UNEP Global Outlook on Methane Gas Hydrates

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Semi-Annual Report

Frozen Heat: A Global Outlook on Methane Gas Hydrates

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ADMINISTRATIVE SUMMARY

The UNEP Global Outlook on Methane Gas Hydrates project has received funding from the US Department of Energy under award number DE-FE0003060. The project director is Yannick Beaudoin and the recipient institution is Stiftelsen GRID-Arendal in Arendal, Norway.

The current report is for the period starting October 1, 2011 and ending March 31, 2012.

EXECUTIVE SUMMARY

The UNEP Global Outlook on Methane Gas Hydrates seeks to provide policy makers, the general public and the media with a synthesis of aspects of natural, social and applied sciences that relate to this type of natural gas occurrence. With an emphasis on visual media, the Outlook is working to define global methane gas hydrate occurrences in their natural settings and examine the implications on communities and society of the potential use of methane gas hydrates as an energy source.

During the time period covered by the current report, the UNEP Global Outlook on Methane Gas Hydrates has pursued efforts to complete the next major project milestone, the production of a final content draft as per Task 5.0 of the main DOE project structure document (SOPO). Delays in content development have been primarily linked to a lack of consensus within the scientific community on certain key topical issues. As of March 31, 2012, a general agreement has been reached for content required for Book 1: Methane Gas Hydrates in the Natural System. Content is now in the editorial phase. Content for Book 2 also remains somewhat contentious although a final draft ready for the editorial phase is now expect for end of April 2012. An update to major milestones can be found in Table 2.
In parallel, graphics development and design was initiated in January 2012 and progresses well. It is also to be noted that, as a response to the content delays, a no-cost time extension was requested and approved extending the project cycle to August 31, 2012.

Also during this time period, GRID-Arendal presented the efforts of the project at the January 2012 Arctic Frontiers meeting held in Tromso, Norway. The effort received much attention and follow up enquiries.
As additional outreach, a documentary producer completed interviews of key experts involved in the project effort as part of a 90 minute documentary on methane hydrates to be broadcast in Europe, Canada and Japan later in 2012.

DISCUSSION

Methodology

The Global Outlook on Methane Gas Hydrates to be produced by bringing together leading international experts from academia, business, governments and intergovernmental and non-governmental organizations selected from throughout the world. Guided by a Steering Committee of scientific and technical experts the Global Outlook on Methane Gas Hydrates will provide unbiased, credible and science based information. Where consensus in the expert community is unclear, debates and uncertainties will be highlighted and needs for new and/or continued research identified.
The drafting of the report involves teams of experts according to the key themes to be addressed. Each chapter will be subject to peer review, which will inform and broaden the editorial process. As a follow up to the Outlook, discussion, consultations and bi- and multilateral outreach initiatives will serve to disseminate the content, encourage dialogue and assist in incorporating key perspectives into policy development.

Thematic Outline

As discussed an agreed upon by the project Steering Committee, the UNEP Global Outlook on Methane Gas Hydrates will be divided into two volumes and expand on key themes deemed of importance to policy makers, industry and society.
Volume 1 examines the settings and roles of methane gas hydrates in the natural system. It begins (chapter 1) with an examination of the history of hydrate science and a basic definition of methane gas hydrates including: molecular, chemical and physical characteristics, occurrence types and their geological settings and a brief overview of the sources of methane that lead to the formation of methane hydrates. The chapter continues with a qualitative examination of global methane gas hydrate occurrences aimed at providing an overview of their global distribution by type and also of the inherent uncertainties linked to the published estimates. This section is meant to provide both a sense of scale but also to properly discriminate between the various global methane reservoirs.
The next section in the volume (Chapter 2) expands on the role of methane gas hydrates in the natural carbon cycle. A more detailed overview of the natural sources of methane (e.g. biogenic and thermogenic) will be provided including a summary of the global methane budget. Various physical processes that regulate natural methane emissions will be examined in addition to a discussion on the time scales of natural variations in gas hydrate occurrences. Examples from the past will be used to illustrate these natural variations and include: negative carbon excursions in the geological past and the role of hydrates in global transition from ice ages to warm periods. Finally, seafloor and terrestrial geomorphological issues will be discussed including slope slides in the marine/lacustrine settings and the reshaping of the ground surface in permafrost settings. Chapter 2 will also discuss chemosynthetic ecosystems that are dependant on near surface methane emissions and how these emissions may be linked to deeper methane gas hydrates occurrences. It will present the various biological processes that regulate natural methane emissions in particular in the marine/lacustrine environment. The sensitivities of the methane consuming ecosystems to natural climate and geological variations will form an integral part of this chapter.

