Statement of
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Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to discuss the importance of the energy resource potential of natural gas hydrates. In this statement I will discuss the USGS assessment of the energy resource potential of natural gas hydrates and examine the research and development issues that need to be resolved to safely and economically produce gas hydrates. It is important to note that many different gases form gas hydrates, but methane, which is the main component of natural gas and is used to heat homes and for other domestic purposes, is the most common gas included in gas hydrates and that is why they are often referred to as methane hydrates. It is also important to note that this testimony will focus on the technical and economic aspects of gas hydrate production potential. The environmental impacts from gas hydrate production, including the potential impacts on global climate change, require additional study and analysis as the role of gas hydrates in the total energy mix is further defined and considered.

In 1995, USGS made the first systematic assessment of the in-place natural gas hydrate resources of the United States. That study shows that the amount of gas in the hydrate accumulations of the United States is estimated to greatly exceed the volume of known conventional domestic gas resources. However, gas hydrates represent both a scientific and technologic challenge and much remains to be learned about their characteristics and possible economic production. The primary objectives of USGS gas hydrate research are to: 1) document the geologic parameters that control the occurrence and stability of gas hydrates, 2) to assess the volume of natural gas stored within various gas hydrate accumulations, 3) to analyze the production response and characteristics of gas hydrates, 4) to identify and predict natural and induced environmental impacts of natural gas hydrates, and 5) to analyze the effects of gas hydrate on drilling safety.

Gas Hydrate Occurrence and Characterization

Gas hydrates are naturally occurring crystalline substances composed of water and gas, in which a solid water-lattice holds gas molecules in a cage-like structure. The gas and water become a solid under specific temperature and pressure conditions within the Earth, called the hydrate stability zone. Gas hydrates are widespread in Arctic regions beneath permafrost and beneath the seafloor in sediments of the outer continental margins. The amount of gas contained in the world's gas hydrate accumulations is enormous, estimates of *in-place* gas within natural gas hydrates range over three orders of magnitude from about 100,000 to 270,000,000 trillion cubic feet (TCF) of gas. By comparison, the conventional global gas endowment (undiscovered, technically recoverable gas resources + conventional reserve growth + remaining reserves + cumulative production) has been estimated at approximately 15,400 TCF (USGS World Petroleum Assessment, 2000). Despite the enormous range of these estimates, and the notable differences between in-place gas-hydrate estimates and the aforementioned estimates of conventional gas, gas hydrates seem to be a much greater resource of natural gas than conventional accumulations.

Even though gas hydrates are known to occur in numerous marine and Arctic settings, relatively little is known about the geologic controls on their distribution. The presence of gas hydrates in offshore continental margins has been inferred mainly from anomalous seismic reflectors that coincide with the base of the gas-hydrate stability zone. This reflector is commonly called a bottom-simulating reflector or BSR. BSRs have been mapped at depths ranging from about 0 to 1,100 meters below the sea floor. Gas hydrates have been recovered by scientific drilling along the Atlantic, Gulf of Mexico, and Pacific coasts of the United States, as well as at many international locations.

Onshore gas hydrates have been found in Arctic regions of permafrost and in deep lakes such as Lake Baikal in Russia. Gas hydrates associated with permafrost have been documented on the North Slope of Alaska and Canada and in northern Russia. Direct evidence for gas hydrates on the North Slope of Alaska comes from cores and petroleum industry well logs, which suggest the presence of numerous gas hydrate layers in the area of the Prudhoe Bay and Kuparuk River oil fields. Combined information from Arctic gas-hydrate studies shows that, in permafrost regions, gas hydrates may exist at subsurface depths ranging from about 130 to 2,000 meters.

