The Secretary of Energy
Washington, DC 20585

November 29, 2011

The Honorable John Boehner
Speaker of the House of Representatives
Washington, DC 20515

Dear Mr. Speaker:

Enclosed please find the report entitled "U.S. Department of Energy FY 2010 Methane Hydrate Program Report to Congress, prepared by the Department of Energy's Office of Fossil Energy. Section 968 of the Energy Policy Act of 2005 requires the Department to submit to Congress an annual report on the results of actions to carry out the specified methane hydrate research. The enclosed report outlines key accomplishments of the DOE-led methane hydrate program during FY 2010.

If you need additional information, please contact me or Mr. Jeff Lane, Office of Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Steven Chu

Enclosure

Printed with soy ink on recycled paper

The Secretary of Energy
Washington, DC 20585

November 29, 2011

The Honorable Joseph R. Biden
President of the Senate
Washington, DC 20510

Dear Mr. President:

Enclosed please find the report entitled "U.S. Department of Energy FY 2010 Methane Hydrate Program Report to Congress, prepared by the Department of Energy's Office of Fossil Energy. Section 968 of the Energy Policy Act of 2005 requires the Department to submit to Congress an annual report on the results of actions to carry out the specified methane hydrate research. The enclosed report outlines key accomplishments of the DOE-led methane hydrate program during FY 2010.

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U.S. Department of
ENERGY

FY 2010 Methane Hydrate Program

Report to Congress
November 2011

United States Department of Energy
Washington, DC 20585

Message from the Secretary

Section 968 of the Energy Policy Act of 2005 requires the Department of Energy to submit to Congress an annual report on the results of methane hydrate research.

I am pleased to submit the enclosed report entitled *U.S. Department of Energy FY 2010 Methane Hydrate Program*. The report was prepared by the Department of Energy's Office of Fossil Energy and summarizes the progress being made in this important area of research. Pursuant to statutory requirements, this report is being provided to the following Members of Congress:

- **The Honorable Joseph R. Biden**
  President of the Senate

- **The Honorable John Boehner**
  Speaker of the House of Representatives

- **The Honorable Jeff Bingaman**
  Chairman, Senate Committee on Energy and Natural Resources

- **The Honorable Lisa Murkowski**
  Ranking Member, Senate Committee on Energy and Natural Resources

- **The Honorable Ralph M. Hall**
  Chairman, House Committee on Science and Technology

- **The Honorable Eddie Bernice Johnson**
  Ranking Member, House Committee on Science and Technology

- **The Honorable Fred Upton**
  Chairman, House Committee on Energy and Commerce

- **The Honorable Henry A. Waxman**
  Ranking Member, House Committee on Energy and Commerce

If you need additional information, please contact me or Mr. Jeff Lane, Assistant Secretary, Office of Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Steven Chu

Executive Summary

Since 2001, the Department of Energy's Methane Hydrate R&D Program has pursued a range of science and technology development efforts designed to determine energy resource and environmental implications of the potential vast occurrence of gas hydrate in nature. In a Congressionally-mandated report released in January 2010, the National Research Council (NRC) concluded that NETL has been *"consistent and effective"* in leading a "high quality research portfolio that has enabled significant progress toward the Program's long-term goals." Specifically, the review compliments *"the overall high caliber of the research, the breadth of investigations undertaken, the training of new, highly qualified personnel under the program's auspices, and the successful collaboration between federal agencies conducting research on methane hydrate,"* and notes that the *"Program has also strengthened the transparency of its activities, notably through implementation of a peer-review process for ongoing research projects and increased communication with the public and the global research community."*

In FY 2010, the program's energy resource evaluation efforts remained focused on the Alaska North Slope and the Gulf of Mexico. Geologic and engineering studies required to obtain alignment between North Slope operators for drilling, sampling, and testing programs within the Prudhoe Bay operating area were completed. The first test, a short-duration field trial of both CO_2-CH_4 exchange as well as production via depressurization, has begun with the installation of a fully-monitored test borehole in April 2011 that will be available for testing during FY 2012. Plans for long-term depressurization tests have been developed, and await resolution of legal issues related to access to the chosen field location. In the Gulf of Mexico, the program continued to evaluate 2009 drilling data and to construct new coring and core analysis devices to support a planned FY 2012 deepwater Gulf of Mexico (GoM) field program. The program also maintained active international R&D collaborations with Japan, India, and South Korea throughout FY 2010.

