UNEP Global Outlook on Methane Gas Hydrates

DOE Award No.: DE-FE0003060

Semi-Annual Report

Frozen Heat: A Global Outlook on Methane Gas Hydrates

Submitted by:
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Prepared for:
United States Department of Energy

September 29, 2010

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 March 1, 2010 and ending September 30, 2010.

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 achieved four major milestones, the first being the development of a detailed thematic scope for each chapter of the assessment. This milestone was achieved as a result of the first meeting of project Steering Committee (see Appendix for full meeting report) held in Arendal, Norway between March 4th and 5th, 2010.

The second milestone involved the establishment of chapter leads and co-leads for the individual assessment chapters. A full list of chapter leads can be found in the meeting report of the first Steering Committee meeting located in the Appendix. Chapter leads and co-leads are independently assembling teams of authours and contributors with some groups having provided initial chapter drafts as of the date of this report.

The third major milestone (and first deliverable to be completed) involved the deployment of the first version of a dedicated project web portal at www.methanegashydrates.com. This original portal is designed mainly at the larger community of experts, energy stakeholder and other stakeholders involved or directly interested in this subject. A second web-portal dedicated to public outreach and engagement is currently under development.

The fourth milestones involves the first high-level awareness raising effort dedicated to the promotion of the UNEP Global Outlook on Methane Gas Hydrates. A focused participation in the 2010 World Energy Congress resulted in clear interest from government representatives to industry executive. In discussion the future of the global energy mix, the UNEP Global Outlook on Methane Gas Hydrates was the only effort to discuss methane gas hydrates visible at the Congress.

These four milestones are clear indicators of the progress of the work to date. They are a combination of organizational, content, technical and outreach achievements consistent with the elements outlined as they key project goals.

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 will involve 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 volume continues (Chapter 2) 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 3) 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 4 will 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 5) 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.

Project focused, informative web portal

This project web-portal, www.methanegashydrates.org aims to keep all project participants informed of developments via a secure intranet facility. The public pages have been designed to provide: key project information, latest news, information on project partners, a video Frequently Asked Questions and a multimedia galley. The target audience for this initial portal includes: stakeholders knowledgeable in the subject of methane gas hydrates, policy makers, the media, scientists, and hydrates research and development experts.

High level project outreach

"World Energy Congress 2010: Acting Now on Global Challenges – Energy in Transition for a Living Planet
This Congress, which is held every three years, has become a key gathering point for all the world's energy leaders. And while every era has its own challenges, the 2010 Congress could take on greater significance than ever before.
Worldwide, all energy sectors now face a growing sense of urgency. More energy is needed from now until 2020, with prices rising significantly, while world energy demand is expected to double by 2050. One third of the world population does not yet benefit from a reliable energy supply. The energy industry is faced with overwhelming problems of environmental, social and political acceptability. In short, the situation is more challenging than ever."
The UNEP Global Outlook on Methane Gas Hydrates was the only entity presenting and discussing the issues of methane gas hydrates within the context of the future energy mix. Represented

on the panel of experts for Arctic Sources of Hydrocarbons (along with Alaska State Senator Lesil McGuire and Northwest Territories Minister of Industry, Energy and Tourism, Bob McLeod), the UNEP Global Outlook on Methane Gas Hydrates achieved a broad level of exposure followed up by 4 media interviews discussing the various topics covered by the work. The same was achieved as part of the panel on Unconventional Sources of Hydrocarbons.

Concluding remarks

It is evident from the details related to the milestones above that the UNEP Global Outlook on Methane Gas hydrates has achieved the main goals described for the current reporting period. No major impediments have occurred or are expected at this stage. The strength of the international scientific and multi-stakeholder partnership has allowed for an efficient development of the work to date. 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

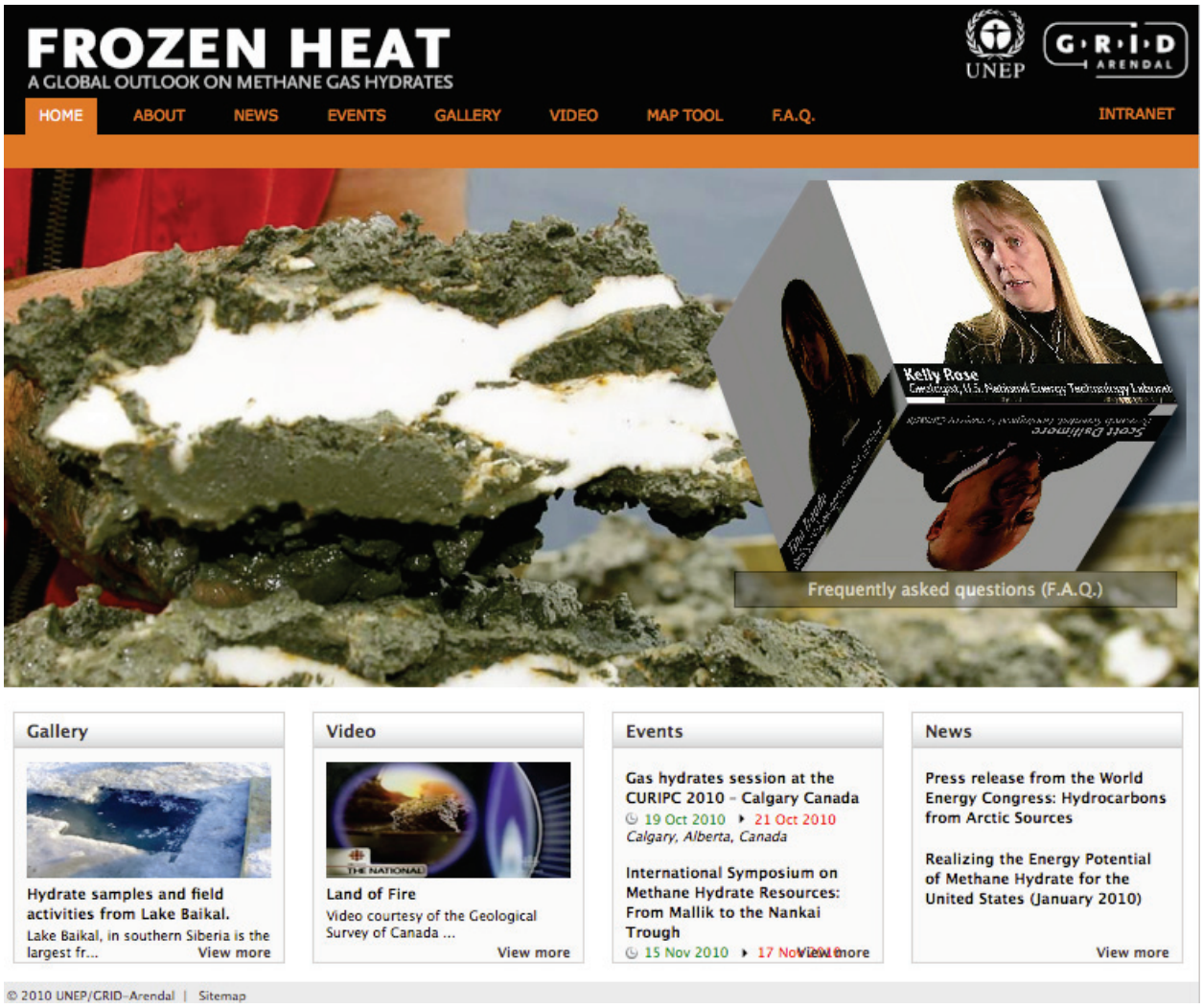
Task/Subtask #	Project Duration Start March 1 2010 End May 31 2012										
	Project Year 1 (1 Apr-30 Sept 2010)				PY2 (01 Oct - 31 May)						
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Baseline Cost Plan											
Federal Share		$50,000			$50,000						
Non-Federal Share	$65,000		$45,000		$10,000	$10,000	$10,000	$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								
Non-Federal Share	$61,630		$39,855								
Total incurred Costs-Quaterly (Federal and non-Federal Share	$61,630	$47,475	$42,380	$0	$0	$0	$0	$0	$0	$0	$0
Cumulative Incurred Costs	$61,630	$109,105	$151,485	$151,485	$151,485	$151,485	$151,485	$151,485	$151,485	$151,485	$151,485
Variance											
Federal Share	0	0	0								
Non-Federal Share	$3,370	$0	$5,145	$0	$10,000	$10,000	$10,000	$55,000	$10,000	$85,000	$10,000
Total Variance-Quaterly (Federal and non-Federal)	$3,370	$0	$5,145	$0	$10,000	$10,000	$10,000	$55,000	$10,000	$85,000	$10,000
Cummulative Variance	$3,370	$3,370	$8,515	$8,515	$18,515	$28,515	$38,515	$93,515	$103,515	$188,515	$198,515

Table 2: Milestone Status Report

Task/Subtask #	Project Milestone Description	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
Task 1.0	Project Infastructure 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 / Approval of Assessement Work Plan and Guidelines		Completed									
Task 3.0	Establishment of Content Development Teams			Completed								
Task 4.0	Second Steering Committee					Completion extimated 30 Nov 2010						
Task 5.0	Finall Assessment Content Development and Vetting								Completion estimated 30 Sept 2011			
Task 6.0	Publish Public Assessement										Completion estimated 31 Mar 2012	

APPENDIX

Screen capture of project website:



Bibliography of conference abstracts:

Beaudoin, Y., Frozen Heat: UNEP Global Outlook on Methane Gas Hydrates, Abstracts-World Energy Congress 2010, September 12-16, 2010, Montreal, Canada.

