSEA Program, once projects were identified, projects must be adequately designed in order to build the confidence of all stakeholders. This requires the scientific assessment of risks, the evaluation of existing environmental impact mitigation methodologies and technologies, and the development and testing of novel concepts based on these assessments and the new data and insights that are being generated during the rapid development in offshore or from multiple shale plays across the U.S. It also requires the accurate, timely and objective dissemination of this information. The movement of the program toward the integration of technical results and the demonstration of their application in actual development situations is critical in accelerating the adoption of improved technical solutions and assuring the public and other stakeholders of the efficacy of these solutions.

Future research conducted in accordance with this PLAN should complement the efforts of other agencies and organizations to ensure that these issues are addressed and the potential positive impact of the shale gas resource is fully realized. RPSEA’s active technology transfer network involving members, contractors and outreach activities can contribute to increasing public confidence in safe and responsible shale gas development.

A 2017 SPE paper describes a program that the end user of the technology (operator) can utilize to get quick access to technology without significant costs in order to increase oil/gas production and decrease operating expenses.\(^6\) This technology transfer program utilizes methods from other technology based industries yet is focused and builds upon past principals established by technology transfer programs like the Research Partnership to Secure Energy for America (RPSEA) and the Petroleum Technology Transfer Council (PTTC). The paper contains several fundamental components including: 1) Technology Leadership guided by industry to initiate and manage the technology transfer process, 2) Problem Identification activities that help create a two-way dialogue between industry and leadership organization, 3) Documented Demonstration Projects rooted in findings from problem identification activities 4) Focused Technology Workshops serving to disseminate demonstration project findings and 5) Regional Resource Centers with Outreach Resources serving as local and online repositories for easy future access from industry. The paper identifies various sources of research and

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\(^{6}\) 2017 ATCE SPE Paper Development of a Technology Transfer Model in the 2020 Era for the Oil and Gas Industry by J. C. Visconi, Petroleum Technology Transfer Council; L.G. Schoeling, NeoTek Energy Inc.; T. E. Williams RPSEA
technology development funding illustrating how an effective technology transfer process can improve the time between idea and technology commercialization. In the last few years the landscape of the oil and gas industry has changed dramatically in relation to technology. Many operators, out of necessity, have adopted a manufacturing or mass production mentality regarding their wells while disregarding optimization and the use of technology for long-term production. The paper specifically addresses the needs of the modern independent oil and gas operator who does not have, or has limited access to industry research labs, government funding and university programs. It provides a step by step process designed to help operators become engaged in technology transfer in a cost-effective manner with a goal of improving their individual businesses as well as the industry at large.

**Coordination**

The general approach that RPSEA uses for technology transfer begins before the project is started, rather than being solely an activity that is initiated after a project is completed, as technology transfer occurs within the timeframe and throughout the progress of any given research project. Through monthly reports, project updates and reviews, workshops, and presentations at public meetings, RPSEA investigators interact with members of advisory committees and other potential technology users at all stages of each project. These interactions not only serve to create interest and demand for the new results, but also to provide valuable feedback to investigators to ensure that their efforts are well aligned with anticipated needs. When a project reaches completion, successful examples and case studies generated during the course of the project are the basis for formal technology transfer efforts. These efforts include workshops and other means of dissemination.

Specific technology transfer approaches incorporated in the Program include:

1. The engagement of Program Advisory Committee (PAC) and Technical Advisory Committee (TAC) members through involvement in needs assessment, project selection, and ongoing project review promotes ongoing interests in developing projects and facilitating field tests and demonstrations using operating company wells, data, and facilities. Operators and service companies represented on these committees represent the likely “early adopters” of Program technologies who will lead the way for wider industry adoption and provide the real-world examples that will facilitate meaningful technology transfer.

2. Continuing commitment to enhance the functionality and value of the RPSEA website by adding relevant, value-added data and information regarding RPSEA’s individual projects.

3. The R&D contracts awarded include requirements for the expenditure of funds allocated to technology transfer in accordance with the program-level plan. In some cases, especially in large projects with few deliverables, the technology transfer may be handled entirely by the recipient in accordance with an
approved plan. In other cases, especially for smaller projects, technology transfer efforts may be more effective if coordinated with other projects.