The USGS 1995 National Assessment of United States Oil and Gas Resources focused on assessing the undiscovered conventional and unconventional resources of crude oil and natural gas in the United States. This assessment included, for the first time, a systematic appraisal of the in-place natural gas hydrate resources of the United States, both onshore and offshore. The offshore assessment, on which USGS partnered with the U.S. Minerals Management Service (MMS), identified eleven gas-hydrate plays within four offshore provinces. There was one gas-hydrate province identified onshore. The offshore provinces lie within the U.S. 200 mile Exclusive Economic Zone adjacent to the lower 48 States and Alaska. The only onshore province assessed in that study was the North Slope of Alaska. In-place gas hydrate resources of the United States are estimated to range from 113,000 to 676,000 TCF of gas, at the 0.95 and 0.05 probability levels, respectively. Although this range of values shows a high degree of uncertainty, it does indicate the potential for enormous quantities of gas stored in gas hydrates in these accumulations. The mean in-place gas hydrate resource for the entire United States is estimated to be 320,000 TCF of gas and approximately half of this resource occurs offshore of Alaska and most of the remainder is beneath the continental margins of the lower 48 states, underlying the Federal outer continental shelf (OCS). It is important to note that this 1995 assessment does not address the issue of gas hydrate recoverability. The USGS mean estimate of 320,000 TCF (gas hydrate *in-place*), despite its uncertainty, is more than two orders of magnitude larger than current estimates of natural gas from conventional sources (*reserves and technically recoverable undiscovered resources*) in the U.S., which is approximately 1,400 TCF.

In the fall of 2008, the USGS completed the first-ever resource estimate of *technically recoverable* gas from natural gas hydrates. That study found that there is 85.4 TCF (mean value) of technically recoverable gas in gas hydrates on the North Slope of Alaska. This assessment indicates the existence of *technically recoverable* gas hydrate resources — that is, resources that can be discovered, developed, and produced using current technology. The area assessed in northern Alaska extends from the National Petroleum Reserve in Alaska (NPRA) on the west through the Arctic National Wildlife Refuge (ANWR) on the east, and from the Brooks Range northward to the State-Federal offshore boundary (located three miles north of the coastline). This area consists mostly of Federal, State, and Native lands covering about 44,310 mi^2. For the first time, the USGS has assessed gas hydrates, an "unconventional resource," as a producible resource in discrete hydrocarbon traps and structures. The approach used to assess the gas hydrate resources in northern Alaska followed standard geology-based USGS assessment methodologies that have been developed to assess conventional oil and gas resources. In order to use this approach for gas hydrate resources, it was documented through the analysis of three-dimensional industry-acquired seismic data, that the gas hydrates on the North Slope occupy limited but discrete volumes of rock bounded by faults and downdip water contacts. The USGS conventional assessment approach also assumes that the hydrocarbon resource being assessed can be produced by existing conventional technology. The production potential of the known and seismically-inferred gas hydrate accumulations in northern Alaska has not been adequately field tested, but has been the focus of multi-organizational research efforts in Alaska and Canada. Numerical production models of gas hydrate-bearing reservoirs suggest that gas can be produced from gas hydrate with existing conventional technology and this conclusion has been verified by limited field testing. Using a geology-based assessment methodology, the USGS estimated the total undiscovered *technically recoverable* natural gas resources in gas hydrates in northern Alaska to be between 25.2 and 157.8 TCF (95% and 5% probabilities of greater than these amounts, respectively), with a mean estimate of 85.4 TCF.

In anticipation of gas hydrate production in Federal waters, the U.S. Minerals Management Service (MMS) has recently launched a project to assess gas hydrate energy resource potential on acreage under MMS jurisdiction. The MMS is currently working to assess the resource potential of gas hydrate on the Atlantic OCS and to address the technical recoverability of gas hydrate in the marine environment. Early in 2008, MMS reported on their systematic geological and statistical assessment of *in-place* gas hydrate resources in the Gulf of Mexico OCS. This assessment integrated the latest findings regarding the geological controls on the occurrence of gas hydrate and the abundant geological and geophysical data from the Gulf of Mexico. The *in-place* volume of undiscovered gas estimated within the gas hydrates of the Gulf of Mexico was reported as a cumulative probability distribution, with a mean volume estimate of 21,436 TCF. In addition, the assessment reported that 6,710 TCF of this mean estimate are in relatively highly concentrated accumulations within sand reservoirs, with the remainder in clay-dominated sediments.

