U.S. Department of Energy

Secretary of Energy Advisory Board Report of the Task Force on Methane Hydrates

January 26, 2016

Contents

Executive Summary

On June 17, 2015, U.S. Secretary of Energy, Dr. Ernest Moniz, asked the Secretary of Energy Advisory Board (SEAB) to form a task force to review the U.S. Department of Energy's (DOE's) methane hydrate research program. The charge was to evaluate the program's pre-commercial research activities and progress in (1) understanding the assessment and exploitation of hydrates as an energy resource, and (2) understanding the environmental impact of hydrates, whether as a result of naturally occurring phenomena or of human activity.

Issues of particular interest included the cooperation of the United States with foreign governments in international research collaborations to investigate hydrates; the participation of such diverse stakeholders as governments, national laboratories, academic institutions, and industry; and the location, design, and execution of field experiments necessary to achieve the program's goals.

Among the task force's key findings and recommendations are the following:

- The program has made valuable scientific contributions since 2000 and should remain a DOE priority. Funding should remain at its current Fiscal Year (FY) 2015 level of $15 million per year. Given the long-term nature of the program, there should be greater funding certainty than in the past.
- Approximately one-third of the program budget should be dedicated to fundamental scientific questions whose answers are necessary for understanding methane hydrates as an energy resource and their environmental impact. Two-thirds of the program budget—approximately $10 million per year—would be used to support U.S. participation in larger international hydrates activities and complex field research.
- The United States views its cooperation with foreign governments on international energy security as a high priority. As such, a $15 million-per-annum hydrates research program is a small investment for keeping U.S. core capabilities relevant and for supporting other countries' efforts to develop their methane hydrates resources more effectively, which they see as both a promising contribution to energy security in future decades and a way to reduce coal consumption. Continued U.S. participation would help assure rigor in international activities, enabling all participants to benefit from international investments and avoid U.S. exclusion from development and information about the technology.
- The program should build on prior strong external engagement to enhance and increase industry input in a strategic direction setting, and on external academic engagement to set program priorities and provide peer review. Field experiment design should be more clearly defined in the context of program objectives, with more engagement of industry on planning.

Introduction

Methane hydrates are a naturally occurring combination of methane gas and water formed under specific conditions of low temperature and high pressure. There are abundant deposits across the world; for instance, in the Arctic permafrost and in shallow sediments of the deep-water continental shelves. The *FY 2010 Methane Hydrate Program Report to Congress* provides detailed introductory background on methane hydrates.[1]

DOE has sponsored research of methane hydrates since 1982. In 2000, the *Methane Hydrate Research and Development Act* authorized the Department to develop a focused national program of fundamental and applied research toward the development of methane hydrates as an option for the nation's future energy resources. Since its inception in 2000, the program has made a number of advances in the understanding of the assessment and development of hydrates through a variety of projects involving university, national laboratory, industry, and international participation. Periodic reports have documented progress.[1, 2, 3, 4] Assessment reports have evaluated that progress, noting opportunities for improvement and further advancement.[5, 6]

Fifteen years later, Secretary Moniz issued the charge to SEAB to review the program. The shale gas revolution has provided the United States with an abundance of natural gas for the next three to four decades. In contrast, there has been an increase in international interest in methane hydrates as an energy resource that might contribute to energy security for several nations, with a commensurate level of international investment. Increased emphasis on the long-term goal of mitigating climate change has renewed scrutiny of the potential environmental impact of methane hydrates, whether from exploitation as an energy resource or from passive release. Alternatives to fossil fuels, which promise a smaller environmental footprint than fossil fuels, continue to make progress toward becoming commercially viable energy resources at scale.

