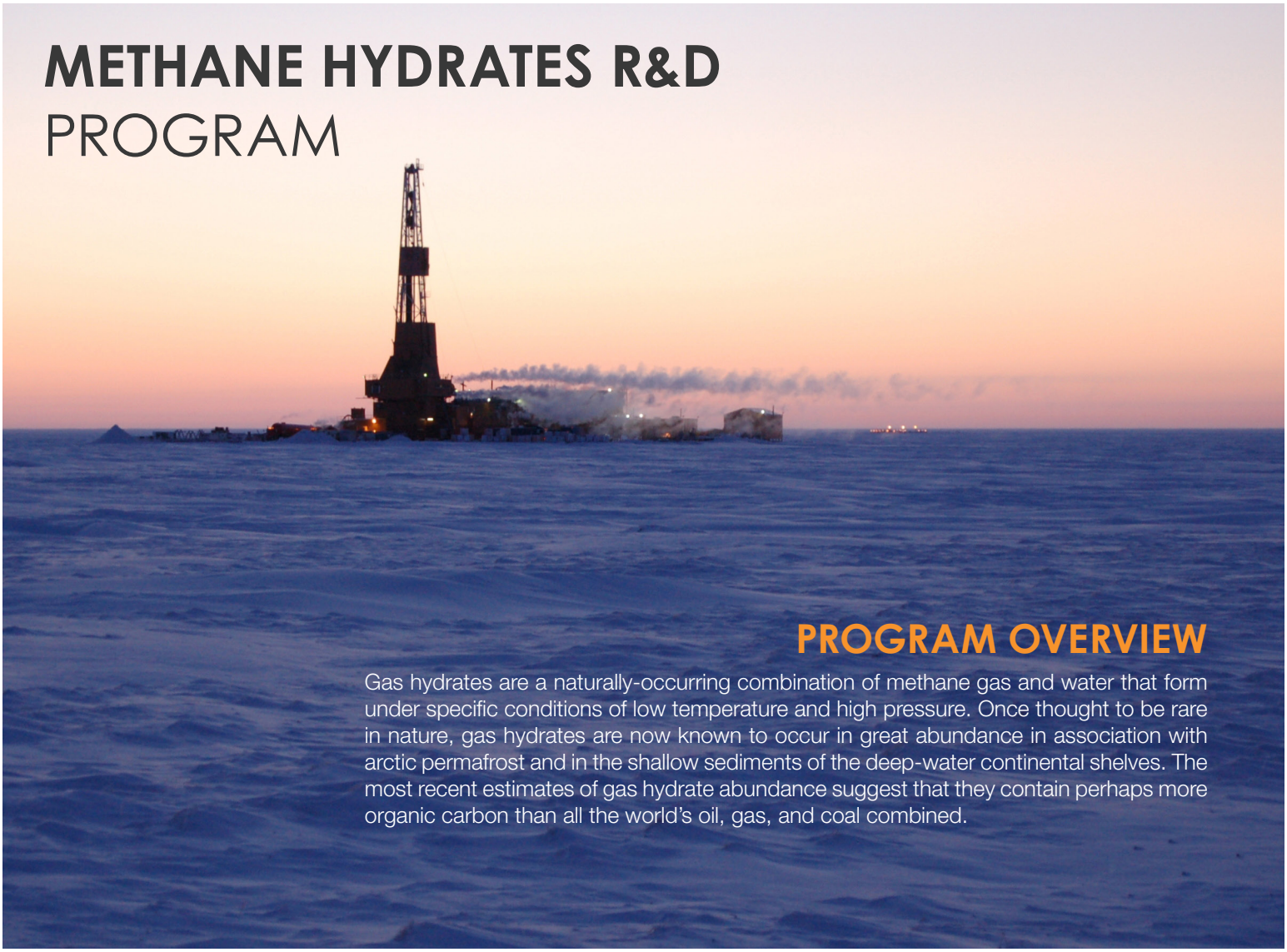
METHANE HYDRATES R&D PROGRAM



PROGRAM OVERVIEW

Gas hydrates are a naturally-occurring combination of methane gas and water that form under specific conditions of low temperature and high pressure. Once thought to be rare in nature, gas hydrates are now known to occur in great abundance in association with arctic permafrost and in the shallow sediments of the deep-water continental shelves. The most recent estimates of gas hydrate abundance suggest that they contain perhaps more organic carbon than all the world's oil, gas, and coal combined.