Gas Hydrate Production

Gas recovery from hydrates is a challenge because the methane is in a solid form and because hydrates are usually widely dispersed in frontier areas such as the Arctic and deep marine environments. Analogous to conventional hydrocarbon production, first recovery of a gas hydrate resource will occur where the gas is concentrated. Proposed methods of gas recovery from hydrates usually deal with dissociating, in-situ, the gas and water from its hydrate (solid) phase by: (1) heating the reservoir beyond the temperature of hydrate formation, (2) decreasing the reservoir pressure below hydrate equilibrium, or (3) injecting an inhibitor, such as methanol, into the reservoir to decrease hydrate stability conditions. Computer models have been developed to evaluate hydrate gas production from hot water, steam injection, and depressurization. These models are based on data from the short term production tests in Canada and Alaska and suggest that gas can be produced from hydrates at sufficient rates to make gas hydrates a technically recoverable resource. Similarly, the use of gas hydrate inhibitors in the production of gas from hydrates has been shown to be technically feasible; however, the use of large volumes of chemicals comes with a high economic and potential environmental cost. Among the various techniques for production of natural gas from in-situ gas hydrates, initial evaluations suggest that the most economically promising method is considered to be depressurization.

The pace of gas hydrate energy projects has accelerated over the past several years. Researchers have long speculated that gas hydrates could eventually be a commercial resource, yet technical and economic hurdles have historically made gas hydrate development a distant goal rather than a near-term possibility. This view began to change over the past five years with the realization that this unconventional resource could be developed in conjunction with conventional gas fields and with existing technology. Research coring and seismic programs carried out by the Ocean Drilling Program (ODP), Integrated Ocean Drilling Program (IODP), government agencies, and several consortia have significantly improved our understanding of how gas hydrates occur in nature and have verified the existence of highly concentrated gas hydrate accumulations at several locations. The most significant development was the production testing conducted at the Mallik site in Canada's Mackenzie Delta in 2002 and 2008. In December 2003, the partners (including the Geological Survey of Canada and USGS, as co-leads, and other partners such as the Department of Energy (DOE)) in the Mallik 2002 Gas Hydrate Production Research Well Program publicly released the results of the first modern, fully integrated field study and production test of a natural gas hydrate accumulation. The Mallik 2002 gas hydrate production testing and modeling effort has for the first time allowed for the rational assessment of the production response of a gas hydrate accumulation. Project-supported gas hydrate production simulations have shown that under certain geologic conditions gas can be produced from gas hydrates at very high rates exceeding several million cubic feet of gas per day.

It is recognized that the Mallik 2002 project contributed much to the understanding of gas hydrates; however, it fell short of delivering all of the data needed to fully calibrate existing reservoir simulators. It was also determined that longer duration production tests would be required to assess more definitively the technical viability of long-term production from gas hydrates. The 2006-2008 Mallik Gas Hydrate Production Research Program was conducted by the Japan Oil Gas and Metals National Corporation (JOGMEC), Natural Resources Canada (NRCan), and the Aurora College/Aurora Research Institute to build on the results of the Mallik 2002 project with the main goal of monitoring long-term production behavior of gas hydrates. The primary objective of the 2006-2007 winter field activities was to install equipment and instruments to allow for long term production gas hydrate testing during the winter of 2007-2008. The following winter (2007/2008), the team returned to the site to undertake a longer-term production test. The 2007/2008 field operations consisted of a six day pressure drawdown test, during which “stable” gas flow was measured. The 2007/2008 testing program at Mallik established a continuous gas flow ranging from about 70,000 to 140,000 ft^3/day, which was maintained throughout the course of the six-day (139-hour) test as reported by JOGMEC, NRCan, and the Aurora College/Aurora Research Institute. The 2006-2008 Mallik production test is a significant event in our understanding of gas production from hydrates, in that “sustained” gas production from hydrates was achieved with existing conventional technology through simple well depressurization alone.