Numerous reports were released in 2010 highlighting the potential role of gas hydrate as a deleterious feedback to ongoing climate change. During the year, the program produced the first quantitative assessment of arctic marine gas hydrate's potential to respond to warming climates, advanced the incorporation of gas hydrate science into global climate models, evaluated methane emissions from arctic permafrost sources, provided the first modeling of the impact of methane release on ocean ecosystems, and evaluated the effectiveness of marine organisms in mitigating deepwater GoM methane releases.

This report outlines key accomplishments of the DOE-led gas hydrates program during FY 2010, and provides: 1) reviews of the status of the program's major field projects with industry; 2) updates on progress in key areas of focus, including gas hydrate exploration/characterization, global carbon cycle modeling, and fundamental scientific studies in both the laboratory and in numerical simulation; 3) the status of international collaborations; 4) updates on the National Energy Technology Laboratory-National Academy of Science Methane Hydrate Fellowship Program; and 5) a review of outreach activities, including a bibliography of refereed papers, articles, and conference presentations that appeared during the year.

FY 2010 METHANE HYDRATE PROGRAM ANNUAL REPORT TO CONGRESS

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I. Legislative Action

This report describes actions taken in Fiscal Year (FY) 2010 to implement the Methane Hydrate Research and Development Act of 2000, as amended by section 968 of the Energy Policy Act of 2005 (EPAct). The Energy Policy Act requires that the Secretary of Energy provide this report to Congress annually.

II. Summary of Progress in FY 2010

During FY 2010, DOE's Methane Hydrate Program achieved significant progress through field projects, geophysical research, global and environmental climate studies, and experimental and modeling studies. Progress was also made in international cooperation, fellowship programs, program management and oversight, and technology transfer.

Gulf of Mexico Field Projects

Chevron-led Joint Industry Project

The Gulf of Mexico Joint Industry Project (JIP) is a cooperative research program between the DOE and an international consortium of industry partners under the leadership of Chevron. The overall objective of the project is to understand the nature of gas hydrate occurrence in the deepwater Gulf of Mexico, to develop technology to detect, delineate, and characterize methane hydrate accumulations, and to assess the implications of naturally-occurring gas hydrate for drilling safety and future energy supply.

During FY 2010, the project team continued the evaluation of field data acquired during the FY 2009 exploration drilling program. This program (*JIP Leg II*) confirmed the existence of gas hydrate in sand reservoirs in the Gulf of Mexico, validated the prospecting approaches employed by the joint JIP-federal science team, and provided an initial calibration of an earlier (FY 2008) Department of Interior Gulf of Mexico gas hydrate resource assessment. Project results were presented in a special session at the December 2009 Annual Meeting of the American Geophysical Union, as well as in a series of seven papers delivered in a special session at the March 2010 Society of Petroleum Engineers' Offshore Technology Conference. In addition, thirteen detailed technical *Initial Results* reports were provided to the public on the National Energy Technology Laboratory's (NETL's) web site (www.netl.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/JIPLegII-IR). Digital logging data were also made available to the public. A compendium of peer-reviewed reports on the project is being developed and is expected to be completed early in 2012.