All of these circumstances prompted a number of questions about the future directions, resources, and composition of the program:

- In light of the expected increase in the adoption of fossil fuel alternatives, what is the appropriate priority for hydrates as a future energy resource option for the nation, and within what time frame might methane hydrates become commercially viable?
- While oil and natural gas markets are currently oversupplied, circumstances will likely change over the next several years, especially with the major cutbacks in investment. Given the current oversupply in oil and natural gas and the anticipated increase in the adoption of fossil fuel alternatives as an energy resource, what is the appropriate priority for hydrates as a national option for a future energy resource and within what time frame might methane hydrates become commercial?
- What are the important fundamental science and engineering questions to be addressed by the DOE research program to advance hydrates as a viable energy resource and minimize environmental impact?
- What contribution does the U.S. hydrates program make in advancing international energy security?
- Does the development of methane hydrates as an energy resource conflict with long-term goals for reducing fossil carbon emissions into the atmosphere?

- Given the significant expense of field experiments, are there opportunities to improve the design and execution of those experiments to more effectively achieve the goals of the program?

These and other issues are further detailed in the charge to the task force (see Appendix 1).

The task force comprises a number of SEAB members and experts from academic institutions and industry who have worked on various aspects of methane hydrates. A wealth of background literature was made available to the task force. All participants in the study, task force members, and other contributors are listed in Appendix 2.

The key findings of the task force are organized as follows:

- Critical questions for hydrates as an option for energy supply
- The most important questions for the fundamental research program
- Environmental impact
- International energy security
- Field experimentation.

Following the key findings, the report concludes with the summary recommendations.

Task Force Findings

Hydrates as a Future Energy Resource Option

The task force recognizes that the methane hydrate research program is answering fundamental, long-term questions about the technical and economic viability of producing methane hydrates—questions not likely to be addressed by industry due to lack of foreseeable commercial operations. Fossil fuel alternatives may progress such that hydrates will never be commercially or environmentally competitive in the United States. Nevertheless, methane hydrates are presently a sizable potential energy resource and present a significant option as a long-term energy resource, especially for countries lacking viable alternatives.[7, 8, 9] While recent estimates of the global resource—gas-in-place—range over two to three orders of magnitude, Boswell[10] cites a typical number as 2×10^{16} m^3, with an uncertainty of two to three orders of magnitude around this number. Of this global resource, estimates of what may be technically recoverable globally also vary over several orders of magnitude, approximately 4×10^{14}, again with an uncertainty of one to two orders of magnitude around this estimate.[8] At today's gas prices, there are no economically recoverable deposits. For comparison, annual U.S. natural gas use is approximately 6×10^{11} m^3.

The methane hydrates research program represents an investment by DOE in developing this option. It is consistent with the DOE mission, as long as the cost of exploring the option remains modest and allows the United States to benefit from its significant international investment.

Similar early investments by DOE in coalbed methane, and, to some extent, shale gas, were important to the ultimate development of these resources.[10, 11] The effort to understand the production of methane from hydrates is important and should continue, even though U.S. domestic demand for natural gas is likely to be met with U.S. production of conventional gas, coalbed methane, and shale gas for several decades.

Resources and Configuration of Activities to Address Fundamental Questions Underlying Energy Resource Potential and the Environmental Impact of Methane Hydrates

It is important that the program provide sufficient resources for fundamental research on the basic science of methane hydrates, as well as the behavior of methane hydrate deposits in the environment, including those that are not targets for methane extraction.

The DOE methane hydrates research program has delivered valued results that have contributed an advanced scientific understanding of gas hydrates as a long-term energy resource, and insights into their potential effect on the environment.[6, 12] The program has sponsored several projects; some investigate present-day possible gas hydrate dissociation in the Arctic and mid-latitude environments, and some focus on the environmental effects of the natural degassing of methane hydrates.

The task force noted that budgets for these research activities have been variable, due in part to the needs of the field projects. Given that the commercialization of methane hydrates is likely to be several decades away, the task force members believe that there should be more stability in funding for understanding fundamental questions about methane hydrates and the behavior of methane hydrates in the environment, as part of the global carbon cycle. This funding should be protected from the variable needs of the field program.