Beaudoin, Y., Frozen Heat: UNEP Global Outlook on Methane Gas Hydrates, Abstracts-Joint International Conference Minerals of the Ocean-5 and Deep Sea Minerals and Mining-2, June 28-July 01, 2010, St Petersburg, Russia.

Beaudoin, Y. and Kullerud, L, Methane Gas Hydrates, a new phase of resource exploitation in the Arctic? What we can learn from the Global Assessment of Methane Gas Hydrates, Abstracts-2010 International Polar Year Oslo Science Conference, June 8-12, 2010, Oslo, Norway.

Thygesen, K., Beaudoin, Y. and Kullerud, L., Methane Gas Hydrates, a new phase of resource exploitation in the Arctic? What we can learn from the Global Assessment of Methane Gas Hydrates, Abstracts-Arctic Days 2010, May 31 to June 4, 2010, Tromso, Norway.

CONFERENCE ABSTRACTS

Conference: Arctic Days 2010, Tromso, Norway, May 31st to June 4th, 2010
Hosted by: The Geological Society of Norway

Title:

Methane Gas Hydrates, a new phase of resource exploitation in the Arctic?

What we can learn from the Global Assessment of Methane Gas Hydrates

Authors & affiliations:

Kristina Thygesen, Marine Programme, UNEP/GRID-Arendal;
Yannick Beaudoin, PhD, Project Manager Marine Programme, UNEP/GRID-Arendal;
Lars Kullerud, President, University of the Arctic.

Abstract:

The 2008 United Nations Environment Programme Annual Report highlighted methane from the Arctic as an emerging challenge with respect to climate change and other environmental issues.

Global reservoirs of methane gas have long been the topic of scientific discussion both in the realm of environmental issues such as natural forces of climate change and as a potential energy resource for economic development. Of particular interest are the volumes of methane locked away in frozen molecules known as clathrates or hydrates. Our rapidly evolving scientific knowledge and technological development related to methane hydrates makes these formations increasingly prospective to economic development. In addition, global demand for energy continues, and will continue to outpace supply for the foreseeable future, resulting in pressure to expand development activities, with associated concerns about environmental and social impacts.

Understanding the intricate links between methane hydrates and 1) natural and anthropogenic contributions to climate change, 2) their role in the carbon cycle (e.g. ocean chemistry) and 3) the environmental and socio-economic impacts of extraction, are key factors in making good decisions that promote sustainable development.

As policy makers, environmental organizations and private sector interests seek to forward their respective agendas which tend to be weighted towards applied research, there is a clear and imminent need for a an authoritative source of accessible information on various topics related to methane gas hydrates.

Building upon this foundation, UNEP/GRID-Arendal, in conjunction with experts from national hydrates research groups from Canada, the US, Japan, Germany, Norway, India and Korea, aims to provide a multi-thematic overview of the key aspects of the current methane hydrate debate for both the land-based Arctic deposits and those in the marine environment.

The presentation will give an overview of the challenges and opportunities for Arctic communities facing a possible exploitation of a form of hydrocarbon resources specific to the north and deep oceans.

Conference: International Polar Year Oslo Science Conference, Oslo, Norway, June 8-12, 2010
Hosted by: International Polar Year

Title:

Methane Gas Hydrates, a new phase of resource exploitation in the Arctic? What we can learn from the Global Assessment of Methane Gas Hydrates

Authors & affiliations:

Yannick Beaudoin, PhD, Project Manager Marine Programme, UNEP/GRID-Arenda.
Lars Kullerud, President, University of the Arctic.

Abstract: (Your abstract must use **Normal style** and must fit in this box. Your abstract should be no longer than 300 words. The box will 'expand' over 2 pages as you add text/diagrams into it.)

The 2008 United Nations Environment Programme Annual Report highlighted methane from the Arctic as an emerging challenge with respect to climate change and other environmental issues.

Global reservoirs of methane gas have long been the topic of scientific discussion both in the realm of environmental issues such as natural forces of climate change and as a potential energy resource for economic development. Of particular interest are the volumes of methane locked away in frozen molecules known as clathrates or hydrates. Our rapidly evolving scientific knowledge and technological development related to methane hydrates makes these formations increasingly prospective to economic development. In addition, global demand for energy continues, and will continue to outpace supply for the foreseeable future, resulting in pressure to expand development activities, with associated concerns about environmental and social impacts.

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The presentation will give a overview of the challenges and opportunities for Arctic communities facing a possible exploitation of a form of hydrocarbon resources specific to the north and deep oceans.

Conference: Joint International Conference, Minerals of the Ocean 5 and Deep-Sea Minerals and Mining 2, Oslo, Norway, June 28 to July 01, 2010, St Petersburg, Russia.
Hosted by: VNIIOkeangeologia

FROZEN HEAT: GLOBAL OUTLOOK ON METHANE GAS HYDRATES

As part of its 2010-2011 Programme of Work, the United Nations Environment Programme via its collaborating center in Norway, UNEP/GRID-Arendal, is undertaking an assessment of the state of the knowledge of methane gas hydrates. Global reservoirs of methane gas have long been the topic of scientific discussion both in the realm of environmental issues such as natural forces of climate change and as a potential energy resource for development. Of particular interest are the volumes of methane locked away in frozen molecules known as clathrates or hydrates. Our rapidly evolving scientific knowledge and technological development related to methane gas hydrates makes these formations increasingly prospective to economic development. In addition, global demand for energy continues, and will continue to outpace supply for the foreseeable future, resulting in pressure to expand development activities, with associated concerns about environmental and social impacts. Understanding the intricate links between methane hydrates and 1) their role in natural systems including the global carbon cycle, 2) their sensitivities to climate variations such as global warming, 3) the key drivers (e.g. economic drivers; resource scarcity drivers; geopolitical drivers) associated with their evaluation as a possible source of natural gas, and 4) the environmental and societal impacts of possible development, are key factors in making good decisions that promote sustainable development.

As policy makers, environmental organizations and private sector interests seek to forward their respective agendas which tend to be weighted towards applied research, there is a clear and imminent need for a an authoritative source of accessible information on various topics related to methane gas hydrates. The 2008 United Nations Environment Programme Annual Report highlighted methane from the Arctic as an emerging challenge with respect to climate change and other environmental issues. Building upon this foundation, the Global Outlook on Methane Gas Hydrates aims to provide a multi-thematic overview of the key aspects of the current methane hydrate debate for both the land-based Arctic deposits and those in the marine environment. Although based on the latest scientific work produced by leading experts, the style and language are designed for non-experts. This Outlook will span a range of themes that include: the history of gas hydrates science, natural systems, human impacts, exploration and extraction technologies, sustainable economics and resource efficiency and policy perspectives and challenges.

Thematic Scope

The 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 will 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.

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.
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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.
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The final section (Chapter 5) 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 decarbonising 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.
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UNEP/GRID-Arendal's mission is to provide environmental information, communications and capacity building services for information management and assessment. Established to strengthen the United Nations through its Environment Programme (UNEP), our focus is to make credible, science-based knowledge understandable to the public and to decision-makers to promote sustainable development. We are dedicated to making a difference by exploring how environmental information impacts on decision-making and the environment. We seek to bridge the gap between science and politics.

Conference: World Energy Congress, Montreal, Quebec, Canada, September 12-16, 2010
Hosted by: The World Energy Council

FROZEN HEAT: GLOBAL OUTLOOK ON METHANE GAS HYDRATES

Introduction

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As policy makers, environmental organizations and private sector interests seek to forward their respective agendas which tend to be weighted towards applied research, there is a clear and imminent need for a an authoritative source of accessible information on various topics related to methane gas hydrates. The 2008 United Nations Environment Programme Annual Report highlighted methane from the Arctic as an emerging challenge with respect to climate change and other environmental issues. Building upon this foundation, the Global Outlook on Methane Gas Hydrates aims to provide a multi-thematic overview of the key aspects of the current methane hydrate debate for both the land-based Arctic deposits and those in the marine environment. Although based on the latest scientific work produced by leading experts, the style and language are designed for non-experts. This Outlook will span a range of themes that include: the history of gas hydrates science, natural systems, human impacts, exploration and extraction technologies, sustainable economics and resource efficiency and policy perspectives and challenges.