Given the funds available, JIP Leg II was limited to 21 days of operation at sea, and as a result, the expedition was designed to maximize the number of sites drilled by focusing on the measurements obtained by a state-of-the-art, logging-while-drilling tool string. The success of the drilling program (in which resource-grade gas hydrates were found in four of seven wells drilled) enabled the JIP and the DOE to agree to extend the project to enable a follow-on

expedition designed to collect and maintain sediment samples under in situ pressures and conduct specific wireline evaluation programs including limited pressure testing in the newly-discovered reservoirs. JIP Leg III is being designed to evaluate both gas hydrate-bearing sand reservoirs and the associated sealing clay sediments through measurement of various petrophysical, hydraulic, and geomechanical properties. These data are not obtainable through laboratory study, and will greatly inform numerical modeling studies of the likely response of gas hydrates-bearing sediments during either natural or induced dissociation.

Also in FY 2010, the JIP Leg III Science Team, which includes science co-leads from NETL and the U.S. Geological Survey (USGS), initiated preparations for the planned coring program. A full science party was named, and initial drilling, sampling, and sample handling/analysis protocols were developed. As there are no devices currently in existence that can acquire, maintain, subsample, transfer, and gather scientific measurements on the pressurized core samples, the JIP is proceeding with the design and construction of a number of new devices. The coring expedition, originally slated for FY 2011, has now been set for FY 2012, due largely to planning uncertainties related to the aftermath of the *Deepwater Horizon* event, including uncertain future regulatory environments, as well as the development of new industry protocols related to deepwater operations.

Mississippi Canyon 118 Seafloor Observatory

The University of Mississippi continues to lead a consortium working to establish and maintain a seafloor observatory for long-term monitoring of gas hydrate occurrences in Mississippi Canyon Block 118 in the Gulf of Mexico. This project is conducted in conjunction with the National Oceanic and Atmospheric Administration and the Bureau of Ocean Energy Management and Resource Evaluation.

FY 2010 DOE-funded activities continued to focus on design and deployment of instrumentation for collection of geophysical, geochemical, and biological data at the Mississippi Canyon 118 hydrate mound. The project team successfully recovered targeted push cores and collected geochemical data and sediment samples from the near-seabed and shallow seabed in the region of the hydrate mound. In addition, a plan for the deployment of various passive seismic array was developed and tested during a cruise to Pensacola Bay. The arrays, which will be used for long-term monitoring of the structural and hydrocarbon fluid dynamics at the site, are scheduled to be deployed during a cruise in 2011. In late March and early April of 2010, scientists from the Naval Research Laboratory successfully deployed the modified, bottom-mounted Deep Towed Acoustics Geophysics System (DTAGS) at MC118 site with the goal of enabling a better understanding of the effects of sediment anisotropy on locating and assessing methane hydrates in deep water sediments.

Alaska North Slope Field Projects

Extended-duration Depressurization Testing Program

The main goals of this project, led by BP Exploration-Alaska (BPXA), are to characterize the nature and commercial implications of methane hydrate resources on the Alaska North Slope through an extended-duration depressurization test. This test will enable the first information with which to calibrate numerical models of the potential productivity of gas hydrate bearing reservoirs as well as assess potential environmental impacts associated with gas hydrate production.

In the early stages of the project, BPXA-donated well and seismic data were used in collaboration with the USGS to assess gas hydrate occurrence within the Milne Point Unit, resulting in the delineation of more than 1 dozen drillable prospects. In order to further understand key reservoir properties needed to properly plan an initial production test, and to assess the potential impacts of scientific activities within the operating production area, BPXA and DOE drilled the Mount Elbert stratigraphic test well in 2007. Evaluation of those data provided critical improvements to reservoir modeling capabilities, enabling both the 2008 release by the USGS of the first assessment of technically-recoverable resources from gas hydrates, as well as the decision by BPXA and DOE to move into the planning of a long-term test focused on depressurization. An optimal test location and plan were developed in FY 2009. In addition, DOE has obtained agreement with the North Slope operators for participation in the production test by DOE's international partners, including Japan, South Korea, and India.