The final section (Chapter 3) of Volume 1 will contain visual models depicting various scenarios of natural global warming and the associated impacts on global methane gas hydrate reservoirs. This is meant to provide a baseline of sensitivity for discussions related to the anthropogenic amplification of climate variability leading to global warming.

Volume 2 changes focus from natural systems to the examination of the human dimensions of methane gas hydrates ranging from key technological aspects related to methane gas hydrates as a potential large scale source of natural gas, to the development of new/sustainable economics models related to potential development, to the various societal and environmental issues surrounding their possible exploitation. The volume begins (Chapter 1) with an ambitious overview of global energy resource efficiency challenges that lead to the key drivers associated with possible methane gas hydrates extraction. These challenges include geopolitical considerations (e.g. regionalization of energy supply), the climate and energy debate, resource scarcity and global growth in energy consumption (i.e. linked to trends in population growth). Models will be used to present scenarios of the impacts (e.g. on global greenhouse gas emissions) of altering the global energy picture towards a more natural gas based economy while integrating and implementing a strategy for de-carbonising the global energy system. From a geopolitical perspective, the possible ramifications of the availability of a large scale energy source that is more globally distributed will de discussed. The environmental and social footprint of potential methane gas hydrates will also be examined in comparison to other non-conventional natural gas sources such as shale gas. Resource valuation taking into consideration ecosystem services (i.e. natural capital) will be proposed as a more realistic and holistic methodology when planning for development. Finally, the main headers of a new/sustainable economics-based business model will be developed and provided as a template for possible future resource development.
Chapter 2 details the technological considerations for the exploration side of possible methane gas hydrates development. An initial definition of the types of methane gas hydrate occurrences that could potentially be developed using existing technologies is followed by a synthesis of the methods used to detect and define these occurrences. Examples of actual real world site that have been technically defined will be used for illustration purposes.
Following the examination of exploration and delineation, the next section (Chapter 3) will detail the technologies and challenges linked to the production of natural gas from methane gas hydrates. An investigation of the recovery approaches using adapted conventional technologies will focus on key elements of the production cycle including accessing the reservoir, dissociation techniques and the requirements for achieving long term production. Disassociation techniques for methane gas hydrates include both methods that can make us of existing technology (e.g. pressure reduction) and those that require additional research and development (e.g. temperature, chemical and mechanical stimulation; CO_2 injection; kinetic inhibitors). Unique technical challenges linked to production include the management of water as a bi-product, sand production and gas leakage. This section will then address the broader environmental impacts of methane gas hydrates development based on various scenarios. Examples of impacts include: possible methane release to the atmosphere and/or hydrosphere; possible impacts on methane-based ecosystems; marine slope stability; impacts on surface morphology (i.e. in permafrost settings).
The following section (Chapter 4) addresses societal perspectives related to energy resource development. As resource development impacts society from the national to local community scale, this section seeks to illustrate various perceptions linked to energy resource development in order to help shape policies relating to potential future methane gas hydrate development. Areas with

previous experience with conventional oil and gas development will provide guidance with respect to concerns related to development, the benefits on well-being of development and practical suggestions to improve the polices linked to potential future development. As occurrences of methane gas hydrates are more globally distributed, many areas with no previous experience with traditional oil and gas development may be affected by methane gas hydrates development. The advice provided in this section will be aimed at ensuring that these previously unaffected areas take into consideration the experiences of others. Case studies from areas including the Arctic region (local community scale) and countries like Japan and India (national scale having not experienced large scale traditional oil and gas development) will be used to illustrate different realities linked to energy resource development.
The final section of volume 2 (Chapter 5) will seek to summarize the main points emphasized in the entire Outlook into the context of sound policy making. Challenges, opportunities, policy responses and options will be provided for stakeholders from government, the private sector, community leaders and the general public in a broad wrap up of the key messages and discussions contained in the Outlook. This section will also examine past experiences in relation to policy issues and how these can be improved upon to shift away from unsustainable practices in global energy resource use towards the most sustainable development possible of non-renewable, finite resources. A development model for methane gas hydrates based on the conversion of financial revenue to new forms of capital (e.g. social capital in the form of national wealth sharing funds; natural capital in the form of revenue diversion towards the longer term need to develop renewable energy sources to replace exhausted hydrocarbon reserves) will be expanded upon to provide both government and industry leaders with new management and policy options.