The term "field program" applies not only to such efforts as the Gulf of Mexico field projects (Chevron-led joint industry project, Mississippi Canyon 118 Seafloor Observatory) and Alaska North Slope field projects (extended-duration pressurization testing program, CO_2-CH_4 exchange field trial) described in the methane hydrate program Reports to Congress,[2, 3, 4, 5] but also to studies that have a significant field experiment component (and expense), such as those involving gas hydrate exploration technologies (e.g., the field testing component of direct current resistivity arrays and field testing of marine electromagnetic surveys).

The variable nature and funding for field program activities should be distinguished from funding for projects classified as fundamental experimental and modeling studies, and global environmental and climate studies, and the laboratory and theoretical work associated with gas hydrate exploration technologies—categories described explicitly in the past four methane hydrate Reports to Congress,[2, 3, 4, 5] wherein the task force expresses its belief that greater certainty and stability of funding will preserve critical scientific capabilities for the program.

The task force understands the importance of increasing industry involvement and rigorous external peer review in both the activities and guidance of the program.

The program should be commended for its efforts to seek industry involvement. Major prior effort in the program has involved industry; for example, the BP Alaska North Slope Methane Hydrate Program (initiated in 2001), ConocoPhillips Methane Hydrate Production Trial Using Carbon Dioxide/Methane Exchange on the Alaska North Slope (2008–2012), and the Joint Industry Project (with several U.S. and international industrial partners) in the Gulf of Mexico led by Chevron Energy Technology Company (2001–2014).[13, 14, 15, 16, 17, 18]

The task force identified ways in which industry engagement can be enhanced and increased. Industry engagement to date has primarily occurred for the purpose of accessing the operational expertise to execute the near-term scientific program (one to five years). Notwithstanding the scientific progress already made, commercial extraction of hydrates is not likely to occur for a couple of decades. There are opportunities to engage the appropriate levels of industry to ensure that industry's major technical concerns about proving hydrates extraction will be commercially feasible. Industry engagement is particularly important in the design and execution of field experiments. To ensure effective industry and external engagement, the committee recommends that the program increase industry participation, even without direct cost sharing. As part of this recommendation, task force members believe that industry participation in the Methane Hydrate Federal Advisory Committee should be strengthened and have a more active and influential role in setting program priorities and reviewing budgets.

The task force review identified a number of basic questions about hydrates that remain open.[6,19,20,21] Given the worldwide abundance of methane hydrates, their distribution, characteristics, and role in the carbon cycle must be better understood. Research into how climate change may affect methane hydrates remains open. For commercial exploitation, it is important to quantify the distribution, concentration, and volume of methane hydrates in adequately permeable reservoirs. The long-term flow characteristics of methane hydrates are not sufficiently understood for commercial exploitation—in particular, the relationship between flow and permeability, and whether the presence of an underlying free gas affects methane hydrate production. Research and development in this area, as part of an expanded fundamental research program, would help define the feasibility of the carbon dioxide/methane exchange at reservoir conditions. Research and modeling indicate that, as a production stimulus, pressure depletion should be three orders of magnitude more efficient than thermal stimulation; however, methane hydrates occur in a variety of geologic and geothermal settings. Methane hydrate dissociation is an endothermic process; therefore, it is important to have a fundamental understanding of *in situ* reservoir geothermal conditions and heat-transfer coefficients.

The task force recommends that the combined research budget for these activities should be equal to approximately one-third of the total program budget, or $5 million per year, and should be separated and protected from the funding for field projects.

Environmental Impact

It is appropriate to question whether this investment by DOE is in conflict with the long-term goals of lowering carbon emissions for climate mitigation, as this program, if successful, would enable the extraction of a potentially vast resource of fossil carbon.[7, 22] The task force considered this question and concluded that continuing the work to understand the technological barriers is not in conflict; in fact, it should help to better quantify the potential environmental impact. Although the size of the global methane hydrate resource is estimated to be enormous—eclipsing even global coal resources (more than several thousand gigatons of carbon)—only a small fraction of all methane hydrate deposits could ever be commercially extractible, even at very high natural gas prices.