In early 2010, BPXA successfully worked to identify means by which both DOE-supported gas hydrate testing programs (the BPXA program focused on depressurization and the ConocoPhillips test focused on CO2 injection and exchange) could be executed from a single surface location on an active gravel production pad in the western Prudhoe Bay Unit. NETL supported this effort through the geologic analysis of reservoir continuity and potential faulting beneath the pad, as well as numerical reservoir simulations designed to assess any interactions between the gas hydrate testing and the many production wells drilled from the pad. In May 2010, BPXA identified a surface location and available drill rig, and circulated a draft agreement to its partners describing the planned testing activities, which were slated to begin in mid-2011. However, these plans were deferred shortly thereafter due to recognition of BPXA's debarment by EPA from receipt of federal funds for any activities within the Prudhoe Bay Unit stemming from a 2006 pipeline rupture in the unit. This debarment remains in effect at the date of this report, and the timing or nature of its resolution is yet to be determined.

CO_2-CH_4 Exchange Field Trial

NETL is continuing to work with ConocoPhillips, Alaska, to test the feasibility of producing methane from gas hydrate deposits using an approach in which carbon dioxide is exchanged for methane in the hydrate structure. If successful, this production strategy will release methane for production while sequestering carbon dioxide in the hydrate reservoir. A review of the scientific background for the project was provided in FY 2010 in the NETL Newsletter *Fire in the Ice*:

http://www.netl.doe.gov/technologies/oil-gas/publications/Hydrates/Newsletter/MHNews_2010_03.pdf#page=19

In FY 2009, the ConocoPhillips project team identified locations in the western part of the Prudhoe Bay Unit as the most appropriate field test site. In FY 2010, approvals were pursued from among the working interest owners. This approval process included full consideration of the potential to merge this testing program with that being evaluated under the DOE's separate agreement with BPXA, who had also determined that the Prudhoe Bay sites were the most favorable locations to conduct their planned long-term depressurization tests (see previous section). Ultimately, it was determined that the BPXA project could not proceed at this time, and ConocoPhillips' request to conduct the test was approved by the Units' operating partners at the end of FY 2010. As ConocoPhillips is not the operator in the Prudhoe Bay Unit, the test will be conducted from a new ice pad built near the production facility. At the time of this report, the initial field program has been completed; with the test well drilled and completed in preparation for CO_2-CH_4 exchange and potential depressurization testing occurring as soon as the winter of FY 2012.

Gas Hydrate Exploration Technologies

In addition to the ongoing work within the major field programs to advance the geophysical evaluation of gas hydrates using existing datasets, a number of projects in partnership with universities and other federal agencies are nearing completion. These projects, which are working to expand the gas hydrate exploration toolkit, were added to the program portfolio in 2008 and are scheduled to be completed in FY 2011. An effort with Baylor University is evaluating the Direct Current Resistivity (DCR) method for detecting and characterizing marine hydrate accumulations. During FY 2010, the deep-towed DCR array system was reconfigured to enable a high resolution 3D survey of the shallow seafloor. The new array system is scheduled for testing at the Mississippi Canyon lease block 118 sea-floor observatory during 2011.

A second project being led by Scripps Oceanographic Institute in partnership with Lawrence Livermore National Laboratory, Massachusetts Institute of Technology and the U.S. Geological Survey is investigating the feasibility of using marine electromagnetic (EM) surveying to image methane hydrate in marine sediments. During FY 2010, scientists designed and constructed devices to enable conductivity experiments on lab-synthesized methane hydrate. Experimental hydrate conductivity data will be used to calibrate EM data collected during surveys in the Gulf of Mexico in October 2008. Demonstrating the ability of resistivity methods to supplement seismic data in the remote detection and characterization of hydrate occurrences could be an important step in assessing the global inventory of methane hydrates.