The potential for gas hydrates as an economically viable resource has been impacted by higher natural gas prices and forecasts of future tighter supply. However, gas hydrates have yet to be produced economically on a large scale. Gas hydrates have been compared to other unconventional resources, which were also considered to be uneconomic in the not too distant past, such as coalbed methane and tight gas sands. Once those resources were geologically understood and production challenges were addressed, these unconventional resources became part of the nation’s energy mix.

Safety and Seafloor Stability

Safety and seafloor stability are two important issues related to gas hydrates. Seafloor stability refers to the susceptibility of the seafloor to collapse and slide as the result of gas hydrate dissociation. The safety issue refers to petroleum drilling and production hazards that may occur in association with gas hydrates in both offshore and onshore environments.

Seafloor Stability

Under the ocean floor, the depth to the base of the gas hydrate stability zone becomes shallower as water depth decreases and the base of the gas hydrate stability zone intersects the seafloor at about 1,500 ft, a depth characterized by generally steep topography on the continental slope. It is possible that both natural and human induced changes can contribute to in-situ gas hydrate destabilization by changing the pressure or temperature regime, which may then convert hydrate-bearing sediments to a gassy water-rich fluid, triggering seafloor landslides. Evidence implicating gas hydrates in triggering seafloor landslides has been found along the Atlantic Ocean margin of the United States. The mechanisms controlling gas hydrate-induced seafloor landslides are not well known; however, these processes may release large volumes of methane, a potent greenhouse gas, to the Earth's oceans and atmosphere.

Safety

Throughout the world, oil and gas drilling is moving into regions where safety problems related to gas hydrates may be anticipated. Oil and gas operators have described numerous drilling and production problems attributed to the presence of gas hydrates, including uncontrolled gas releases during drilling, collapse of wellbore casings, and gas leakage to the surface. In the marine environment, gas leakage to the surface around the outside of the wellbore casing may result in local seafloor subsidence and the loss of support for foundations of drilling platforms. These problems are generally caused by the dissociation of gas hydrate due to heating by either warm drilling fluids or from the production of warm hydrocarbons from depth during conventional oil and gas production. The same problems of destabilized gas hydrates by warming and loss of seafloor support may also affect subsea pipelines.

National Research Agenda for Gas Hydrate Energy Development

In 1982, scientists onboard the Research Vessel *Glomar Challenger* retrieved a three-ft-long sample of massive gas hydrate off the coast of Guatemala. This sample became the impetus for the first national research and development program dedicated to gas hydrates by the United States. Over the next 10 years, the USGS, Department of Energy (DOE), and a number of other organizations compiled data demonstrating the potential for vast gas hydrates accumulations around the world. By the mid 1990s, it was widely accepted that gas hydrates represented an enormous storehouse of gas.

Recognizing the importance of gas hydrate research and the need for coordinated effort, the U.S. Congress enacted Public Law 106-193, the Methane Hydrate Research and Development Act of 2000. The Act called for the Secretary of Energy to begin a methane hydrate research and development program in consultation with the National Science Foundation; the U.S. Departments of Commerce, represented by the National Oceanographic and Atmospheric Administration (NOAA); Defense, represented by Naval Research Laboratory; and Interior, represented by USGS and MMS. In August, 2005, the Act was reauthorized through 2010 as Sec. 968 of the Energy Policy Act of 2005 (Public Law 109-58), and the Bureau of Land Management (BLM) was added to the interagency effort.