NETL

NATIONAL ENERGY TECHNOLOGY LABORATORY

The primary mission of the Methane Hydrates R&D Program is to collaborate with industry, academia, international research organizations, and other U.S. government agencies to advance scientific understanding of gas hydrates as they occur in nature so that their role as a resource and potential for offsetting climate change can be more fully understood. In pursuit of this primary mission, the program is proceeding along three parallel paths. The first path is to confirm the scale and nature of the potentially recoverable resource through complex drilling and coring programs. The second is to develop the technologies needed to safely and efficiently find, characterize, and recover methane from hydrates through field testing, numerical simulation, and laboratory experimentation. The third is to better understand gas hydrate's role in the natural environment, including its linkage to global climate change.

METHANE HYDRATES R&D PROGRAM

THE ISSUES

Gas hydrates have only relatively recently been recognized to exist at a massive scale in the natural environment. This finding has prompted research that, in turn, has highlighted four important issues:

- Gas hydrates are potentially a significant source of clean-burning natural gas for meeting future domestic energy needs. Large volumes are available in Alaska. The U.S. Geological Survey (USGS), in 2008, reported a mean estimate of 85 trillion cubic feet of technically recoverable resource. This could supply Alaskan native communities, broaden U.S. gas supplies, and enable access to other Arctic resources, including stranded conventional gas. In the Gulf of Mexico (GoM), the marine in-place gas hydrate resource in the most favorable reservoir settings has been assessed by the Bureau of Ocean Energy Management (BOEM) at more than 6,000 trillion cubic feet, and a 2012 report from BOEM indicated large potential resources off the U.S. Atlantic and Pacific coasts.

- The opportunities for international scientific collaboration on methane hydrate research have never been greater. International interest and investment is high, because gas hydrates have the promise of providing supplemental energy resources to a number of economies that are largely and increasingly reliant on energy imports.

- The role of gas hydrates in mediating the movement of carbon in the geosphere is not well known but could have major implications on both long- and short-term environmental processes, particularly climate change. This issue is most acute in Arctic regions where climate change is most pronounced and where gas hydrate deposits are common and least effectively buffered from environmental change.

- Unintended dissociation of gas hydrates while drilling to and producing from deeper oil and gas reservoirs can threaten the integrity of wells and destabilize surface structures. To address these hazards, industry has historically opted for simple avoidance. However, this issue has only recently begun to be studied in detail.

INTERAGENCY COORDINATION TEAM

DOE-NETL

U.S. Geologic Survey

Bureau of Ocean Energy Management

National Oceanic & Atmospheric Administration Naval Research Laboratory

Bureau of Land Management National Science Foundation

RELEVANT LINKS

NETL Methane Hydrates home page: http://www.netl.doe.gov/research/oil-and-gas/methane-hydrates

Fire in the Ice: A periodical highlighting the National Methane Hydrate R&D Program http://www.netl.doe.gov/research/oil-and-gas/methane-hydrates/fire-in-the-ice

DOE's Office of Fossil Energy Methane Hydrate web page: http://energy.gov/fe/science-innovation/oil-gas-research/methane-hydrate

METHANE HYDRATES R&D PROGRAM

The need for scientific data collection and technology development is being driven by:

- Resource volumes, particularly those resources in the marine setting that are the most prospective for production, remain poorly defined, but could be substantial. Large areas of the U.S. outer continental shelf are virtually unexplored with respect to methane hydrates. Only a handful of wells have been drilled for hydrate evaluation in the GoM and the Pacific and Atlantic seaboards.

- The commercial viability of gas hydrate reservoirs is not yet known. A very limited number of production tests have been conducted to date, with the first deepwater test occurring offshore Japan in 2013. A series of controlled scientific field experiments, followed by extended duration production tests that lead to commercial-scale multi-well demonstrations, are needed to quantify the rates and volumes at which methane can be extracted and to assess any potential environmental impacts.

- Multiple gas hydrate production scenarios are under evaluation. Simple depressurization holds the most promise in terms of potential rates. However, methane production via carbon dioxide (CO_2) injection (and sequestration) and thermal stimulation may have roles in what will ultimately become the optimal production system.

- The potential environmental impacts of possible gas hydrate production scenarios (such as movement of liberated methane and geomechanical stability of produced reservoirs) are not yet known. These must be closely studied through laboratory modeling and closely monitored field tests.

- There is need for a more robust understanding of gas hydrates' role in the natural environment, including the potential for release of methane (a powerful greenhouse gas) into the natural environment, its impact on the health of the oceans, and its role as a potential near-term feedback to climate change.