During FY 2010, scientists from Oregon State University utilized the extensive scientific database acquired by the government of India in FY 2006 (in collaboration with the DOE and USGS) to develop geologic models to assess the relationship between subsurface heat flow anomalies and continental margin gas hydrates. Preliminary analysis suggests that structural features such as

large-scale faulting contributes significantly to observed anomalies. If successful, this research may lead to a method—when coupled with other geochemical and geophysical data—for assessing the relationship of residual heat flow anomalies to fluid flow and ultimately, to predicting methane hydrate distribution in the subsurface.

Global Environmental and Climate Studies

DOE is supporting a range of studies designed to determine the sources, sinks, and fluxes of methane in arctic and marine gas-hydrate-bearing environments. The portfolio of projects includes field work in a range of geologic settings, as well as the initial attempts to incorporate gas hydrate into global climate and environmental process models.

Lawrence Berkeley National Laboratory (LBNL) is partnering with Los Alamos National Laboratory to model the effects of future climate warming on marine hydrate accumulations. Specifically, researchers are investigating the effect of rising ocean temperature on the stability of marine hydrate deposits, the impacts of methane release on ocean ecosystems and ocean acidification, and the quantity of methane that could reach the atmosphere under different forward climate scenarios. During FY 2010, researchers expanded one-dimensional simulations of hydrate dissociation under various conditions of depth, temperature, and rate of warming to large-scale 2-D simulations of dissociating hydrates along continental margins. These initial regional scale simulations are focused on the Sea of Okhotsk, offshore New Zealand, the Gulf of Mexico, and the arctic continental margin.

Also during FY 2010, a team of scientists from the University of Alaska and the USGS collected samples of sediment, water, and gas from Lake Teshekpuk, a freshwater lake near Harrison Bay (North Slope) Alaska. In recent years, methane has been observed bubbling from this and other thermokarst lakes in the region. This project is aimed at pinpointing the source of the methane and estimating the quantity being released to the atmosphere. The research team collected samples to evaluate spatial variation in the methane flux compared to that observed in another lake near Barrow, Alaska in 2009. In addition, the USGS conducted multiple geophysical surveys of Lake Teshekpuk – including seismic reflection, ground penetrating radar, and resistivity profiling. The surveys were carried out to map the lake bottom, its underlying stratigraphy, and possible structures that could be responsible for methane seepage. Sediment, water, and gas samples are undergoing laboratory analyses to determine the source and nature of the methane.

Researchers from the University of California, Santa Barbara (UCSB) are investigating biological controls on methane release from subsea sediments to the ocean and atmosphere through case studies in the Santa Monica and Santa Barbara basins off the coast of California. During FY 2010, project scientists completed field surveys and analyses of the water turnover and methane oxidation rates in the water column. Additionally, genetic sequencing of benthic microbial mats collected from the seafloor in 2009 was initiated. These microbial mats are being studied for their role in subsea, biological oxidation of methane. The next step is to quantify the efficacy of microbial communities in metabolizing methane so that this mechanism of biofiltering can be

incorporated into models of the global carbon cycle. Utilizing the methodologies developed for this project, researchers from UCSB also joined a team of scientists in the summer of 2010 to investigate the biofilter efficacy and the fate of a methane associated with the Macondo well release in the deepwater Gulf of Mexico, resulting in the publication of results that suggested enormous capacity of marine microorganisms to rapidly adjust to, and consume, methane emitted into deep waters.

Texas A&M University – Corpus Christi, in conjunction with Florida State University, is leading an effort to develop a new method for detecting and quantifying natural hydrocarbon seeps in the using satellite imagery. During FY 2010, project scientists continued their efforts to map natural oil and gas seeps in the Gulf of Mexico. In addition, researchers began the analysis of water, sediment, and gas samples collected from the locations of vent sites previously identified on the imagery to determine rates of gas release from the seafloor and volumes that might survive the transit through the water column and be released into the atmosphere. Researchers, in collaboration with a German team, are attempting to use these same methods to detect and verify the locations of seeps in the Batumi region of the Eastern Black Sea. Project results should lead to more accurate global estimates of methane flux from submarine seeps and associated methane hydrate deposits, and these estimates should ultimately provide better inputs for climate models.