Thematic Scope

The 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 will 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.

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 volume continues (Chapter 2) 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 3) 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 4 will 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 5) 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 decarbonising 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.

Deliverables

The Global Outlook on Methane Gas Hydrates is organized along the lines of 3 key deliverables to be finalized and launched by Spring 2012:

1. An electronic publication (e-book) which would have the advantages over a printed publication of broad exposure and ease of distribution, as well as allowing for periodic content updating as new information and research emerges beyond the initial project cycle. This medium also allows for dynamic graphics, interactive figures and multimedia content. An example e-book produced by UNEP/GRID-Arendal can be viewed at www.grida.no/publications/vg/kick/ebook.aspx .
2. A limited printing of a hardcopy version for distribution to policy makers and to targeted stakeholders. This version will be prepared as a two-volume box set with Executive Summary.
3. A dedicated hydrates web portal containing the latest scientific research results in a format accessible to decision makers, the general public and the media. Versatile web applications, interactive, dynamic visualization tools and dedicated evolving indicators are all tools to be included in the portal. This tool is planned to allow for research scientists to update outputs with new data and is meant as a long term repository of scientific knowledge of global methane gas hydrates.

Methodology

The Global Outlook on Methane Gas Hydrates to be produced by bringing together leading international experts from academia, business, governments and intergov- ernmental and non-governmental organizations (see Appendix A for a list of partners) , 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 will involve 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.

APPENDIX A: PROJECT PARTNERS

Project Coordinating Institution

UNEP/GRID-Arendal

UNEP/GRID-Arendal is an official United Nations Environment Programme (UNEP) collaborating centre located in Arendal, Norway with outposted offices in Ottawa and Stockholm. UNEP/GRID-Arendal's mission is to provide environmental information, capacity building services and innovative communication tools, methodologies and products for information management and outreach. UNEP/GRID-Arendal seeks to make credible, science-based knowledge understandable to the public and to decision-makers (www.grida.no).

Partner Institutions:

UNEP DTIE encourages decision makers in government, local authorities and industry to develop and implement policies, strategies and practices that are cleaner and safer, make efficient use of natural resources, ensure environmentally sound management of chemicals, reduce pollution and risks for humans and the environment, enable implementation of conventions and international agreements, and incorporate environmental costs. http://www.unep.fr/en/index.asp

IFM-GEOMAR: as lead agency for German SUGAR Project (Steering Committee)

The Leibniz Institute of Marine Sciences at the University of Kiel (IFM-GEOMAR) was founded in January 2004 through the merger of the Institut für Meereskunde (IfM) and the Research Center for Marine Geosciences (GEOMAR). The institute is a member of the Leibniz-foundation and employs approximately 500 scientific and technical staff. The institutes' mandate is the interdisciplinary investigation of all relevant aspects of modern marine sciences, from seafloor geology to marine meteorology. Research is conducted worldwide in all oceans. The institute has four major research divisions: ocean circulation and climate dynamics, marine biogeochemistry, marine ecology and the dynamics of the ocean floor. The Leibniz Institute of Marine Sciences is associated with the University of Kiel in undergraduate and graduate teaching in the following fields: oceanography, meteorology, biological oceanography, fisheries biology, marine chemistry and geology. Basic research on marine gas hydrates has a long tradition at IFM-GEOMAR. Recently a new national program on applied gas hydrate research has been launched at the institute to develop environmentally acceptable technologies for gas hydrate exploitation (www.ifm-geomar.de/index.php?id=3563&L=1).

Canadian Polar Commission (Liaison Organisation)

Established in 1991 as the lead agency in the area of polar research, the Canadian Polar Commission has responsibility for: monitoring, promoting, and disseminating knowledge of the polar regions; contributing to public awareness of the importance of polar science to Canada; enhancing Canada's international profile as a circumpolar nation; and recommending polar science policy direction to government. http://www.polarcom.gc.ca/

Geological Survey of Canada (Steering Committee)

The Geological Survey of Canada, a part of the Earth Science Sector of the Ministry of Natural Resources Canada (NRCan) is Canada's premier agency for geoscientific information and research, with world-class expertise focusing on geoscience surveys, sustainable development of Canada's resources, environmental protection, and technology innovation. The Gas Hydrates program of the NRCan is working with many national and international partners to quantify the distribution and properties of Canada's marine and terrestrial gas hydrates. NRCan experts are also contributing to improving gas hydrate exploration techniques and to finding economically viable and environmentally responsible extraction and production methods. The program is also assessing the possible environmental issues posed by gas hydrates and associated geohazards.
http://gsc.nrcan.gc.ca/gashydrates/index_e.php

National Energy Technology Laboratory (NETL), Department of Energy (USA): as Focal Point for National Methane Hydrates R&D Programme (Steering Committee)

The National Energy Technology Laboratory (NETL), part of DOE's national laboratory system, is owned and operated by the U.S. Department of Energy (DOE). NETL supports DOE's mission to advance the national, economic, and energy security of the United States.
The National Methane Hydrates Research and Development Programme is a US-based interagency initiative operating under the auspices of the Methane Hydrate Research and Development Act of 2000. The goals of the National Methane Hydrate R&D Program are to create a comprehensive knowledge base and suite of tools/technologies that result in an accurate assessment of gas hydrate's role in global environmental processes and the fullest realization of gas hydrate's energy supply potential.
http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/maincontent.htm

Korea Institute of Geoscience and Mineral Resource: as Focal Point for Korean National Gas Hydrates Programme (Steering Committee)

Korea Institute of Geoscience and Mineral Resources (KIGAM) was established in 1918, and prolongated its central roles in comprehensive mineral exploration and energy development as the government supported research institute. For the last century, KIGAM strives to achieve the core technology, which mobilizes national competitiveness and endless productivity. KIGAM accomplishes national projects to enhance the quality of our daily lives by improving safety levels, educating cautions of natural disasters, and developing new materials and energy sources. KIGAM covers various fields of geological research in nationwide and overseas such as gas hydrate, mineral exploration, groundwater flow research, usage of underground space, and efficient utilization of national territory. More so, KIGAM endeavors to develop the prominent unchallenged technologies in geological disasters such as earthquakes and landslides, as well as global climate change mitigations on CO2 geological storage, mineral carbonations, and waste disposals. http://www.kigam.re.kr/english/

Gas Hydrates on the Norway-Barents Sea-Svalbard Margin (GANS) Project (Steering Committee)

The main aim of GANS is to quantify gas accumulations in the 1) form of hydrates in sediments on the Norway - Barents Sea - Svalbard (NBS) margin; including an assessment of their dynamics and impacts on the seabed, and 2) their response on sediments and biota, to provide knowledge vital for a safe exploitation in oil and gas production. The overall objective is to make a coordinated effort on a national level to achieve the main objective by the following sub-goals:

- Geophysical characterisation of gas hydrates
- Geological and geochemical setting of gas hydrate reservoirs and seeps
- Gas hydrate dissociation and its effects on geomechanical properties
- Theoretical and experimental evaluation of gas hydrate dynamics

Directorate General of Hydrocarbons: as Focal Point for the Indian National Gas Hydrates Programme (Steering Committee)

The Directorate General of Hydrocarbons (DGH) was established in 1993 under the administrative control of Ministry of Petroleum & Natural Gas through Government of India Resolution. Objectives of DGH are to promote sound management of the oil and natural gas resources having a balanced regard for environment, safety, technological and economic aspects of the petroleum activity.
www.dghindia.org

Japan Oil, Gas and Metals National Coporation: as Focal Point for the Japanese National Gas Hydrates Programme

Japan Oil, Gas and Metals National Corporation (JOGMEC) was established on February 29, 2004 pursuant to the Law Concerning the Japan Oil, Gas and Metals National Corporation, which was promulgated on July 26, 2002. JOGMEC integrates the functions of the former Japan National Oil Corporation, which was in charge of securing a stable supply of oil and natural gas, and the former Metal Mining Agency of Japan, which was in charge of ensuring a stable supply of nonferrous metal

and mineral resources and implementing mine pollution control measures.
http://www.jogmec.go.jp/english/index.html

Methane on the Move Project (Steering Committee)