International Energy Security

The commercialization of methane hydrates has the potential to contribute to international energy security—an important DOE priority. International investment in methane hydrates is increasing, and it includes the active research and development involvement of several countries—Japan, China, India, and Korea—that have substantial investments and activities extending to planned onshore and offshore field tests.[9, 23] Other nations, including New Zealand, the European Union, Norway, Canada, Taiwan, Brazil, Mexico, Columbia, and Uruguay, are in earlier stages, engaged in energy and geohazard focus studies. International funding now far exceeds U.S. federal funding; however, the United States maintains much of the world's scientific and technological leadership on many aspects of fundamental and applied hydrate research. To provide some context: the cost of a hydrates offshore field experiment led by one of the foreign nations has ranged from $100 million to $300 million over the two- to three-year duration of the experiment. It is also important to note that by comparison, private sector oil and gas investment is focused on other hydrocarbon sources that are economically recoverable at today's commodity prices. Global private sector oil and gas exploration and production investment has ranged from $600 billion to $750 billion per annum over the past five years, with global private sector oil and gas research and development investment on the order of $3 billion to $5 billion per year (not including state-owned national companies that do not report their expenditures).

As long as cooperation on international energy security remains a priority, it is important that the international collaboration on methane hydrates continues, and that the United States contributes its expertise. For this reason (among others), the task force budget recommendation is approximately $15 million per year. This funding level allows for support of basic research on methane hydrates and a steady budget of $10 million per year for U.S. participation in field programs that will be largely supported/leveraged by other countries. U.S. scientific and technological expertise—acknowledged as the best in the world—is critical to ensuring that field experiments are well designed and executed to answer the critical questions. It is noteworthy that Japan, in particular, is placing significant emphasis on methane hydrates, owing to its energy position, and that U.S. engagement on methane hydrates will contribute to cooperation between the United States and Japan on energy security and climate policies.

Field Experimentation

Understanding methane hydrates cannot happen in a laboratory. Addressing many of the fundamental questions underlying hydrates exploitation and its environmental impact will require direct field observations and drilling. Therefore, it is important that the goals of the field experiments be clearly defined and aligned with addressing technological barriers to methane extraction from hydrates. Based on the presentations it received, the task force identified differences between the stated goals of the field experiments (e.g., demonstrating production rate) and the major technical concerns of industry.

Research conducted by the industry and DOE has provided a good understanding of the geohazards associated with the short-term risks of drilling through hydrates and, therefore, should no longer be a program priority. However, if the program is to contribute a deeper understanding of the barriers to extraction of methane from hydrates, field research efforts should address the major issues associated with the technical viability and environmental risks of producing methane from hydrates. Given the high cost of field tests, it is important to design experiments that resolve the highest technical risks for the least cost, particularly to determine the feasibility of commercial exploitation.

As part of DOE's participation in international field experiments involving production of methane from hydrates, it would be most useful to address a series of key topics of high concern to the industry and the reservoir engineering community.

Assuring sufficient heat transfer for hydrate dissociation. Hydrate dissociation is an endothermic process requiring the continuous infusion of heat.

- In what geological settings will the rate of heat transfer be sufficient to maintain hydrate dissociation?
- How might one create a more favorable setting for assuring adequate heat transfer for producing methane from hydrates?
- Would the use of long horizontal wells, rather than vertical wells or hydraulic stimulation, create a larger heat-receiving sink?

Maintaining formation and well stability. The depositional settings of hydrates, particularly in deep oceans, are often unconsolidated sands where the hydrate provides the geomechanical stability of the formation.

- In what geologic and hydrate concentration settings should one expect geomechanical risks for formation and well stability?

- How might one create more favorable well and formation integrity during the disassociation of hydrates?
- Would enhanced near-wellbore methods, such as a gravel pack, prove to be valuable?

Assuring continuity of methane release and production. A loss of adequate heat transfer or a rise in the hydrate reservoir's pressure will bring the dissociation of hydrates to a halt.