Researchers from the University of Chicago and University of California-Berkeley are developing a two-dimensional model for deep marine environments to simulate the formation and dissociation of methane hydrate in marine sediments over geologic time-scales. The project was designed to address the question of whether methane released from subsea sediments is likely to escape to the ocean or the atmosphere or remain in place below the seafloor. In FY 2010, researchers worked to develop models of hydrate formation and dissociation on active and passive continental margins. Simulations are being conducted to assess the sensitivity of the models to organic carbon concentrations, flow anisotropy, and 50 million-year cycles in ocean temperature. The 2-D basin scale models will ultimately be subjected to warming of the overlying water column, which will result in predictions of the response of the methane hydrate inventory to climate change.

Late in FY 2009, an International science team conducted a variety of sampling programs designed to quantify methane fluxes emanating from sediments in the Arctic Beaufort Shelf and slope regions. The expedition was led by the U.S. Naval Research Laboratory in collaboration with DOE/NETL, the Royal Netherlands Institute for Sea Research, the University of Delaware (UD), and a team of scientists from the U.S., Netherlands, Belgium, and Germany. Water column samples indicated elevated methane levels throughout shallow water regions of the Beaufort Sea. Elevated methane near the seafloor and in the shallow sediments was only observed at three locations near the shelf-slope break, coincident with subsurface features that indicate the presence of free-gas and/or gas hydrate accumulations associated with shallow faulting. Researchers from UD conducted extensive genetic sequencing of the microbial communities found within the sediment cores and leveraged through metagenomic sequence data from DOE's Joint Genome Institute Community Sequencing Program (CSP). These combined analyses

revealed a complete pathway for sulfate reduction at depths. Ultimately, these data will be combined with other microbial and biogeochemical data to obtain a complete picture of methane degradation and other biogeochemical processes in these methane-rich Arctic sediments.

In August 2010, USGS and NETL-NAS scientists began geophysical imaging of the shallow Beaufort Sea shelf. The purpose of this study was to investigate high-latitude climate effects on the shallow shelf permafrost and to determine if hydrates may be degassing as the recently inundated permafrost retreats. This 2010 USGS reconnaissance effort will provide the basic data that is needed to determine if a larger-scale effort with more substantial geophysical imaging capabilities, coring, sediment and water column oxidation rate studies, and ocean atmosphere flux measurements is merited to quantify the various sources and sinks of methane and, particularly, the role of degassing hydrates in the shallow offshore northern Alaska.

Fundamental Experimental and Modeling Studies

DOE continued support of a number of experimental and modeling efforts within the DOE National Laboratory system and other federal agencies. These studies access unique facilities and capabilities to address fundamental knowledge gaps related to the nature of gas hydrate in sediments and the response of hydrate-bearing sediments to various natural or induced perturbations.

The USGS continued its investigation of a unique fingerprinting method to distinguish gas released from methane hydrates from other methane sources (e.g., wetlands, soils, coal or leaky hydrocarbon reservoirs). The technique accounts for the preferential partitioning of the noble gases krypton (Kr) and xenon (Xe) that is hypothesized to occur as hydrates form. Analysis conducted in 2010 support a unique noble gas fractionation pattern for the gas hydrates. Future work will expand on these initial findings and investigate the conditions controlling this partitioning phenomenon. Ultimately, tests will be conducted on natural hydrate samples and if successful, a new method of characterizing methane hydrate occurrence will become available to scientists and industry.