The mass of organic carbon in sedimentary basins amounts to a staggering 10^{16} tons, dwarfing the mass contained in coal, oil, gas and all living systems by ten thousand-fold. The changing fate of this giant mass during subsidence and uplift, via chemical, physical and biological processes, is known to ultimately control fossil energy resource occurrence worldwide. But what has been overlooked and/or ignored until now is its enormous capacity for driving global climate: only a tiny degree of leakage, particularly when focussed through the clathrate cycle, can result in high greenhouse gas emissions, both in the present as well as in the geologic past. Understanding the workings of sedimentary basins in time and space is fundamental to gaining insights into Earth's climate. http://www.gfz-potsdam.de/portal/gfz/Struktur/Departments/Department+4/sec43/Projekte/Laufende+Projekte/Methane+on+the+Move

Schlumberger (Steering Committee)

Schlumberger is the leading oilfield services provider, trusted to deliver superior results and improved E&P performance for oil and gas companies around the world. Through our well site operations and in our research and engineering facilities, we are working to develop products, services and solutions that optimize customer performance in a safe and environmentally sound manner.
http://www.slb.com/content/about/index.asp

Statoil (Steering Committee)

Statoil is an international energy company with operations in 40 countries. Building on more than 35 years of experience from oil and gas production on the Norwegian continental shelf, we are committed to accommodating the world's energy needs in a responsible manner, applying technology and creating innovative business solutions. www.statoil.com

MEETING REPORT
FIRST MEETING OF THE STEERING COMMITTEE

UNEP/GRID-Arendal

FROZEN HEAT: GLOBAL OUTLOOK ON METHANE GAS HYDRATES

REPORT OF FIRST STEERING COMMITTEE MEETING MARCH 4-5, 2010, ARENDAL, NORWAY

UNEP/GRID-Arendal, Teaterplassen 3 • 4836 Arendal, Norway • fax: +47 3703 5050 • www.grida.no

Table of Contents

Background

Global reservoirs of methane gas have long been the topic of scientific discussion both in the realm of environmental issues such as natural forces of climate change and as a potential energy resource for economic development. Of particular interest are the volumes of methane locked away in frozen molecules known as clathrates or hydrates. Our rapidly evolving scientific knowledge and technological development related to methane hydrates makes these formations increasingly prospective to economic development. In addition, global demand for energy continues, and will continue to outpace supply for the foreseeable future, resulting in pressure to expand development activities, with associated concerns about environmental and social impacts.

Understanding the intricate links between methane hydrates and 1) natural and anthropogenic contributions to climate change, 2) their role in the carbon cycle (e.g. ocean chemistry) and 3) the environmental and socio-economic impacts of extraction, are key factors in making good decisions that promote sustainable development.

As policy makers, environmental organisations and private sector interests seek to forward their respective agendas which tend to be weighted towards applied research, there is a clear and imminent need for a an authoritative source of accessible information on various topics related to methane gas hydrates. The 2008 United Nations Environment Programme Annual Report highlighted methane from the Arctic as an emerging challenge with respect to climate change and other environmental issues. Building upon this foundation, the proposed project aims to provide a multi-thematic overview of the key aspects of the current methane hydrate debate for both the land-based Arctic deposits and those in the marine environment.

It is proposed that for purposes of clarity and coherence, the report be 'divided' into 2 sections: 1) section covering the various thematic issues related to gas hydrates (based on the approved thematic scope) and 2) a section assembling key case study sites emphasising the various elements of the thematic section.

In this outline, the subtopics are suggested to assist in developing a consistency in flow and treatment of the topics. They are, however, suggestions and will be adapted as the writing progresses.

Results of meeting

Goals of meeting:

The primary goals of the first meeting of the Steering Committee were:

1. finalising of the thematic scope
2. finalising of the chapter outline
3. finalising of the chapter leads and co-leads

Secondary goals of the first meeting of the Steering Committee included:

1. examination of draft project website
2. examination of draft cover design
3. examination of authour terms of reference
4. gathering of outreach multimedia material

All primary goals were achieved with the resulting documentation annexed to this report. In addition, all secondary goals were in the least presented.

Highlights of key decisions taken by the Steering Committee:

- The print version of the publication will consist in 2 volumes of no more than 300 pages each with an accompanying Executive Summary brief of no more than 20 pages. The Executive Summary may be included at the beginning of each Volume rather than as stand alone. The print version will be accompanied by a DVD that will include the more interactive electronic version and any digital media (e.g. wiki-style "library" of case studies) developed during the course of the project cycle.
- Division of volumes: Volume 1 on hydrates in the context of natural systems and physical properties; and volume 2 on hydrates in the context of the human dimension.
- Case studies: a core selection of "case study" examples will be included in the print publication; the effort with repect to case studies will be part of the development of a wiki-style geospatial knowledge-base displaying sites and location on a virtual globe (e.g. Google Earth); also possibility of adding a hydrates layer directly to the Google Oceans content management system.
- Engage with and include environmental NGOs and the media early on in the process; also possibility
- Development of a FAQ section that can be used both for marketing purposes and as a volume guide.
- Development of project material toolkits based on the different target audiences: Government and industry toolkit; media toolkit; NGO toolkit; education system toolkit.
- Chapter Leads to take overall responsibility of ensuring initial content production and have discretion as to how to go about it (e.g. size of original drafting group); but general consensus is that a broad spectrum of the expert community needs to be engaged in the process to ensure its robustness to scrutiny. In general terms, this means that for each Chapter, as many key experts as manageable are to be invited to provide comment and feedback and be listed as contributors (as opposed to reviewers).
- Project web component: agreement that any major content and updates news items to be displayed on the project website should be vetted by at least one expert (initial expert reviewer to be Ray Boswell).
- Agreement that UNEP/GRID-Arendal will take the lead role in coordinating the content linked to the Resource Efficiency/New Economics and the Societal Implications chapters.
- Tentative decision to organise a content work session in Tokyo the week of November 15th 2010. This session is proposed not to be a Steering Committee meeting per say but a chance for chapter leads and co-leads to assemble in order to discuss, review and further the content that will have been produced thus far. The rationale behind the the venue and date is linked to a Mallik-Nankai symposium being held in Tokyo from November 15-17. Many of the Chapter leads are expected to attend this symposium thus reducing the project costs in relation to travel. Suggestions for a different venue should be made as soon as possible to the Project Coordinator, Yannick Beaudoin.

Near term follow up actions:

- The top priorities to be handled by UNEP/GRID-Arendal in the near term are:
- Fundraising: USD 325,000 (over 2 years) has been secured. A further USD 275,000 is further required to provide all agreed upon deliverables. the remaining funding requirement is expected to come from a mix of governmental and private sector sources and be completed by a contribution from UNEP. Any assistance in approaching the respective national governments of members of the Steering Committee would be greatly appreciated.
- Project website launch: Outreach efforts over the next month will be focused on integrating multimedia material received from various sources in order to produce an attractive and functional project website to be launched in mid-April. This site will incorporate features such as: general project information; partners links; photos; videos; hydrates news; a FAQ list; general public outreach components (e.g. Knowledge Cube) and a content management system for chapter authours. The site will grow over the project cycle to become a central web focal point for the state of the knowledge on methane gas hydrates by adding features such as: a geolocated wikipedia style knowledge base; a web-based GIS application; a geolocated literature library (abstracts in the least. Many other features can/will be developed based on consultation with respective experts.
- UNEP/GRID-Arendal will be attending 3 hydrates-related conferences before the summer to properly promote the project amongst the scientific community. Efforts also be made to lay the groundwork for providing the results of the work to the Arctic Council of Ministers and the Economic Community of West African States.

ANNEX A: AGREED UPON CHAPTER OUTLINE WITH LEADS AND CO-LEADS

Comments: Please note that although the general themes of the chapters are outlined below, the actual chapter and sectional titles and headers are not finalised and will be modified. Authours should feel free to suggest titles they think are appropriate. These will be reviewed in due course.

It is expected that some chapter content will evolve with the work. Therefore this chapter outline is meant to be an evolving document although the core themes of each chapter should not vary to much from what has been agreed upon.

EXECUTIVE SUMMARY AND HIGHLIGHTS

(1) Reasons/objectives for work

(2) Particular deposits of interest from a resource perspective

(3) Particular deposits of interest from an ecosystem and environment perspective

(4) Perspectives of hydrates in comparisons to other recent non traditional gas development (shale gas)

VOLUME 1: METHANE GAS HYDRATES IN THE NATURAL SYSTEM (max 200 A4 pages)

1. Chapter 1: What are Methane Gas Hydrates (define the types)? (20 pages)

Chapter lead RAY BOSWELL co-lead: WILLIAM WAITE

1.1. Introduction

1.2. Hydrate Science

(1) State of the knowledge and history of the science (why are we interested in hydrates?)