Project-Level Activities
Project-level technology transfer activities are a key part of the project selection and management approach used by RPSEA in each of the programs. The SPE paper discusses how RPSEA has funded research projects that was adapted to the target audience. In as much as the efforts for transferring program results to smaller independent operators requires a much different approach than that utilized to reach the ultra-deep-water community and larger companies developing, unconventional onshore. The common and most successful element however involved the use of advisors, which included peers, members of academia, and end users (normally operators), to develop the program and help progress the selected projects towards maturity. The RPSEA mechanism brought industry together to create a common understanding on technical issues impacting oil and gas exploration and production. RPSEA has been highly regarded for its ability to bring various segments of industry and government together for discussion. This ability contributed to the success of the technology transfer effort. In particular:

- In the offshore program, ongoing projects are reviewed at TAC meetings, which were open to all interested parties regardless of membership status. The relatively small size and regional concentration of the offshore community results in strong representation among potential technology adopters at the TAC meetings in which projects are reviewed. These meetings serve as an effective forum for introducing developing technology, ensuring that the resulting products are well aligned with industry requirements and identifying potential participants in field trials. While TAC events form a key part of project-level technology transfer, they are supplemented by presentations, publications, and other activities outlined in the technology transfer plans developed jointly by the subcontractors and RPSEA project management staff.

- While the onshore community is similarly involved in the selection and review of projects, this is a numerically larger and more geographically dispersed community. This requires additional emphasis on approaches designed to reach the widest possible cross-section of potential adopters of program technology. In addition to providing funds for contractors to engage in project-level technology dissemination, RPSEA has organized program-level activities to provide opportunities for additional dissemination and cross-fertilization of program results.

- The Onshore Program includes a focus on the thousands of small producers operating across the nation. Technology Transfer activities must be adaptive to the challenge of connecting with these companies. While engagement of service providers and others in the operation of the program will help ensure that new
technologies are available to these small producers, a particular emphasis on program-level activities is required.

- RPSEA has an alliance with the Petroleum Technology Transfer Council (PTTC) to assist with certain aspects of this technology transfer program. This alliance is particularly helpful with smaller independent producers. PTTC provides cost-effective services, performed through a network of industry experts and supporters. They provide a multi-pronged package of services that, through synergy, will deliver results beyond that of any single technology transfer service. They have promoted and coordinated technology transfer review meetings in which investigators of RPSEA projects present their results. These meetings enhance communications at the program level and allow the oil and gas community to network together to discuss cooperation and opportunities to develop additional resources at both the regional level and the national level.

- In addition to participating in various industry conferences, RPSEA has also conducted Technology Conferences held to disseminate information and offer the opportunity to hear the latest perspectives and exchange ideas on current RPSEA-sponsored collaborative research projects.

### Leveraging through Participation and Coordination with Existing Conferences, Forums, and Workshops

There is an abundance of industry conferences, forums, and workshops. These events are produced and sponsored by a variety of entities, including for-profit companies, governmental/regulatory agencies, professional societies, and other non-governmental organizations (NGOs). Event objectives for organizers may range from simply earning a profit to transferring technology, so that event quality and effectiveness at meeting desired goals can vary significantly. RPSEA, on a regular basis, reviews existing industry events and on a prioritized basis, works with the organizers to incorporate an effective RPSEA technology transfer component.

It is also important to have an established working relationship with OTC, PTTC, SPE, AAPG, SEG, AADE, IPAA, IADC, DEA, Hart’s, PennWell, World Oil, American Oil and Gas Reporter, state and regional oil and gas associations and others. RPSEA works with these groups by participating as session chairs, on planning and program committees, in speaking roles, and/or in other roles as appropriate to leverage RPSEA’s limited resources. The objective of this participation is for the timely and cost-effective dissemination of RPSEA-sponsored project results and targeting existing events with audiences that have specific needs for the technologies being presented. RPSEA also supports technology transfer to regulators through the IOGCC.

### Select/Focused RPSEA Workshops and Forums

In some technical areas, several contractors work on different aspects of a single key challenge. The most effective technology transfer occurs when these contractors each
present their own results, but do so in a way that emphasizes their contribution to the solution of the larger problem. RPSEA will first investigate leveraging existing conferences and forums; however, there are situations where the volume of technology and the focus of the technology may best be accomplished as a standalone event. In these cases, RPSEA will organize or partner with others on focused workshops targeted on a particular technology or closely-related suite of technologies. While these workshops will be open to the public, RPSEA will encourage key stakeholders and technology adopters to attend. These workshops are designed to be interactive, involving a relatively small number of participants (target less than 50), along with experts from the technology developer or the operator participating in the initial field trials. In some cases, the workshops will be presented multiple times in regions that benefit from the application of the subject technology. Depending on the nature of the technology, the workshop might involve simulations, training based on case studies, or exposure to the actual application of the technology in a field setting. The desired result is to enhance the capability of the operator/staff to make appropriate decisions regarding the application of new, commercially available technology that is developed through the program. Program-level technology transfer funding will be required to support a third-party organization capable of organizing, conducting, and securing appropriate participation in regional workshops.

In addition to the focused workshops as mentioned, RPSEA has sponsored a series of forums hosted by various RPSEA members across the country. These forums have served as excellent vehicles for identifying critical research needs and obtaining input for research program content that drives the future of each RPSEA program. As the RPSEA Program develops research results, these forums will shift to greater emphasis on Program results and the transfer of information, while maintaining a technical input component. This plan is an example of these focused workshops.