It is important to highlight that for two decades prior to this Act the bureaus of the Department of Interior studied gas hydrates within their various missions using base research funds. This base funded research continues, but in partnership with a variety of organizations. The USGS is investigating many aspects of gas hydrates to understand their geological origin, their natural occurrence, the factors that affect their stability, the environmental impact and the possibility of using this vast resource in the world energy mix. The USGS is investigating the resource potential of gas hydrates around the world in partnership with many organizations: (1) in the Mackenzie Delta of Canada in partnership with an international consortium; (2) on the North Slope of Alaska in partnership with DOE and BP Exploration (Alaska); (3) the DOE/ConocoPhillips gas hydrate production by CO_2 sequestration project, (4) in the U.S. Gulf of Mexico Joint Industry Partnership (JIP) with Chevron, DOE, and others; (5) the DOE/North Slope Borough, Alaska project; (6) in India in partnership with the Indian Directorate General of Hydrocarbons; and (7) Ocean Drilling Program (ODP) Leg 204 and Integrated Ocean Drilling

Program (IODP) Expedition 311. Other countries and groups have expressed interest in cooperative activities including Japan, China, South Korea, Taiwan, and others.

A major emphasis of USGS research focuses on the North Slope of Alaska, where USGS is participating in several gas hydrate energy research projects with DOE, BLM and various industry partners. The USGS is analyzing the recoverability and potential production characteristics of onshore natural gas hydrate accumulations overlying the Prudhoe Bay, Kuparak River, and Milne Point oil fields. With the success of the 2008 technically recoverable Alaska gas hydrate assessment, the USGS and BLM have expanded their cooperative gas hydrate research efforts in northern Alaska to further characterize the potential environmental and economic impact of gas hydrate exploration and development.

Another major emphasis of USGS research is the U.S. Gulf of Mexico. Several Gulf of Mexico hydrate research programs are underway and the most comprehensive study is a Joint Industry Project (JIP) led by DOE in partnership with Chevron which is designed to further characterize gas hydrates in the Gulf of Mexico. Participants include ConocoPhillips, Total, Schlumberger, Halliburton Energy Services, MMS, Japan Oil Gas and Metals National Corporation, and India's Reliance Industries.

On May 6, 2009, the JIP, including DOE, USGS, and MMS research scientists, completed the first-ever drilling project with the expressed goal to collect geologic data on gas-hydrate-bearing sand reservoirs in the Gulf of Mexico. This was an important goal because other resource assessment studies in northern Alaska by the USGS and offshore Japan, have shown that gas hydrates in conventional sand reservoirs are likely the closest to potential commercialization. In 2005, the Gulf of Mexico Gas Hydrate JIP Leg I conducted drilling, coring, and downhole logging operations designed primarily to assess gas hydrate-related hazards associated with drilling through the clay-dominated sediments that typify the shallow sub-seafloor in the deepwater Gulf of Mexico. Upon analysis of Leg I results, the JIP membership decided to expand its effort to assess issues related to the occurrence of gas hydrate within coarser-grained sediments. The 2009 drilling project, named the Gulf of Mexico Gas Hydrate Joint Industry Project Leg II (GOM JIP Leg II), featured the collection of a comprehensive set of logging-while-drilling (LWD) data through expected gas-hydrate-bearing sand reservoirs in seven wells at three locations in the Gulf of Mexico. The semi-submersible drilling vessel Helix Q4000 was mobilized at sea in the Gulf Mexico and drilling was conducted in the Walker Ridge, Green Canyon and the Alaminos Canyon blocks. The LWD sensors just above the drill bit provided important new information on the nature of the sediments and the occurrence of gas hydrate. The full research-level LWD data set on formation lithology, electrical resistivity, acoustic velocity, and sediment porosity enabled the greatly improved evaluation of gas hydrate in both sand and fracture dominated reservoirs.