PROJECT PORTFOLIO OVERVIEW

Since 2009, more than 50 different projects under the Methane Hydrates Program have received funding. The efforts represent a total potential value of roughly $160 million, including both government and non-government costs. The bulk of the funding supports field and laboratory programs being conducted through partnerships with industry and academia and supported by work conducted with DOE's National Laboratories and collaborating federal agencies.

Investigations of the production potential of gas hydrates have used the natural laboratory of the Alaska North Slope to pursue a range of scientific field experiments.

- NETL maintains separate Memoranda of Understanding with the State of Alaska's Department of Natural Resources (DNR) and the Japan Oil, Gas, and Metals National Corporation (JOGMEC) designed to advance opportunities for gas hydrate field-based research on the Alaska North Slope. DOE and JOGMEC are currently working with the USGS and Petrotechnical Resources, Alaska to develop field testing plans and engage potential industry partners.

- In 2012, ConocoPhillips and JOGMEC joined with NETL in conducting a field trial in the Prudhoe Bay Unit to assess the potential for injecting CO_2 into a gas hydrate reservoir where it will be sequestered while releasing the methane (CH_4) for use as an energy resource. The test confirmed significant challenges to commercial-scale gas exchange technology.

- In 2007, BP Exploration Alaska conducted initial test drilling in the Milne Point Unit to confirm gas hydrate occurrence and evaluate gas hydrate exploration technologies on the Alaska North Slope.

METHANE HYDRATES R&D PROGRAM

Recent and ongoing investigations of the nature and occurrence of marine gas hydrate resources include:

- An international industry consortium in 2009, led by Chevron, conducted a landmark expedition that prospected for, and discovered, resource-quality gas hydrate accumulations at two deepwater sites. The exploration approach validated in that program is now being used around the world.
- Bilateral agreements have enabled DOE participation in international field studies of gas hydrates, including India (2006) and Korea (2007 and 2010). DOE, USGS, and BOEM are currently working closely with the National Program of India in the planning of future field programs.
- The University of Texas at Austin is currently leading the effort to conduct gas hydrate sampling at the GoM sites discovered in 2009, and to pursue further advances in gas hydrate exploration and resource confirmation.
- The University of Texas, Ohio State University, and Columbia University are using the 2009 data to investigate the nature and formation of marine accumulations.
- Ohio State University is collaborating with the BOEM to access data on more than 1,700 deepwater wells to evaluate indications of gas hydrates in the northern GoM.
- The geophysical evaluation of gas hydrates is being advanced through separate projects with Oklahoma State University and with Fugro GeoConsulting which use log data gathered over two GoM deepwater sites in 2009.
- Georgia Tech is developing new tools for the in situ measurement of gas hydrate-bearing sediment properties.
- NETL, in collaboration with The Consortium for Ocean Leadership, published a review in 2012 of marine gas hydrate R&D opportunities and recommendations for future offshore drilling campaigns.
- In 2013, NETL, the USGS, and the BOEM teamed to acquire high-resolution multi-component seismic images of the sites discovered in the GoM in 2009.
- The University of California at San Diego (Scripps Institution of Oceanography) is assessing controlled source electromagnetic (CSEM) technologies for locating marine hydrate deposits. Research will provide a fundamental understanding of the electrical properties of hydrate-bearing sediments and assess the usefulness of CSEM as a complementary technology for locating and characterizing gas hydrates. It will also contribute data at locations of known or suspected gas hydrate occurrence in the GoM.

Investigations of the environmental role of gas hydrates include:

- The University of Texas at Austin is developing models to assess conditions under which gas may be expelled from deepwater gas hydrate into the overlying ocean.
- Oregon State is participating in an international investigation of gas hydrate response to climate change offshore Norway.
- Texas A&M and Georgia Tech are developing new models that will advance the ability to integrate geomechanics into simulations of the behavior of hydrate deposits.
- Southern Methodist University, the USGS, Oregon State, and others are conducting numerical modeling, field data collection, and experimental studies to constrain the nature of gas hydrates on the U.S. Arctic and Atlantic shelves and their response to environmental change.
- The University of Washington is investigating gas hydrate response to climate change offshore in the Pacific Northwest.
- MIT, the USGS, and the University of New Hampshire are investigating gas hydrate dynamics on the U.S. Atlantic Shelf, including the fate of methane bubbles from seeps.

METHANE HYDRATES R&D PROGRAM

- Oregon State University is generating computer models that will enable researchers to interpret modern day methane fluxes and reconstruct past episodes of methane flux in gas hydrate-bearing regions from shallow geochemical data. In an allied effort, the University of New Hampshire is reconstructing the history of methane flux at three sites on the Cascadia margin using sedimentological data.