**Webcasts/Podcasts**
Webcasts and podcasts have become a popular and effective medium for communication. Presentations by researchers and discussions among researchers, service companies, and producers regarding potential applications are among the types of material that might be appropriate for this medium.
The PRIZE

In EIA’s Short-Term Energy Outlook (thanks to advances in drilling and completion technologies and innovations that have improved efficiencies), the total U.S. crude oil production is forecast to average 9.3 million barrels per day (b/d) in 2017, up 0.5 million b/d from 2016. In 2018, EIA expects crude oil production to reach an average of 9.9 million b/d, which would surpass the previous record of 9.6 million b/d set in 1970. EIA forecasts that most of the growth in U.S. crude oil production through the end of 2018 will come from tight rock formations within the Permian region in Texas and from the Federal Gulf of Mexico.

U.S. shale development has led to an increase in domestic natural gas production, to the point that the U.S. is expected to become a net exporter of natural gas on an average annual basis by 2018. Abundant gas in the U.S. has led to a revival in the U.S. petrochemical industry. The Potential Gas Committee (PGC) recently released the results of its latest biennial assessment of the nation’s natural gas resources, which indicates that the United States possesses a total technically recoverable resource base of 2,817 trillion cubic feet (Tcf) as of year-end 2016. This is the highest resource evaluation in the Committee’s 52-year history, exceeding the previous high assessment (from 2014) by 302 Tcf (increase of 12%). The increase resulted from reassessments of shale gas resources in the Atlantic, Gulf Coast, Mid-Continent and Rocky Mountain areas.

The current average recovery from shales in the U.S. is less than 10% for oil production and 15% from gas wells as reported by multiple sources. A recent report from World Oil shows the breakeven prices for 45 different active U.S. shale plays and sections in these plays. The economics, even in those regions of the plays considered “sweet spots,” vary significantly. For example, in the Eagle Ford the breakeven price for oil production varies from $26.67 in DeWitt County to $59.62 in Giddings. In the Marcellus, the breakeven price varies from $2.20 in Appalachian Pennsylvania West to $3.60 in the Appalachian Pennsylvania South. These are general and average prices. The variability in these prices can be due to multiple cost factors, as well as the quality of the reservoir, the operator’s stage in the learning curve and access to sales. There are many non-technical factors that also increase the break-even price, including the State-to-State and State-to-Federal variability. Regulatory compliance costs also range significantly from State to State and State vs. Federal BLM. Understanding all the variabilities and determining how each may be applied in other regions will be one of the merits of research under this PLAN.

The Gulf of Mexico production has also benefited from advances in exploration and production technology. According to the EIA, set an annual high of 1.6 million barrels per day (b/d) in 2016, surpassing the previous high set in 2009 by 44,000 b/d. In January 2017, GOM crude oil production increased for the fourth consecutive month, reaching 1.7 million b/d. On an annual basis, oil production in the GOM is expected to continue increasing through 2018, based on forecasts in EIA’s latest Short-Term Energy Outlook (STEO). In 2016, eight projects came online in the GOM, contributing to the high production levels. Another seven projects are anticipated to come online by the end of 2018. Based on anticipated production levels at these new fields and existing fields, annual crude oil production in the GOM is expected to increase to an average of 1.7 million b/d in 2017 and 1.9 million b/d in 2018.

Because of the length of time needed to complete large offshore projects, many up to ten years, oil production in the GOM is less sensitive to short-term oil price movements than onshore production in the Lower 48 states. Recent crude oil price increases have had a significant impact on exploration operations in the GOM, but not as much on activities to bring prior discoveries on line. In deepwater, the investment required from discovery to production can approach a billion dollars before there is any return on that investment is realized. Since the offshore rig count in the GOM dropped significantly when oil prices declined, the long-term trend implies the drop will affect GOM oil production. While there are new reserves discovered, many are not economical with current technology at the current price of oil and gas. Investments in R&D is required to reduce the costs, improve safety and assure there is a long-term trend in offshore production.

The U.S. has a lot to gain from reliable, safe and environmentally conscious development of our domestic natural resources. Advances in technology have allowed us to increase our production and decrease our dependence on foreign production. A public-private partnership focused on cross-cutting applied R&D has been demonstrated as an effective way to assure funding is leveraged and properly invested where advances in technology can continue.

Certain R&D topics are not listed in this PLAN because some technologies are rapidly being developed by industry and do not require government investments; but other topics and challenges included in this report are best advanced through collaborative government and industry investments.

RPSEA acknowledges the considerable contribution from hundreds of experts in developing this PLAN. All stakeholders benefit for this type of investment.