- How might one assure the continuity of methane release and prevent hydrates from reforming near the wellbore should the well need to be shut-in or becomes shut-in due to formation collapse or other reasons?
- Should a hybrid system involving heated glycol or other methods be a part of the field test production process?

Addressing these and other key scientific and technical issues will require that well and field tests be highly instrumented, including measuring formation stability, multiphase flow, downhole pressures, temperatures, and other key parameters. It will also require in-depth consultation and participation of industry in field test design and the interpretation of data and results.

It is important to keep in mind, as the field experiments are designed, that commercial extraction of natural gas from methane hydrates is unlikely to occur in the next two decades. Given the lack of time pressure, it may be more effective to separate mission objectives and experiment with narrower, lower-cost field tests that specifically address individual risks, such as whether geomechanical compaction can be safely handled. The task force suggests that when available resources are limited and when the strategic goal of commercial viability is likely to be decades away, it might be an acceptable trade-off. More stable funding levels and greater involvement of industry and the Methane Hydrate Federal Advisory Board in strategic planning for the field program will allow these issues to receive appropriate consideration.

Recommendations

1. **DOE should continue to support funding at approximately its current FY 2015 level ($15 million per year).** The effort to understand the production of methane from hydrates is important and should continue, even though U.S. domestic demand for natural gas is likely to be met for several decades via U.S. production of conventional gas, coalbed methane, and shale gas. The same is not necessarily true, however, for the global market. Other nations, owing to their own energy profiles, see methane hydrates as a potentially important resource in the medium term. The program has made valuable scientific and technological contributions and should remain a DOE priority, with funding at its current level of $15 million per year. The program will benefit greatly from steady, more reliable funding that will facilitate planning around the long-term strategic objectives.
2. **Estimates suggest that carbon emissions could be less than existing alternatives.** The potential contribution of fossil carbon to the atmosphere through the commercial extraction of methane from hydrate reservoirs is relatively small compared to that of other fossil resources. If extracted, natural gas is likely to replace future coal use, providing a net climate benefit.
3. **Approximately one-third of the program budget should be dedicated to fundamental science questions.** It is important that the program provide sufficient resources for fundamental research on the basic science of methane hydrates, as well as the behavior of methane hydrate deposits in the environment, including deposits that are not targets for methane extraction. The task force recommends that the combined research budget for these activities should be equal to approximately one-third of the total program budget ($5 million per year) and should be separated and protected from the funding for field projects.
4. **Two-thirds of the program budget is adequate for U.S. participation in larger international hydrates activities.** International investment in methane hydrates is increasing dramatically and includes the active research and development involvement of Japan, India, Korea, New Zealand, the European Union, Norway, Canada, Taiwan, Brazil, Mexico, Columbia, and Uruguay. International funding now far exceeds U.S. federal funding; however, the United States still maintains the world's scientific and technological leadership on fundamental hydrate research. The contribution of U.S. expertise enhances the ability of collaborative efforts to improve international energy security. The task force recommendation of a budget of approximately $15 million per year (see recommendation #2) allows for support of fundamental research on methane hydrates, but also allows a steady budget of $10 million per year for U.S. participation in field programs that will be largely supported by other countries.
5. **Industry and external academic engagement to set program priorities should be increased.** The committee recommends that the program enhance the depth of consultation, input, and industry participation to ensure effective industry engagement, even if the industry is unwilling to provide direct support for the program. Industry participation in the Methane Hydrate Federal Advisory Committee should be strengthened. The role of the Federal Advisory Committee in setting program priorities has been limited; the committee has been consulted only after program leadership has made important decisions. More stable funding levels should enable more systematic long-term planning and committee engagement in the planning process. In particular, the task force recommends that the Federal Advisory Committee strengthen active industry participation in strategic planning for field experiments.
6. **The task force recommends that, as much as possible given the international collaborations, research priority for field experiments be placed on questions involving the production of hydrates, such as understanding the instabilities that can arise during production.** Industry now understands

the management of short-term risk of drilling into hydrates; therefore, that aspect need not be a program priority.