The USGS also continued laboratory studies of gas hydrate formation from dissolved methane, a process responsible for much marine gas hydrate occurrences but previously very difficult to realize in the laboratory setting. Tests in 2010 were designed to establish parameters for efficient hydrate formation and to automate the formation control and data acquisition processes. USGS scientists involved in this research continue to engage in and lead protocol comparisons in collaboration with experiments at Georgia Tech, Oak Ridge National Lab (ORNL), Lawrence Berkeley National Lab (LBNL), Pacific Northwest National Lab (PNNL), and NETL regarding formation of gas hydrate from dissolved phase methane. In addition, ORNL in collaboration with Georgia Tech, conducted experiments within the Seafloor Process Simulator (SPS) to assess the effects of sediment heterogeneity on hydrate accumulation processes. Different sediment configurations (e.g., large void spaces, sand lenses, fine/coarse grain material in different geometries) have been assembled within the SPS to create model sediment columns.

Gas hydrate production modeling and laboratory studies continued to be focused at LBNL, NETL, and PNNL. LBNL-NETL lab efforts continued to optimize techniques for estimating relative permeability and capillary pressure and for the collection of enhanced geophysical, geomechanical and hydrological properties of hydrate bearing sediments. Numerical simulation work at LBNL in FY 2010 included code enhancements to both serial and parallel versions of the Tough + Hydrate simulator and unification of code architecture between two code versions. Simulations completed during the year included the production potential of promising Alaskan deposits, production from hydrates from South Korean offshore deposits, and assessment of resource recoverability from oceanic deposits in the Gulf of Mexico.

Simulations were also performed to assess the geomechanical response of the reservoirs to the identified production. NETL modeling of the thermal disturbance of gas hydrates by existing wellbores was central to the approval of Alaska North Slope operators of planned field production tests. In the lab, thermal property measurements of CO_2 hydrates were evaluated, and results of these studies were published. In addition, CO_2-CH_4 molecular dynamic models and thermodynamic relationships were developed and advanced. PNNL utilized a new version (jointly supported by DOE-NETL and Korean Institute of Geoscience and Mineral Resources (KIGAM)) of the STOMP simulator to consider the exchange of gas hydrate guest molecules as a kinetic process. This version of the simulator solves separate conservation equations for the mobile and immobile guest molecules for a combined carbon dioxide/methane hydrate system as well as considering carbon dioxide and methane components in the aqueous, gas, and liquid-CO2 phases separately from the same components in the hydrate phase.

In FY 2010, researchers from the University of Texas at Austin and the Massachusetts Institute of Technology extended grain-scale numerical models to investigate methane migration through sediments within the gas hydrate stability zone. The team also conducted the initial numerical models of the process by which free gas accumulations in Alaska may be converted to gas hydrates during recent imposition of Arctic temperature conditions.

International Collaboration

DOE maintained active collaborations with several nations in FY 2010. Formal agreements continued with government entities in Japan, South Korea, and India. Entities from each of these countries are participants in the DOE's Gulf of Mexico JIP lead by Chevron, and are prepared and enabled to participate in future DOE Alaska North Slope extended duration field tests. In addition to these Departmental-level agreements, NETL maintains active collaborations with gas hydrate efforts in New Zealand, China, Canada, and Taiwan.

During FY 2010, NETL participated in expert panels invited to South Korea and India to assist in the evaluation of potential drill sites for each nation's second marine gas hydrate evaluation expedition. South Korea conducted its UBGH-2 program in the summer of 2010, and NETL contributed a geochemist to the field party. U.S.-South Korea co-funded research programs

enabling further evaluation of 2010 field samples are underway at NETL, as are research programs in numerical simulation with LBNL and PNNL. A workshop to discuss the findings of these collaborative programs occurred in Daejeon, South Korea, in early 2011.

Fellowship Programs

DOE awarded its only FY 2010 NETL-NAS National Methane Hydrate R&D Program Fellowship to Dr. Laura Brothers. Dr. Brothers will work with the USGS to conduct geophysical studies related to the evaluation of the nature, extent, and methane releases from submerged (relict) permafrost and associated gas hydrates on the shallow Beaufort Shelf (north Alaska). These research fellowships are awarded through a partnership between DOE and the National Academies of Sciences. Six fellowships have been awarded since the fellowship program was initiated in 2007.