Public outreach, multi-media site and global gas hydrate spatial explorer and Wiki-base

This public outreach web-portal, found at www.methanegashydrates.org aims to: 1) keep to provide an interested public with a multimedia experience of gas hydrates and gas hydrates research and 2) establish a non technical geospatial knowledge base of global gas hydrates research sites and occurrences. The site has already been profiled on the main UNEP web portal with further targeted advertising planned. (see screen shot of front page of web portal).

Concluding remarks

Despite some delay in completing the vetted content development, the general consensus is that the progress of the UNEP Global Outlook on Methane Gas Hydrates remains good. The strength of the international scientific and multi-stakeholder partnership continues to allow for an efficient development of the work with a strong focus on quality control. The UNEP Global Outlook on Methane Gas Hydrates is on target to achieve its primary goal of mainstream knowledge and information on the latest developments in the methane gas hydrates research community.

Table 1: Cost Plan/Status Report

Task/Subtask #	Project Duration Start March 1 2010 End May 31 2012										
	Project Year 1 (1 Apr-30 Sept 2010)				PY2 (01 Oct - 31 May)						
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Baseline Cost Plan											
Federal Share		$50,000			$50,000						
Non-Federal Share	$65,000		$45,000		$10,000	$10,000	$10,000	$55,000	$10,000	$85,000	$10,000
Total Planned (Federal and Non-Federal)	$65,000	$50,000	$45,000	$0	$60,000	$10,000	$10,000	$55,000	$10,000	$85,000	$10,000
Cummulative Baseline Costs	$65,000	$115,000	$160,000	$160,000	$220,000	$230,000	$240,000	$295,000	$305,000	$390,000	$400,000
Actual Incurred Costs											
Federal Share		$47,475	$2,525			$4,085	$36,307	$6,438	$3,170		
Non-Federal Share	$61,630		$39,855	$30,148	$6,802	$17,910					
Total incurred Costs-Quarterly (Federal and non-Federal Share	$61,630	$47,475	$42,380	$30,148	$6,802	$21,995	$36,307	$6,438	$3,170	$0	$0
Cumulative Incurred Costs	$61,630	$109,105	$151,485	$181,633	$188,435	$210,430	$246,737	$253,175	$256,345	$256,345	$256,345
Variance											
Federal Share	0	$2,525	$0	$0	$50,000	$45,915	$9,608	$3,170	$0	$0	$0
Non-Federal Share	$3,370	$3,370	$8,515	($21,633)	($18,435)	($26,345)	($16,345)	$38,655	$48,655	$133,655	$143,655
Total Variance-Quarterly (Federal and non-	$3,370	$5,895	$8,515	($21,633)	$31,565	($26,345)	($6,737)	$41,825	$48,655	$133,655	$143,655
Cummulative Variance	$3,370	$9,265	$17,780	($3,853)	$27,712	$1,367	($5,370)	$36,455	$85,110	$218,765	$362,420

Table 2: Milestone Status Report

Task/Subtask #	**Project Milestone Description**	**Project Duration Start March 1 2010 End March 31 2012**							
		Project Year 1				**PY2**			
		Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Task 1.0	Project Infrastructure Development		completed						
subtask 1.1	Project Website Development		completed						
subtask 1.2	Virtual Office Development		completed						
subtask 1.3	Project Steering Committee	completed							
Task 2.0	Development/Approuval of Assessment Work Plan and Guidelines		completed						
Task 3.0	Establishement of Content Development Teams			completed					
Task 4.0	Draft Assessment Content Development and Vetting				draft 0 completed for Book 1; in progress for Book 2	in progress for Book 2			
Task 5.0	Final Assessment Content Development and Vetting					in progress for Book 1			