(2) Hydrate physics (looks..molecular; different chemical types; physical characteristics)

(3) Occurrence types (e.g. disseminated; massive; pore space); identify which are most relevant to which topic

(4) Sources (brief)

1.3. Formational Environments Introduction

1.4. Conclusions

2. Chapter 2: Global Outlook of Methane Gas Hydrates Occurrences (20 pages)

Chapter Lead: WILLIAM WAITE co-lead: RAY BOSWELL

2.1. Introduction

(1) World map of distribution: provide sense of scale

2.2. Global distribution of occurrences of methane gas hydrates

(1) Maps; charts; qualitative distribution

2.3. Conclusions

3. Chapter 3: Methane Gas Hydrates in the Natural Carbon Cycle (40 pages)

Chapter Lead: KELLY ROSE co-lead: TINA TREUDE

3.1. Introduction

3.2. Sources of methane

3.2.1. (global methane budget; graph..schema)

3.2.2. Biogenic origins

3.2.3. Thermogenic origins

3.3. Natural methane emissions from hydrates and their regulation by physical processes

3.3.1. “Methane Capacitor”

3.4. Time scales of natural variations in gas hydrate occurrences

3.5. Possible examples from the past

(1) Negative carbon excursions: e.g. possible case study: PETM example

(2) Role of hydrates in transitions from ice ages to warm periods

(3) "Clathrate Gun" hypothesis (could a box rather than a sub-chapter…perhaps not use "clathrate gun" title)

(4) possible box: Bermuda Triangle "myth"

3.6. Sediment stability issues related to gas hydrates (**Charlie Paull)**

3.6.1. Physical/geomechanical changes **(Johnny Rutqvist)**

3.6.2. Slope slides in the aqueous environment **(Brandon Dugan)**

3.6.3. Seafloor and terrestrial geomophological manifestations

(1) "mythbuster box" Storegga slide

3.7. Conclusions

4. Chapter 4. Chemosynthetic Ecosystems Dependent on Near Surface Methane Gas Hydrate Occurrences (40 pages)

Chapter Lead: TINA TREUDE co-lead: KLAUS WALLMANN

4.1. Introduction

4.2. Natural methane emission from hydrates and their regulation by biological processes

(1) Microbial processes in sediments: benthic methane filter

(2) Chemosynthetic communities linked to methane degradation

(3) Methane consumption in the water column

(4) Natural processes linked to the evolution of the communities

4.3. Sensitivities of communities to climate and geological variations

4.4. Conclusions

5. Global scenarios of Sensitivity of Methane Gas Hydrates to Global Warming (30 pages)

Chapter Lead: KLAUS WALLMANN co-lead: SCOTT DALLIMORE

5.1. Introduction

5.2. Impacts of warming scenarios on methane gas hydrates stability

VOLUME 2: POSSIBLE TITLES: (max 200 A4 pages)

1) **HYDRATE AS A RESOURCE**

2) **HUMAN INTERACTIONS WITH METHANE GAS HYDRATES**

1. Chapter 1: Sustainable Economics For Methane Gas Hydrates Resource Development (highlight the varying international viewpoints) (50 pages)

Chapter Lead: ANNE SOLGARD co-lead: YANNICK BEAUDOIN

1.1. Resource efficiency challenges in a global context

1.1.1. Drivers, demand, scarcities

(1) Geopolitical considerations

(a) Regionalization of energy supply

(b) Global energy consumption

(2) Climate and energy debate (brief outline)

(3) E.g. global population growth

(4) Global energy models; scenarios of moving to a more gas based economy?? As opposed to conventional non-natural gas fossil fuels

(a) Scenario A: Effects of adding hydrates ON TOP of traditional supply

(b) Scenario B: effects of using hydrates as a REPLACEMENT to some of the traditional hydrocarbon supply

(c) How do scenarios A and B affect climate???

(d) Link to IPCC findings about GHG reduction by replacing coal/oil with natural gas: driver for methane gas hydrate development

(e) Diversification of natural gas sources (geographically): effect of regionalization of energy as opposed to current model based on reduced sources

1.1.2. Scenario-based policy indicators: Policy barometers according to different regions (e.g. EU, North America, Asia/Japan)

1.1.3. Putting hydrates in perspective: e.g. coal development, shale gas (footprint, social issues (jobs)…)

1.1.4. Issues of mismanagement and inefficiencies

1.1.5. Economic limitations to resource development

1.1.6. Resource valuation: resource, ecoystems; vulnerability index for specific sites (e.g. geohazards) and ecosystems (shallow marine hydrate deposits)

1.1.7. Risk considerations for policy makers: specific risks to methane gas hydrates;

1.2. A new economics business model for methane gas hydrates resource development

2 Chapter 2: Hydrates as a Global Resource for Natural Gas (40 pages)

Chapter Lead: TATSUO SAEKI co-lead: NADER DUTTA

2.1 Introduction

2.2 Global inventory of methane gas hydrates

2.3 Definition of a resource according to traditional valuation methods

2.3.1 Occurrence type (e.g. pore space)

2.3.2 Technological constraints (current available technology)

2.4 Detection and delineation methods

2.5 Examination of currently known quantified occurrence at specific sites (e.g. Nankai, Alaska, Gulf of Mexico etc)

3 Chapter 3: Technologies related to potential development of methane gas hydrate occurrence (50 pages)

Chaper Lead: SCOTT DALLIMORE co-lead: KOJI YAMAMOTO

Contributors: JOHN THURMOND, ESPEN SLETTEN ANDERSEN;

3.1 Introduction: in situ dissociation and recovery of natural gas based on conventional technology

3.2 Accessing the reservoir

3.2.1 Conventional technologies

(1) E.g. well technology

3.2.2 Unique challenges

3.3 Disassociation Techniques: Conventional and novel

3.3.1 Pressure reduction

3.3.2 Temperature stimulation

3.3.3 Chemical stimulation

(1) CO2 injection

(2) Kinetic inhibitors

3.3.4 Mechanical stimulation (i.e. fracking)

3.3.5 Technological challenges

3.4 Achieving long term production

3.4.1 Managing water as a bi-product

3.4.2 Sand production control

3.4.3 Gas leakage management

3.4.4 Gas lift issues, flow assurance

3.5 Timeline of gas hydrate development

3.5.1 Example from conventional oil and gas industry

3.5.2 Regional/national factors

3.6 Future trends in technical development and impacts on development

3.7 Environmental Impacts based on production scenarios

3.7.1 Evaluation of impacts based on physical settings of targets

(1) Marine settings

(2) Permafrost settings

(3) Contrast with examples of shallow gas production

3.7.2 Impacts and footprint management

3.7.3 Impacts to methane-based ecosystems

(1) Flux reduction affecting ecosystems

3.7.4 Atmospheric/hydrospheric methane leakage

(1) Thermodynamic constraints that prevent large volume release

(2) Explanation of risks related to possible marine leakage

3.7.5 Production induced sediment movement and slope failures

(1) Affects to well stability

(2) Surface interactions

3.7.6 Water handling

3.8 Conclusions

4 Chapter 4: Societal Perspectives of Methane Gas Hydrate Development (30 pages)

Chapter Lead: ANNE SOLGARD co-leads: JOO YONG LEE, JEAN-MARIE BEAU-LIEU

Contributor: SCOTT DALLIMORE

4.1Introduction

4.2 Arctic communities perspectives

(1) Concerns in relation to natural resources development

(2) Benefits (from the community perspective)

(3) Practical suggestions for improvements in relation to traditional oil/gas development

4.3 Marine coastal communities perspectives (is this possible at this stage??)

4.4 Impacts of infrastructure development on areas that have no previously had conventional oil/gas development

4.5 Implications of gas hydrate development in new areas (different than traditional oil and gas development); Learn from areas with experience

4.5.1 Arctic: Alaska, Canada, Norway, ECORA

4.5.2 Marine: Japan; West Africa; India

4.6 "Advice" for areas without experience

4.7 Impacts on well-being;

4.8 Conclusions

5 Chapter 5: Challenges, opportunities, policy responses and options (20 pages)

Chapter Lead: Yannick Beaudoin co-lead: MALCOLM V LALL

Proposing hydrates as a REPLACEMENT of "dirtier" hydrocarbons as opposed to being used in conjunction with….Hydrates as a TRANSITIONAL energy source

Recommendations: use shale gas as an example to contrast; developing policy based on sound science before development rather than playing catch up.

Hydrate development based on timeline; related to changes in global economic regime (e.g. carbon price)

This section will include a broad wrap-up of the key messages and discussion in relation to: interactions with other pressures; challenges and opportunities, including with regard to economic activities.The earlier sections of the report will contain examples of policy responses – this section will provide some generalised discussion of policy responses and options. This chapter will also contain a way forward with respect to continuing to report on developments in the field of methane gas hydrates research, exploitation, community perspectives, general public feedback and meeting policy maker needs for information.