The two holes drilled at Walker Ridge yielded evidence of a laterally continuous thick fracture-filling gas hydrate section, but more importantly both wells also encountered sand reservoirs, between 40- to 50-ft-thick, nearly saturated with gas hydrate. Gas-hydrate-bearing sands were also drilled in two of the Green Canyon wells, with one occurrence slightly more than 100-ft-thick. Initial interpretation of the Alaminos Canyon drilling results is that the sands appear to exhibit uniformly low gas hydrate saturation over a large area. Nevertheless, the discovery of thick hydrate-bearing sands at Walker Ridge and Green Canyon validates the integrated geological and geophysical approach used in the pre-drill site selection process in order to predict hydrate accumulations before drilling, and provides increased confidence in assessment of gas hydrate volumes in the Gulf of Mexico and other marine sedimentary basins. The presence of significant gas hydrate accumulations as both pore-filling sands and fracture-filling material in shallow muds, make both Walker Ridge and Green Canyon likely locations for future research into energy targets of gas hydrates in marine environments. While the primary goal of this JIP is to better understand the safety issues related to gas hydrates, the results of the program will also allow a better assessment of the commercial potential of marine gas hydrates.

Seismic-acoustic imaging to identify gas hydrate and its effects on sediment stability has been an important part of USGS marine and onshore studies since 1990. USGS work in this area has allowed for prediction of the occurrence as well as the thickness and saturation of gas hydrates ahead of drilling. USGS has also conducted extensive geochemical surveys and established a specialized laboratory facility to study the formation and dissociation of gas hydrate in nature and also under simulated deep-sea conditions.

The USGS, as well as many groups, participate in the IODP, the ODP, and their predecessor the Deep Sea Drilling Project (DSDP) – which have contributed greatly to our understanding of the geologic controls on the formation, occurrence, and stability of gas hydrates in marine environments. The gas hydrate research efforts under IODP-ODP-DSDP have been mostly directed to assess the role of gas hydrate in climate change. In the summer of 2002, ODP Leg 204 investigated the formation and occurrence of gas hydrates in marine sediments at Hydrate Ridge off the Oregon coast. The shipboard scientists successfully deployed new core systems for recovering and analyzing gas-hydrate-bearing sediments at in situ pressure conditions; thus allowing the correlation of sediment properties with seismic, conventional wireline and logging-while-drilling downhole data. IODP Expedition 311 with a USGS co-chief scientist, established a transect of four research drill sites across the northern Cascadia margin off the west coast of Canada. In addition to the transect sites, a fifth site was established at a cold vent with active fluid and gas flow. The most significant findings of the coring and logging programs during IODP Expedition 311 included the observation that gas hydrate is formed mainly within the sand-rich reservoir-quality formations and is virtually absent in the fine-grained and clay-rich sediments. Thus, the presence of gas hydrate is mainly controlled by lithology much like conventional hydrocarbon resources.

BP Exploration (Alaska), DOE, and the USGS have undertaken a project to characterize, quantify, and determine the commercial viability of gas hydrates and associated free gas resources in the Prudhoe Bay, Kuparuk River, and Milne Point field areas in northern Alaska. Under Phase 1 of this project, gas hydrates and associated free gas-bearing reservoirs in the Milne Point oil field have been studied to determine reservoir extent, stratigraphy, structure, continuity, quality, variability, and geophysical and petrophysical property of these hydrocarbon-bearing reservoirs. The objective of Phase 1 is to characterize reservoirs and fluids, leading to estimates of the recoverable gas reserve and commercial potential, and the definition of procedures for gas hydrate drilling, data acquisition, completion, and production. Phases 2 and 3 will integrate well, core, log, and production test data from additional test wells. Ultimately, the program could lead to development of a gas hydrate pilot project with a long term production test, and determine whether gas hydrates can become a part of the Alaska North Slope gas resource portfolio. In 2005, extensive analysis of 3-D seismic data and integration of that data with existing well log data by the USGS identified more than a dozen discrete and mappable gas hydrate prospects within the Milne Point area. Because the most favorable of those targets was a previously undrilled, fault-bounded accumulation, BP Exploration (Alaska) and DOE decided to drill a vertical stratigraphic test well at that location (named the "Mount Elbert" prospect) to acquire critical reservoir data needed to develop a longer term production testing program. The Mount Elbert gas hydrate stratigraphic test well acquired sediment cores, well logs, and downhole production test data. Gas hydrates were expected and found in two stratigraphic zones — an upper zone containing about 45 ft of gas hydrate-bearing reservoir-quality sandstone, and a lower zone containing about 50 ft of gas hydrate-bearing reservoir. Both zones displayed gas hydrate saturations that varied with reservoir quality, with typical values between 60% and 75%. This result conclusively demonstrated the soundness of the gas hydrate prospecting methods developed primarily at the USGS. The Mount Elbert gas hydrate stratigraphic test well project also included the acquisition of pressure transient data from four short-duration pressure-drawdown tests. Each test consisted of a period of fluid withdrawal (thereby reducing formation pressure) followed by a period where the pump is shutoff and the subsequent pressure build-up is monitored. The Mount Elbert press tests confirmed again that gas could be produced from hydrates by simple depressurization and the presence of a mobile pore-water phase even in the most highly gas hydrate-saturated intervals lends itself to higher expected gas hydrate production rates. This project yielded one of the most comprehensive datasets yet compiled on naturally-occurring gas hydrates.