Program Management and Oversight

Throughout FY 2010, DOE/NETL continued to monitor a broad portfolio of R&D projects as specified by the Energy Policy Act (EPAct) of 2005. The effectiveness of this management was positively reviewed in a report released by the National Academies in January 2010. A week-long review meeting of all ongoing efforts within the program was held in Atlanta in early 2010 with the intent of furthering collaboration and integration of research efforts within the program. Throughout the fiscal year, the Program continued to utilize its interagency coordination committee to ensure integration of methane hydrate research activities across the collaborating Federal agencies. Two meetings of the Technical Coordination Team were held in FY 2010. In addition, the Program continued to utilize its Federal Advisory Committee for advice and consultation on program direction as needed.

Technology Transfer

DOE and its research partners continued to disseminate research results to the scientific community during FY 2010. Appendix A provides a list of 93 peer-reviewed publications, 60 grey literature publications, and 95 professional conference presentations during the fiscal year. In particular, 23 peer-reviewed articles detailing the Scientific Results of the 2007 BPXA-DOE-USGS Mount Elbert Stratigraphic Test well were released on-line in advance of compilation into a *Special Issue of Marine and Petroleum Geology (Elsevier)* that was published in hard copy form in February, 2011. An additional 14 articles were included in AAPG Memoir 86, published in December 2009.

A review of the status of gas hydrate resource evaluation was published in the high-impact journal *Energy & Environmental Science*, and an NETL co-authored review of gas hydrate exploration technologies was included as a chapter in a new book published by the Society of

Exploration Geophysicists. The grey literature list includes a series of thirteen technical reports detailing the findings of the 2009 Gulf of Mexico gas hydrate exploration drilling program that were published on the NETL website and seven additional full-length reports included in the proceedings of the SPEs Offshore Technology Conference. The DOE/NETL Methane Hydrate Newsletter, *Fire in the Ice*, continued to report on global developments in gas hydrate R&D in FY 2010. This periodical publication is distributed to 1,500 subscribers in more than 40 countries.

Information on the DOE Methane Hydrate Program, including detailed summaries of all active and completed projects and reports and publications resulting from DOE-funded investigations, are available at www.netl.doe.gov. Information on the Methane Hydrate Program, including program reports and activities of the Methane Hydrate Advisory Committee, are available at www.fe.doe.gov.

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III. Conclusion

Since 2001, the Department of Energy's Methane Hydrate R&D Program has pursued a range of science and technology development efforts designed to determine energy resource and environmental implications of the potential vast occurrence of gas hydrate in nature. In FY 2010, the program's resource evaluation efforts remained principally focused on the Alaska North Slope and the Gulf of Mexico while supporting research in the areas of methane hydrate behavior,

reservoir characterization, exploration technologies, and environmental effects. This report outlines key accomplishments of the DOE-led gas hydrates program during FY 2010.

Appendix A: FY 2010 Publications and Reports

Peer-Reviewed Publications

Addison, A., Battista, B., Knapp, C., 2009. "Improved Hydrogeophysical Parameter Estimation from Empirical Mode Decomposition Processed Ground Penetrating Radar Data," *Journal of Environmental and Engineering Geophysics* vol. 14, no. 4, pp. 171-178.

Allison, E., Boswell, R., 2009. Overview of the Department of Energy Gas Hydrate Research Program; in Collett, T., Johnson, A., Knapp, C., Boswell, R., eds, *Natural Gas Hydrates: Energy Resource and Associated Geologic Hazards*; American Association of Petroleum Geologists Memoir **89**.

Anderson, B., Hancock, S., Wilson, S., Enger, C., Collett, T., Boswell, R., Hunter, R., 2010. "Modular Formation Dynamics testing at the Mount Elbert-01 stratigraphic test well, Milne point unit, North Slope Alaska: Operational summary, history matching, and interpretation," *Marine Petroleum Geology*, doi:10.1016/j.marpetgeo.2010.02.012.

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