ANNEX B: ONLINE CONTENT

Case Study Knowledge Base:

LEAD: KELLY ROSE

CO-LEAD: YANNICK BEAUDOIN

CO-LEAD: YOSHIHIRO NAKATSUKA

1 **Hydrate Ridge/Cascadia margin**

2 **Blake Ridge**

3 **Seafloor observatories**

4 **Messyaka (Russia)**

5 **Santa Barbara Basin**

6 **Mallik Site**

7 **Nankai Trough**

8 **SUGAR site**

9 **GANS site, Voering Plateau**

10 **GANS site, western Svalbard Margin**

11 **GANS site, Barents Sea**

12 **Gulf of Mexico**

13 **Southern Chile Margin**

14 **New Zealand**

15 **Taiwan**

16 **Costa Rica**

17 **China offshore: GMGS-1**

18 **China Qinghai Province**

19 **Northern Indian Ocean**

20 **Korea**

21 **Alaska, Mt Elbert**

22 **Alaska, BP production test**

23 **Alaska, Conoco Phillips CO2 injection test site**

24 **Lake Baikal**

25 **Jurisdictional Case Study: Canadian Arctic**

WEBSITE (PROJECT WEBSITE)

LEAD: YANNICK BEAUDOIN
CO-LEAD: RAY BOSWELL

Responsibilities:
Vetting news events section
Vetting major content

ANNEX C: PRELIMINARY FAQ LIST

FAQs

What are hydrates and why should I care?

Are there a lot of hydrates?

When will commercial production occur?

Aren't hydrates very dangerous?

Could hydrates be responsible for runaway climate change?

Why does industry ignore hydrates?

Is The Swarm real?

Where are gas hydrates found?

How are hydrates found?

Are hydrates easily destabilized?

How de we produce natural gas from hydrates?

Why should we develop another fossil fuel?

Why does government subsidize research for hydrates?

How will R&D lead to commercialization?

Will development of hydrates have an impact on ecosystems?

Can hydrate development cause tsunamis?

Why do you want use methane for energy production?

Can I make a career in the hydrates development industry?

Are the hydrates on other planets or moons?

Are hydrates poisonous?

Why do hydrates fizz?

How can life live off hydrates?

When or how were hydrates first discovered?

ANNEX D: VERY PRELIMINARY LIST OF POSSIBLE EXTERNAL REVIEWERS AND CONTRIBUTORS

POSSIBLE REVIEWERS:

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ERWIN SUESS
MIKAEL IVANOV
BO BARKER JOERGENSEN
M V RAMANA
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POSSIBLE CONTRIBUTORS

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CHARLIE PAULL
VLADYMYR YAKUSHEV
MASANORI KURIHARA
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BOB HARDAGE
BILL REEBURGH
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ANNEX F: GUIDELINES AND INFORMATION FOR AUTHOURS

March 2010

Table of Contents

1. INTRODUCTION TO THE GLOBAL OUTLOOK ON METHANE GAS HYDRATES

Global reservoirs of methane gas have long been the topic of scientific discussion both in the realm of environmental issues such as natural forces of climate change and as a potential energy resource for economic development. Of particular interest are the volumes of methane locked away in frozen molecules known as clathrates or hydrates. Our rapidly evolving scientific knowledge and technological development related to methane hydrates makes these formations increasingly prospective to economic development. In addition, global demand for energy continues, and will continue to outpace supply for the foreseeable future, resulting in pressure to expand development activities, with associated concerns about environmental and social impacts.

Understanding the intricate links between methane hydrates and 1) natural and anthropogenic contributions to climate change, 2) their role in the carbon cycle (e.g. ocean chemistry) and 3) the environmental and socio-economic impacts of extraction, are key factors in making good decisions that promote sustainable development.

As policy makers, environmental organizations and private sector interests seek to forward their respective agendas which tend to be weighted towards applied research, there is a clear and imminent need for a an authoritative source of accessible information on various topics related to methane gas hydrates. The 2008 United Nations Environment Programme Annual Report highlighted methane from the Arctic as an emerging challenge with respect to climate change and other environmental issues. Building upon this foundation, the proposed project **aims to provide**

a multi-thematic overview of the key aspects of the current methane hydrate debate for both the land-based Arctic deposits and those in the marine environment.

2. LEAD AUTHORS' GUIDE TO PREPARING CHAPTERS

The first content draft of this report (Draft 0) is being prepared over a 5 months (from April 2010 inclusively). UNEP/GRID-Arendal as coordinator, as well as the Chapter Leads, will assist you as much as possible in locating material and helping you to edit and pull your sections together. Please contact us if you need assistance on any aspect of your chapter.

Please read through the background information and conceptual framework for the overall Global Outlook on Methane Gas Hydrates (Annex to this document). Although the language should be as simple as possible and unnecessary technical details should be avoided, ensure that your chapter is based on authoritative, up-to-date sources, and that statements are backed up with direct references to these sources. Although you should reference peer-reviewed sources where possible, you are not limited to these sources. Information on referencing different types of sources is provided in the Style Guide (below).

2.1 ACCESSIBILITY

Please write for the reasonably informed and curious individual, not specialists. Avoid technical terms and the use of terms that have specific meanings in the context of a discipline. If it is important to introduce a technical or specialized term, explain what it means in plain language. For example, terms like resiliency, feedback mechanisms, and ecological footprint represent important concepts but need to be explained to the general reader. Bear in mind that many readers will not have English as their first language. Avoid over-long sentences. Break them down into smaller chunks.

Many people will not read this report cover to cover, but will skim through it and read parts that catch their interest. The chapters should be written so that it is easy to find specific pieces of information.

2.2 AVOIDING REPETITION

Please avoid repetition of material in introductions, body, boxes and conclusions. Introductions may summarize the most salient aspects of what follows. Conclusions should look towards what is unfinished, what remains to be resolved, themes that might be the subject of ongoing debate or major problems not yet fully or effectively addressed and may which demand urgent attention.

2.3 LENGTH AND ELEMENTS OF EACH CHAPTER

Please pay close attention to these guidelines, so that the final document is well-balanced in terms of text and graphics and so that we can move smoothly from the first draft, to the review and revisions, and then to final editing and production. You can move words and space allocation among the main text, text boxes, figures and illustrations, but try to maintain the overall balance for each small section. It is better to start with a draft that is too short than with one that is too long. Reviewers have a tendency to ask for additions, rather than deletions!

Make use of **text boxes** to provide examples and to elaborate on elements of the main text. In general keep these to a maximum of about 250 words. In some cases you might want to produce a full page 'feature' box with, for example, a map, a photograph and text – in this case your text might be longer than 250 words.

To make this report visually appealing, we would like to include a range of **photographs, imagery, maps, illustrations and graphics** of varying sizes. Please bear this in mind and provide suggestions. We would like to begin working on the graphics early on in the process, so please submit your ideas and needs for graphics development as you develop sections. Please contact Yannick Beaudoin (contact information below) if you want to discuss ideas and needs for graphics development. Do not spend a lot of time formatting charts and maps yourself, but focus instead on the information.

The **guidelines for length** in the table below are based on the following approximations, and it is expected that you will trade off words and space among these suggested elements:

Per **double-page** spread, average:

- 600 words of main text
- 1 to 2 maps, charts or other images, depending on size
- 1 photograph
- 1 text box

Your Rough Guide to Chapter Page Count and Elements (as a guide):

Chapter	Page Length	Percentage textual content	Number of maps, charts & other figures	Number of photographs
VOLUME 1				
1	20	<50%	2-4	5
2	20	<50%	2-4	2
3	40	<50%	8-10	10
4	40	<50%	8-10	10
5	30	<50%	6-8	2
VOLUME 2				
1	50	<50%	10-12	4
2	40	<50%	2-4	4
3	50	<50%	5-10	10
4	30	<50%	2-4	4
5	20	75%	4-6	2

In sections where you plan to have a large map, for example showing the distribution of methane gas hydrates world wide, please reduce the word length accordingly.

We will help to locate suitable **photographs**, but please do make suggestions and provide pictures where you can.

References will be in small print at the end of each chapter, and a rough space allocation is included in these estimates. Do not include the references in your total word count.

2.4 FORMATTING DRAFTS FOR REVIEW AND EDITING

Keep formatting very simple. Do not use Microsoft Word's Text Box function for boxes, images or captions. Instead include Box material in the main body, as follows: BEGIN BOX Title/text END BOX. Use a common font, such as Times New Roman or Arial, and avoid using special characters (such as special font symbols for bullet points).

If you include images in the Word document, please make sure these are low resolution – high resolution images make the document difficult to handle. However, we will need high resolution, copyright-cleared images with sources clearly indicated. If you have photos that you are providing for the report, please upload them to the content management system or email them to us separately.

For maps and charts, either present a simple version suitable for review, or insert an image from another report. We will redo charts in one style, so we will need the original data sets. These can be added in on or below the chart, placed on the wiki, or emailed separately. We will also redo maps to provide a consistent look.