International Gas Hydrate Research and Development Efforts

Many countries are interested in the energy resource potential of gas hydrates. Countries including Japan, India, China, South Korea, and Canada have established large gas hydrate R&D programs, while Norway, Mexico, Columbia, Chile, and others are investigating the viability of forming government-sponsored gas hydrate research programs. It is also not surprising that the most aggressive and well funded gas hydrate research programs are in countries highly dependent on imported energy resources, such as Japan and India.

In 1995, the Government of Japan established the first large-scale national gas hydrate research program, which now plays a leading role in worldwide gas hydrate research efforts. The first five years of the Japan National Gas Hydrate Program culminated in 1999/2000, with the drilling of a series of closely spaced core and geophysical logging holes in the Nankai Trough. In 2001, the Ministry of Economy, Trade and Industry (METI) launched a more extensive project entitled "Japan's Methane Hydrate Exploitation Program," operated by the Methane Hydrate 2001 Consortium, to evaluate the resource potential of deepwater gas hydrates in the Nankai Trough area. This project is intended to promote the technical development and recovery of gas hydrates, and to provide a long-term stable energy supply, with plans for field production testing as soon as 2011 and development of the technologies needed for commercial production by 2016.

The government of India also is funding a large national gas hydrate program to meet its growing energy requirements. One of the primary goals of the Indian National Gas Hydrate Program (NGHP) is to conduct scientific ocean drilling/coring, logging, and analytical activities to assess the geologic occurrence, regional context, and characteristics of gas hydrate deposits along the continental margins of India in order to meet the long term goal of exploiting gas hydrates as a potential energy resource in a cost effective and safe manner. In 2006, the Directorate General of Hydrocarbons (India) and the USGS conducted research drilling off the Indian Peninsula and along the Andaman convergent margin, with special emphasis on gaining an understanding of the geologic and geochemical controls on the accumulation of gas hydrate in these two diverse settings. NGHP Expedition 01 was among the world's most complex and comprehensive methane hydrates field ventures yet conducted. NGHP Expedition 01 established the presence of gas hydrates in the Krishna-Godavari, Mahanadi, and Andaman sedimentary basins. The expedition discovered one of the richest gas hydrate accumulations yet documented in the Krishna-Godavari Basin, recorded the thickest and deepest gas hydrate stability zone yet known in the Andaman Sea, and established the existence of a fully-developed gas hydrate system in the Mahanadi Basin. It is anticipated that future NGHP efforts will likely include drilling, coring, and field production testing.