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Appendix 1

MEMORANDUM FOR THE CHAIR

SECRETARY OF ENERGY ADVISORY BOARD

FROM: ERNEST J. MONIZ

SUBJECT: Establishing a Task Force on Methane Hydrates

I request that you form a Secretary of Energy Advisory Board (SEAB) Task Force composed of SEAB members and independent experts to recommend a framework for DOE methane hydrate research programs.

Methane hydrates are a massive natural gas resource in the United States and elsewhere in the world. The estimated cost of producing methane hydrates is such that industrial research remains limited and development and commercialization are not expected as long as conventional and unconventional North American natural gas production remain so cost effective. Both the exploration and production of methane hydrates involve significant environmental impacts including, importantly, leakage of methane (a potent greenhouse gas) into the atmosphere. Yet, the status of methane hydrates as a potential future resource today is similar to the circumstances of shale gas and coal bed methane in the 1970s.

At that time, DOE sponsored work to characterize the resources and experiment with tailored extraction techniques well in advance of any assurance of when, if ever, either resource would become commercially viable. This early work was of significant value and remains technically sound today. Technical advances made unconventional natural gas production and coal bed methane economically viable.

The purpose of this task force is to provide a framework for DOE's pre-commercial methane hydrate research effort, in particular, the balance of effort between (1) characterization of the resource and technical issues concerned with its recovery, and (2) technical and procedural measures to reduce the environmental impacts of this activity.

The SEAB Methane Hydrates Task Force will:

- Review the existing DOE program and evaluate this program taking into account the findings of the 2010 National Research Council Study[1] and the reports of DOE's Fossil Energy Methane Hydrate Advisory Committee.[2]
- Review plans for understanding what answers field experiments on Alaska's North Slope and other relevant regions of interest such as the Gulf of Mexico, including collaboration with U.S. Geological Survey and Japan, should provide.
- Recommend the roles of private industry, the U.S. government, and foreign governments in developing methane hydrates production technology and environmental controls.

1 nap.edu/download.php?record_id=12831#.

2 energy.gov/fe/services/advisory-committees/methane-hydrate-advisory-committee.

Schedule: The Task Force made a preliminary presentation at SEAB's September 2015 meeting and present its final report at SEAB's January 2016 meeting. This Task Force is expected to carry out most of its work in sessions open to the public.

Liaison to the Task Force: Paula Gant, Deputy Assistant Secretary, Office of Oil and Gas, Office of Fossil Energy

Designated Federal Officer: Corey Williams, Deputy Director, Office of Secretarial Boards and Councils

Appendix 2

Task Force Members, Study Participants, and Process

Task Force Members

- Martha Schlicher,* Chair
- Scott Dallimore, Geological Survey of Canada
- John Deutch,* (Ex-Officio) Massachusetts Institute of Technology
- Miriam Kastner, Scripps Institute of Oceanography
- Carolyn Koh, Colorado School of Mines
- Vello Kuuskraa, Advanced Resources International
- Mark Myers, Alaska Department of Natural Resources
- Daniel Schrag, Harvard University
- Ram Shenoy*
- Daniel Yergin, IHS Energy and Center for Environmental Risk Assessment

Designated Federal Official

- Corey Williams-Allen, U.S. Department of Energy

Study Participants

- Ray Boswell, National Energy Technology Laboratory
- Timothy Collett, United States Geological Survey
- Guido DeHoratiis, U.S. Department of Energy
- Koji Hoshi, Japan Oil & Gas Metals National Corporation
- Takami Kawamoto, Japan Oil & Gas Metals National Corporation
- George Moridis, Lawrence Berkeley National Laboratory
- Kiyoshi Nagomi, Japan Oil & Gas Metals National Corporation
- Craig Shipp, Shell International Exploration & Production

Process

- Teleconference, June 24, 2015
- Meeting, DOE, September 16, 2015
- Teleconference, November 20, 2015

* Denotes SEAB member.