2.5 PRODUCTION TIMELINE

Date Deadline	Activities Outputs
4-5 March 2010	1st Steering Committee meeting, Arendal, Norway
April 2010 – November 2010	• Content Draft 0 completed • Proposed content meeting in November 2010
December 2010 to end of January 2011	• Content Draft 0 internally reviewed • Secretariat to send recommendations to lead authors
April 2011	Tentative 2nd Steering Committee meeting (if desired)
January 2011 – end of June 2011	• Content Draft 1 completed
July 2011 – end of September 2011	• Content Draft 1 externally reviewed • Secretariat to send recommendations to lead authors
September 2011 to December 2011	• Lead authours finalize chapters • Merging of Final Content with Final Layout
January 2012	• Tentative 3rd Steering Committee meeting (if needed) • Review of all deliverables
Post January 2012	• Targeted launches

2.6 CONTACTS AND LOGISTICS

2.6.1 Contacts for Information and Assistance

Please do not hesitate to contact us to assist you in any way we can.

Overall Project Coordinator:

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2.6.2 Sharing files and accessing resources on the WIKI

- We will use a web-based, password-access system for sharing files located at: NEEDS TO BE CONFIRMED. You can register yourself on this site and obtain a username and password.
- The content management system will contain background documents and resources as provided by the coordinators and various thematic experts. It will also contain locations for authors and contributors to upload and download files. There will also be a short guide to its use. The system is very simple and has worked well for the production of other similar scaled assessments.
- All authours are invited to upload maps, graphics and other materials, such as case study information, onto the wiki, organized by chapter. These will be shard amongst authours and will also make up the foundational multimedia material that will incorporated in the final layout of the publication. Proper credit should be clear attached to each submitted piece.

3. STYLE GUIDE

(ADAPTED FROM UNEP GLOBAL ENVIRONMENT OUTLOOK (GEO) STYLE GUIDE)

- Use **English spelling** not American.
- Use **Oxford style** not Collins (*The Concise Oxford Dictionary is available online at http://www.askoxford.com/dictionaries/compact_oed/?view=uk)*. Use the main spelling listed, not the 'also' or 'us' spelling that is in parentheses.
    - This means using **'-ize' endings** as in 'organize' not 'organise' in nearly all cases (but never after 'y', as in 'analyse').
    - It means using **programme** and not program;
    - but **gram** (not gramme);
    - and **kilogram** (not kilogramme).
    - It means using **centre** and not center (unless it is part of the title of an institution which officially uses Center).

3.1 OVERALL GEO STYLE GUIDELINES

- Use initial capitals (as in Prime Minister) very sparingly and only when absolutely necessary.
- Use only **metric units**, with their correct SI abbreviations.
- In the text **spell out numbers one to ten** (unless followed by units), and put numbers higher than ten in numerals; sentences that contain both numbers less than ten and greater than ten should use numerals ('5 lions and 12 tigers').
- Do not use a full point after contractions (Dr, Mr, Ms, and so on), only after abbreviations (for example, ed. for editor).
- **Avoid Latin words** whenever possible; many readers do not have English as their mother tongue and cannot be expected to know Latin as well; use the English equivalent ('among others' for *inter alia*, 'for example' for *eg*, and so on). Use common names for **plant or animal species**, and, if necessary to avoid confusion, add the Latin name, italicized, in brackets afterwards. The generic name starts with an uppercase, and species name with a lower case. For example: baobab (*Adansonia digitata*).
- Distinguish levels of sections carefully: **BOLD CAPS FOR LEVEL 1 TITLES**, **Bold Upper and Lower Case for Level 2 Titles**, ***Bold italics for level 3 titles***. Please avoid using more than three levels of titles or readers will get lost in the structure.
- When mentioning treaties for the first time, give the **full name**.
- When using acronyms for the first time, **spell them out and put the abbreviation in parentheses**. After that use the abbreviation.

- Do not insert a **comma** before the grammatical conjunction (nearly always *and* or *or*) that precedes the last item in a **list of three or more items** unless it is needed to reduce ambiguity. For example, 'snow, ice or permafrost' but 'summer and winter, arctic and antarctic, and coastal and interior'.

3.2 REFERENCES

3.2.1 General guidelines

- Please pay particular attention to **punctuation** while writing references.
- Please check the **alphabetical order** of the list before submission.
- Note that there are **no full stops** at the end of any of the references.
- Where you wish to refer to **several publications by the same author in the same year**, distinguish them as follows: Smith 1996a, Smith 1996b, and so on.
- Where there are **several publications by the same author published in different years**, distinguish them in temporal order, starting with the earliest date (Smith 1996, Smith 2001, and so on).
- Where there are **multiple authors for one publication** use the surname, comma, initial, full stop, comma, next surname, and so on. **Before the last name, however, use 'and' instead of a comma.** For instance:

  Barnett, T.P., Adam, J.C. and Lettenmaier, D.P. (2005). Potential impacts of a warming climate on water availability in snow-dominated regions. *Nature*, 438(23), 303-309
- Where references have **three or more authors**, include all the names in the full reference to the publication at the end of the section, but use the form (Smith and others 1969) in the citation within the text.
- **Names of books** should be given in full, using initial caps for the major words in the title; names of journals should be abbreviated only where there is an official abbreviation and this is known to you. Names of books and journals should be italicized. Titles of journal articles should not be italicized.
- Note that while **full stops** are used for initials of authors, there are no full stops after an acronym for an organization that is quoted as the author of a report. So use

  Cochrane, M.A. (2002). *Spreading like wildfire*…, but

  UNEP (2005). *Caribbean Environment Outlook*...
  - References *originally* in **other languages** should not be translated to English. Keep the original.
  - For all **boxes** (including the Key Fact boxes), **images**, **maps**, **tables**, and **figures**, please list the sources in alphabetical order at the end of the box as *Source(s):* in the same for-

mat used in the rest of the text, and provide the full references at the end of the chapter along with the other references for the chapter.

- For **pictures**, give the full credit and source at the bottom of the picture, but do not give a full reference at the end of the chapter. For instance: *Source: Yves Herman/ Reuters*

3.2.2 Referencing a book

Ainsworth, M. D. (1996). *Journey across Africa*. Heinemann, London

In cases where the author is an organization:

UNEP (2005). *Environment in Iraq: Progress Report*. United Nations Environment Programme, Geneva

Note that there is no full stop after the UNEP acronym.

3.2.3 Referencing a journal

Tinbergen, N. (1972). Functional ethology and the human sciences. *Proc. R. Soc.*, 360(1462), 2139-2148

Note the style for including the volume, number and page numbers of the journal – comma after title of journal, then the volume, followed by the number in parentheses without space between the two, then a comma followed by the page numbers.

3.2.4 Referencing a chapter in a book or journal with a separate editor

Ainsworth, A. (1969). Fighting malaria. In *Common Diseases of the 19th Century* (ed. B. Foss). Methuen, London

Note that only the published title (title of a book or journal) takes italics.

3.2.5 Referencing unpublished papers

Ainsworth, M. D. (2005). Journey across Africa. In print

Note that papers that are not published do not take italics.

3.2.6 Referencing personal communications

Please note that personal communications should only be used when it is impossible to cite another source.

Ainsworth, M.D. (1996). Personal communications

3.2.7 Referencing newspaper articles

Please note that references to newspaper articles should only be used when it is impossible to cite another source.

Venkataramani, G. (2004). Mangroves can act as shield in tsunami. *The Hindu*, 27 December

Or in cases where the author is not mentioned,

The Hindu (2004). Mangroves can act as shield in tsunami. *The Hindu*, 27 December

3.2.8 Referencing a conference paper

Silver, K. (2004). Women, men and environmental change. In: *Global meeting on Gender, Poverty and Environment, 5-10 October 2004 Nairobi*

To reference the published proceedings of a conference, please use the following format:

Silver, K. (2004). Women, men and environmental change. In: Raitt, D.J. ed. *Global meeting on Gender, Poverty and Environment.* Oxford, Oxford University Press

3.2.9 Reference to an Internet source

Holland, M. (2004). *Guide to citing Internet sources*. Bournemouth University. http://www.bournemouth.ac.uk/library/using/guide.html [Accessed 4 November 2004]

For an institutional Internet source, with no author:

WHO (2004). *Africa Malaria Report 2003*. World Health Organization. http://www.rbm.who.int/amd2003/amr2003/amr_toc.htm [Accessed 4 November 2004]

Note: Please do not accept Microsoft Word's automatic underlining of URLs, as this hides the _ character in some URLs. Don't end URLs with a full stop.