Production Potential of Gas Hydrates – Technical Challenges

In order to release, or produce, the gas from a gas hydrate, we must change the temperature or pressure conditions controlling its occurrence and stability. The most economically promising method of producing gas from gas hydrates appears to be depressurization of the reservoir. Results from the Mallik and Mount Elbert test wells support this supposition. However, it is important to note that much more information is needed before production of this unconventional resource in these frontier regions becomes economic. For example, gas production is dependent upon the permeability of the host rock, and therefore, the type of sediment in which the hydrate occurs and understanding flow rates and paths is critical to potential production.

Onshore Alaska and the offshore Gulf of Mexico are proven exploration targets for gas hydrates. In the Gulf of Mexico, industry has begun assessing hydrate potential on their oil and gas leases. New and existing industry-Government partnerships are expected to drill hydrate prospects on the North Slope of Alaska in the near future – hence, the first domestic production of hydrates is expected to occur in Alaska, where gas from the hydrates will either support local oil and gas field operations, or be available for commercial sale if and when a gas pipeline is constructed. In both Alaska and the Gulf of Mexico, critical drilling and transportation infrastructure exists, which will allow gas hydrate prospects to be drilled and produced from existing installations.

The timing for expected commercial production of hydrates is uncertain. The DOE has estimated that gas production from gas hydrate could begin no earlier than 2015. In September of 2003, the National Petroleum Council (NPC) reported that we will not likely see significant production from gas hydrates until sometime beyond 2025. Initial production from gas hydrates could occur much sooner, especially in areas such as the North Slope of Alaska or in other countries. Estimates vary on when gas hydrate production will play a significant role in the total world energy mix. It is not currently possible to determine whether hydrates will be able to contribute to the domestic energy supply. The future contribution of this resource will depend not only on further progress in gas hydrate production, but also on research into the environmental impacts of gas hydrate production, which are not fully understood.

Next Steps to Gas Hydrate Production

The immense volume of gas hydrates worldwide may be a significant potential energy resource at some point in the future. Our understanding of these resources, however, is still evolving – we do not yet know if these accumulations exist in sufficient concentration to make them economically viable, nor do we know whether even concentrated accumulations can be developed economically. Additional science-driven production tests will contribute to our understanding of gas hydrate production. It is generally believed that gas hydrates can be produced by standard techniques used today to exploit conventional oil and gas resources. However, it is very likely that new drilling and production technology would contribute to the ultimate producibility of gas hydrates. We know that hydrates must be produced by releasing the gas from the hydrate form by the methods previously described. However, there has only been one industry scale hydrate production test to date (the 2008 Mallik project). Much more information is needed on: (1) the geology of the hydrate-bearing formations, both on a large scale (the the distribution of hydrates throughout the world) and on a small scale (their occurrence and distribution in various host sediments); (2) the reservoir properties/characteristics of gas hydrate reservoirs; (3) the production response of various gas hydrate accumulations; and (4) the economics controlling the ultimate resource potential of gas hydrates. The USGS will continue to play a vital role in studying, evaluating, and understanding the geologic and engineering properties critical to the realization of hydrates as a viable energy source. The USGS will also continue to work with other Federal agencies and within domestic and international consortiums to conduct needed gas hydrate production test studies.

Conclusions

Our knowledge of naturally occurring gas hydrates is growing and it can be concluded that: (1) a huge volume of natural gas is estimated to be stored in gas hydrates; (2) production of natural gas from gas hydrates is technically feasible with existing technology; (3) gas hydrates hold the potential for natural hazards associated with seafloor stability and release of methane to the oceans and atmosphere; and (4) gas hydrates disturbed during drilling and petroleum production pose a potential safety problem. USGS research on gas hydrates is focused on: (1) the energy-resource potential they represent; (2) the hazards they might pose to drilling and the environment; and (3) the impact they might have on global climate change. Thus, the USGS welcomes the opportunity to collaborate with domestic and international scientific organizations and industry to further collective understanding of these important geologic materials.

Thank you, Mr. Chairman for the opportunity to present this information. I will be happy to respond to any questions you may have.