Volume 1: Introduction

Methane-gas hydrates are solid, ice-like combinations of methane and water (**Fig. I-1**) that are stable under conditons of relatively high pressure and low temperature. Gas hydrates contain most of the world's methane, accounting for roughly a third of the world's mobile organic carbon. Because gas hydrates tend to occur in relatively inaccesible and harsh polar and marine environments, they have not been studied extensively until recently. Upon their discovery in the early 1800s, gas hydrates were considered only an academic curiosity. In the 1930s, they were recognized as an industrial hazard after gas hydrates were found to be responsible for forming blockages in oil and gas pipelines. It wasn't until the early 1980's that the abundance of gas hydrates in the natural environment became widely recognized.

Figure I-1. Gas hydrate nodules (white) recovered while coring in the East Sea (Sea of Japan) (Courtesy KIGAM, as shown on UNEP web site).

Growing energy resource demands and climate concerns have brought increased attention to the potentially immense quantity of methane held in natural gas hydrates, sparking a significant acceleration in the investigation of gas hydrates over the last two decades (**Fig. I-2**). Japan launched the first major national effort in 1995, and other countries subsequently developed sustained and coordinated national programs. The pace of scientific discovery in naturally occurring gas hydrates continues to accelerate. Industry remains focused primarily on mitigating unwanted hydrate formation in production and transport infrastructure, and is increasing its investment in understanding the hazards natural gas hydrates pose to ongoing deepwater and Arctic energy development. Academia, supported by national programs, is making significant progress in understanding the basic physics and chemistry of gas hydrates, and their impact on the physical properties of sediments. These advances further our understanding of gas hydrates' role in global environmental processes, including natural geohazards,

implications for long-term carbon cycling and, given that methane is a potent greenhouse gas, global climate change. However, the primary driver for much of the current interest

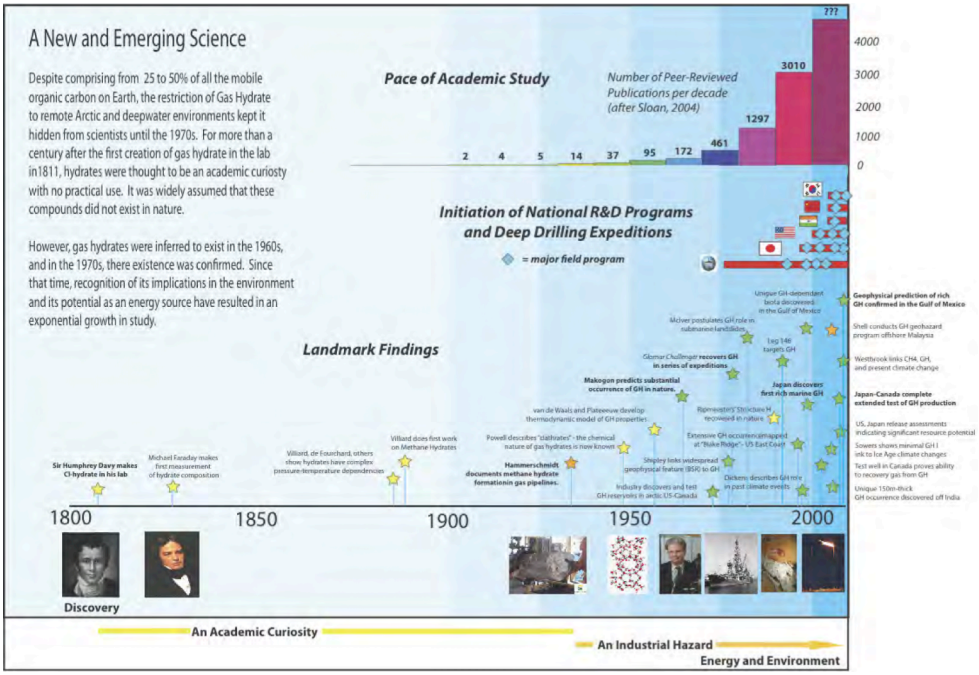

Figure I-2. A timeline of major milestones in gas hydrate research (A higher-res version will be generated for the final volume).

is the potential for energy security offered by gas hydrates. For a world in which energy demands are steadily increasing and future energy supplies are uncertain, the widespread occurrence of new and potentially immense natural gas resources requires investigation.