3.3 NUMBERS

3.3.1 General guidelines

- **No punctuation is used to separate thousands**, a space being left: 1 000; 2 312; 1 550 734 (except in years: 1989; page numbers: p. 1139; genotype names with numbers: 'Across 8047', 1566/1 x L-12).
- **The decimal** is a full point in English (while it is a comma in French and Spanish); numbers of less than one take a zero before the decimal point: 0.05.
- **Spell out 'per cent'** in text but use"**%**' in tables and figures. Note the spelling of '**per cent**' and 'percentage'.

- **In text, numbers from one to ten** are written in words, not numerals except before units (6 kg, 2 ha, 3 t) and before the word million (7 million). However, where the number is an approximation, the number can be written as a word (two million).
- **Sentences containing figures** in a fairly close and logical sequence or in a series take numerals: the number of graduates in the three courses were 3, 7 and 9; 25 villages, 10 districts, 3 regions; 4 automatic stage recorders and 9 stop gauges; 3 labourers, 6 foremen, and 4 consultants; the life of the system would be 25 years if built in China and 10 years if built elsewhere; in only 4 of 39 trials.
- When a phrase such as three-week course in preceded by another number, adjust accordingly: two 3-week courses; 27 three-week courses.
- **Fractions** are always hyphenated, whether adjective or noun: one-half, two-thirds.
- **Map scales** use the colon: a map at 1:50 000 scale.
- **If a sentence begins with a number**, the number must be written out in words; to avoid awkwardness, it is sometimes better to rephrase the sentence. Numbers written out are hyphenated as follows: one hundred and sixty-seven; twenty-six; one hundred and nineteen.

3.3.2 Units

- Units are not repeated: 3 x 5 cm; 0.7 to 1.5 ha; 15 and 21 t.
- If the unit is an unfamiliar one for most people, spell it out for the first time and use the short form thereafter. For common units, use the short form.
- Use either ‘between 8 and 9 t’, or simply ‘8-9 t’. Do not use ‘between 8-9 t’.
- Use ‘yield per hectare’, not ‘yield per ha’.
- Use either ‘7 kg/ha’ or ‘7 kg per hectare’, but not ‘7 kg per ha’.

3.3.3 Dates and time

- For dates, use the ***Date Month Year*** format (for instance, 6 September 2004). Examples of usage:
    - from 6 to 10 September, or 6–10 September;
    - on 8 May 1990 in Rome; or 8 May 1990, in Rome;
    - 1 January 1990-12 June 1990; 1974-75 (period of two years);
    - from 1960 to 1961 (not 1960 to 61);
    - decades: the 1980s;
    - centuries: the 20th century;
    - 09.00 hours; 15.30 h (not 09:00 hours or 9 a.m.).

3.3.4 Currencies

- Express figures as far as possible in US$. Note that there are no spaces before and after $: US$450 000.

3.4 GEOGRAPHY: NAMES AND MAPS

To ensure that country names are spelt correctly, please visit the **UN Editorial Manual** that is accessible at http://69.94.137.26/editorialcontrol/useful_links/useful_links.htm

and the **UN Cartographic Section** at http://www.un.org/Depts/Cartographic/english/htmain.htm.

3.5 BULLETS

Where **bullets are used for listing facts**, they may begin with a capital letter and end in a full stop. However, if **bullets are used to break up a sentence**, use a colon at the end of the introductory line before the bullets start, begin each bullet in lower case, and use a semi-colon at the end for all but the last bullet, which should end with a full stop.

ANNEX: BACKGROUND INFORMATION ON THE FRAMEWORK FOR A GLOBAL ASSESSMENT

(This material is adapted from the UNEP Global Environment Outlook framework employed by UNEP and is intended for broad guidance and context-setting for authors and reviewers of the Global Assessment of Methane Gas Hydrates.)

Assessing and reporting on the world's environment and its inherent resources is a fundamental mandate of the United Nations Environment Programme (UNEP). To this end, the UNEP Division of Early Warning and Assessment (DEWA) is responsible for undertaking assessments of the state and trends of the global environment.

A. What is an Assessment?

The need to strengthen the links between science and policy was stressed both in the World Summit on Sustainable Development in 2002 and in the consultative process on strengthening the scientific base of UNEP, also referred to as the Science Initiative. Processes for keeping various aspects of the global environment under review must be based on a close relationship between science and policy, at different geographic and temporal scales. Assessments are geared towards achieving this interaction, as they are fundamentally communication processes, not simply reports, which share many similar features regardless of their scope (for definition and characteristics see Boxes 1 and 2 below). The key challenge is to design assessment processes that ensure the interaction between science and the different stages of the policy and decision-making cycle at different scales.

Assessments must be policy relevant, and feed into and support policy and decision-making processes to have utility and value to environmental and resource management. Key characteristics of "effective" assessments (i.e. assessments perceived as being credible, relevant and legitimate) include who is involved (participation), how assessments are conducted (science and governance) and the scope of the assessment (focus)[1].

Box 1 Definition of an assessment

An assessment is the entire social process for undertaking a critical and objective evaluation and analysis of *data and information*, including indigenous and local knowledge, designed to support decision-making. It applies the judgment of experts to existing knowledge to provide scientifically credible answers to policy relevant *issues, quantifying, where possible, the level of confidence; showing trends; and providing relevant indicators.*

Box 2 Characteristics of a credible, legitimate and relevant assessment

- It is a critical, peer-reviewed evaluation of information, for purposes of guiding decisions on a complex, public issue, following a well-defined process.
- The scope (topic under consideration) is defined by the stakeholders, who are typically decision-makers. Findings are policy relevant, but not prescriptive and reflect, for instance, an "if … then" approach.
- It is conducted by a credible group of experts with a broad range of disciplinary and geographical experience and representation, in a balanced and transparent way.
- It reduces complexity but adds value by summarizing, synthesizing and building scenarios, and identifies consensus by sorting out what is known and widely accepted from what is not known or not agreed.
- It sensitizes scientific communities to policy needs and the policy community to the scientific basis for action.

[1] Eckley, Noelle (2001). Designing effective assessments: the role of participation, science and governance, and focus. Report of a workshop co-organized by the European Environment Agency and the Global Environmental Assessment Project, Copenhagen, Denmark, 1 to 3 March 2001. EEA Environmental issue report No. 26.

B. Global Environment Outlook (GEO) Assessment: Mandate and outputs

The Global Environment Outlook is the practical implementation of UNEP's mandate to keep the global environment under review. The first GEO assessment report was initiated by UNEP Governing Council in its decision 18/27 (1995) where the Executive Director was requested to prepare a new comprehensive report on the present and future state of the world environment, including possible response measures to address the situation. Following the establishment of the GEO process and production of the first GEO report, the Governing Council renewed the mandate for GEO in 1997, 1999 and 2003 and 2005[2]. The 2003 Governing Council decisions extended the interval between the GEO reports to five years, and added an "annual GEO statement" to the request. The 2008 Governing Council decisions request the establishment of a process of developing GEO-5 as an integrated assessment of the global environment which involves governments and builds upon national, subregional and regional information, and assessments and experiences.

The GEO has over the years evolved into a series of integrated environmental assessments. Meeting user needs cuts across all elements of GEO outputs. The most tangible outputs of the process are the GEO series of publications that provides guidance for decision-making processes. UNEP has published three volumes of the comprehensive *Global Environment Outlook (GEO)* report series: *GEO-1* in 1997, *GEO-2000* (GEO-2) in 1999, *GEO-3* in 2002 prior to the World Summit on Sustainable Development and *GEO-4 in 2007*. The first volume of the annual statement was published in March 2004 as the *GEO Year Book 2003*. *GEO Year Book 2004/5,* the second issue in the GEO annual series, was released in February 2005. At sub-global level, the GEO process has been replicated to undertake many regional, sub-regional, national and sub-national assessments. Major publications are produced in the official United Nations languages of Arabic, Chinese, English, French, Russian and Spanish in printed and electronic formats to broaden access for users. The GEO process has also produced technical reports, manuals and GEO educational materials, the GEO Data Portal, meeting reports, capacity building materials and associated products responding to specific user needs (see http://www.unep.org/geo/).

C. GEO Assessment: Objectives

GEO aims to ensure that environmental problems and emerging issues of wide international significance receive appropriate, adequate and timely consideration by governments and other stakeholders.

The overarching objectives of GEO are:

(a) Providing access to the best scientific knowledge for international environmental governance and the mainstreaming of environmental concerns into social and economic sectors, and in support of internationally agreed environment goals

(b) Facilitating the interaction between science and policy through multi-scaled and multi-dimensional integrated assessment process and products of high legitimacy, credibility and utility

(c) Building geographic and gender-balanced partnerships and capacity for environmental assessments.

[2] GC19/3; GC20/1; GC22/1/IB; GC23/6

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Acknowledgment: "This material is based upon work supported by the Department of Energy under Award Number DE-FE0003060."