- The University of Mississippi completed studies to gather time-series, direct current resistivity measurements at cold vent sites on the continental slope of the northern GoM.

- The Naval Research Laboratory has participated in collaborative field programs with New Zealand and Germany to investigate gas hydrates offshore New Zealand.

- The Lawrence Berkeley National Lab and Los Alamos National Lab recently completed an effort to couple leading gas hydrate reservoir simulators and ocean circulation models to enable predictions of the response of marine gas hydrates to changing conditions and the potential impact of methane hydrate destabilization on ocean ecology.

- The University of Oregon is studying phenomena associated with gas hydrate-related natural geohazards.

- The University of Rochester will advance understanding of the environmental implications that methane leaking from dissociating gas hydrates could have on the ocean-atmosphere system. It will also enhance knowledge of the distribution and amount of methane emissions from the U.S. Atlantic Margin upper continental slope in the mid-Atlantic zone.

- Texas A&M University is leveraging prior NETL research and its own data to study the fate of methane in water columns. This effort will result in new analysis and improved models that will help to clarify hydrate's role in the global natural environment.

METHANE HYDRATES R&D PROGRAM

These field efforts are supported by a wide range of ongoing fundamental science investigations, including:

- An international modeling consortium (led by NETL) that has catalyzed significant advances in all the leading methane hydrate numerical models.
- Experimental efforts at Georgia Tech, Lawrence Berkeley National Laboratory, NETL, and elsewhere that have advanced the understanding of the physical nature of gas-hydrate-bearing sediments.
- Georgia Tech is investigating the behavior of gas hydrates hosted in fine-grained sediments to further evaluate the potential to produce gas from such deposits.
- The Colorado School of Mines is conducting laboratory studies to enable more accurate determination of the concentration of gas hydrates using seismic data.
- Arizona State University is providing improved parameterization of capillary pressure and relative permeability phenomena for use in the numerical simulation of gas hydrate dissociation and gas production.
- The Lawrence Berkeley National Lab is continuing its program of integrated laboratory and numerical modeling to enable the prediction of gas hydrate response to depressurization-induced production.
- Pacific Northwest National Lab is using the STOMP-HYD code for evaluation of the CO_2-CH_4 exchange.
- NETL is using PetroMod petroleum systems models to investigate the evolution and dynamics of gas hydrate systems in the deepwater GoM.
- NETL is conducting a range of experimental and numerical modeling studies designed to enable improved planning, implementation, and interpretation of DOE-sponsored field programs related to gas hydrate resource potential.
- The University of Texas at Austin is conducting a laboratory evaluation of the dynamic petrophysical attributes of gas hydrate–bearing sands in response to pressure reduction at macro- and micro-scale. This research will enhance understanding of hydrate system behavior, improve the ability to simulate hydrate production, and make more realistic estimates of the hydrate resource.
- Louisiana State University is conducting a laboratory evaluation of the migration of fine-grained particles during gas production, with a specific focus on factors unique to gas production from hydrate-bearing sediments.
- Texas A&M University is advancing the capabilities of a leading integrated model for hydrate system behavior. The research will increase understanding of deep oceanic and arctic hydrate deposits and will yield simulation capabilities useful in assessing and predicting production-related performance of hydrate deposits.

Together, these projects are advancing marine resource characterization and enabling initial assessments of gas hydrate production potential. International collaboration continues to be a vital part of the program since gas hydrates have resource potential that is important on a global scale. The fundamental science needed to properly gather and evaluate field data is being provided through a range of efforts in the laboratory and through numerical modeling.

METHANE HYDRATES R&D PROGRAM

Key accomplishments of the program to date include:

- Characterization of potential testing sites on the Alaska North Slope, including the drilling and evaluation at the Ignik Sikumi test site in 2011, and a three-month production trial of CO_2-CH_4 exchange technology in early 2012
- Confirmation of the ability to reliably detect and characterize gas hydrate accumulations prior to drilling
- Confirmation of the occurrence of resource-quality gas hydrate accumulations in the GoM
- Acquisition of data in Alaska that enabled the first quantification of technically-recoverable resource volumes from gas hydrates
- Development of new tools for measuring physical properties of gas hydrate-bearing sediment samples in the field
- Development of collaborative agreements with leading global gas hydrate research programs
- Expansion of numerical modeling capability to enable the first simulations of field-scale production, geomechanical stability of hydrate bearing sediment, and gas hydrate-climate interaction

Overall, the Gas Hydrates program is working to advance the science and technologies necessary to fully understand the energy resource potential and environmental implications of naturally-occurring gas hydrate.

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