The shift in gas-hydrate research from the level of individual scientists to coordinated national research programs has engaged policy makers, business leaders and private citizens in the discussion about the most appropriate directions for research in gas hydrates, including management and funding issues. To facilitate decisions that must often rely on highly technical and multidisciplinary information, and recognizing that the large quantities of naturally occurring gas hydrates distributed around the globe give rise to numerous societal and scientific concerns, UNEP has compiled a comprehensive summary of current issues in global gas-hydrate research and development titled: “Frozen Heat: A global outlook on methane-gas hydrates.” Frozen Heat is presented as a two-part

review covering the role of gas hydrates in natural systems (Volume 1) and the potential impact of gas hydrates as a possible new and global energy resource (Volume 2).

Volume 1 Summary

To provide a basis for understanding how gas hydrates occur and evolve in natural systems, Volume 1 describes the crystal structures of gas hydrates, their stability requirements, the environmental settings in which gas hydrates commonly occur, and provides estimates of the global quantity and distribution of gas hydrates. These gas-hydrate basics provide a context for a central message in this volume: gas hydrates are a key part of the planet's global carbon cycle, dynamically storing and releasing vast quantities of methane in response to changing environmental conditions. Understanding the behavior of gas hydrates over long time periods is an important element in understanding how the Earth works. For example, gas hydrates have fundamental linkages to deep marine ecosystems, in which microbes consume most of the methane passing through the upper sediment layers and water column, preventing much of this methane from reaching the atmosphere (see Volume 1, Theme 2).

As discussed in Volume 1, Theme 2, breakdown of gas hydrates due to natural events such as long-term changes in bottom water temperature and/or sea level, can release large volumes of gas from marine sediments, potentially transferring significant amounts of methane into the oceans and potentially to the atmosphere. Themes 2 and 3 in Volume 1 consider models of past climate change and future climate predictions in relation to potential feedbacks from gas hydrates. Theme 2 concludes that methane from gas hydrate has likely contributed to, but did not trigger, past global warming events. As noted in Theme 3, near-term contributions of methane from gas hydrates to Earth's current progressive climate warming will likely be of minor significance. Despite the tremendous quantity of methane contained in gas hydrates globally, only a small fraction of those gas hydrates exist in environments that will warm sufficiently over the next century or so to destabilize the gas hydrates and release methane to the atmosphere.

Volume 2 Summary

The central message in Volume 2 is that gas hydrates represent an enormous potential energy resource for a world with ever increasing energy demands. However, just as only a small subset of the global-hydrate stores are susceptible to near-term warming, only a small subset of the global-gas-hydrate resource provides a likely target for energy production. Nonetheless, there may be substantial numbers of highly concentrated gas-hydrate accumulations that can be feasibly developed for commercial production in locations of current or planned conventional hydrocarbon production or where there are strong societal motivations for developing domestic energy resources. To date, a few short-term pilot-scale methane production tests in research wells have been conducted with positive results, but no commercial gas-hydrate production has yet occurred. Several nations are currently researching the energy potential of gas hydrates, however, with positive findings (**Fig. I-3**). Recent detailed assessments of the energy potential of methane-gas hydrates concluded there are no anticipated technical roadblocks to producing gas from hydrate deposits [*National Research Council*, 2010; *Council of Canadian Academies*, 2008]. Ultimately, a combination of technological advancements and favorable global/regional market conditions may make gas-hydrate production economically viable. Therefore, Volume 2 provides a summary of gas-hydrate-based, energy-related information useful in evaluating future energy resource options. Topics addressed in Volume 2 include (a) characterization of prospective gas-hydrate resources, (b) technologies for exploration and development, and (c) potential environmental, economic, and social implications of gas-hydrate production.


Fig I-3. Gas hydrates as a resource interest. (Left) Methane from hydrate flared from the Mallik 5L-38 Arctic gas hydrate research well in Canada (Courtesy of the Mallik 2002 Gas Hydrate Production Testing Program). (Right) Well-logging gas-hydrate-bearing sediment in the Gulf of Mexico (Courtesy R. Boswell, DOE).