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BULGARIAN NATIONAL PROGRAM FOR GAS HYDRATES RESEARCH

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ABSTRACT
Results present model estimations of the Black Sea MHs and Draft of Bulgarian National Program for GHs on the base of the US National MH Multi-Year R&D Program Plan from 1999.
MHs represent an enormous gas resource. The estimate of 20.10^6 km^3 worldwide is many times the estimated oil and gas. For the Bulgaria, resources are estimated in the range 1-10.10^3 km^3. In the same time we are dependent on imports for 70% of energy supplies. In 2000, total oil and gas production and consumption in equivalent natural gas are 0.06 and 12.14 km^3. If the production of methane is economically viable, a long-term energy security for centuries would be ensured, and environmental quality would be improved.
The Program must coordinate research to: (1) estimate GH resources; (2) obtain/develop technology for production of methane from hydrates; (3) understand the roles of hydrates in the global carbon cycle and global climate change; and (4) respond to industry for safety and sea floor stability, currently associated with the exploration, production, and transportation of conventional hydrocarbons. The Program is framed as four technology areas which will share data, concepts, and results.

INTRODUCTION

In the 1950s, Arthur C. Clarke wrote a novel in which energy was harvested deep in the Gulf of Mexico by submarines. Today fantastic became reality. One strange methane source – gas hydratess (GHs) - is most interesting object in the field of geo-sciences. And most money are spent for their research. Because clathrates – other name for these geological phenomena – are not only interesting, but in close dependence to humanity fate: its economical prospect and environmental conditions. But even between geo-scientists could found specialists, which haven't heard of them. What to say about wide public, state and private companies' managers, teachers, students and professors, inventors, ministries? After 20 years, all they and we will use, know, work and take in account GHs. The place between developed and developing countries; the prosperity of a nation and quality of life will be determined from our knowledges, skill and technologies to research and develop them. Or not?

Only a NPGH Research and Development (RD) will allow a country to follow right direction – the direction of prosperity. US, Great Britain, Germany, France, Japan (from 1995 5-years program for over $50 millions; now – second 5-years plan) and India started their programs. Some of them include as one of most perspective regions the Black Sea. More than dozen European scientific projects are carried out or plan expeditions for GHs research here.

As a result of this analysis the author develop proposal for creation draft NPGHRD in the frame of EC funded project "Centre for Sustainable Development and Management of the Black Sea Region" (CESUM-BS - ICA1-1999-70075).

GHs History

GHs have been discovered experimentally in 1811 by Sir Humphry Davy (chlorine bubbling in cold fresh water). Later (1832) Michael Faraday has established first chemical formula of GHs. In 1934 the phenomenon of pipeline blockage by hydrates was described in the USA by Hammerschmidt. In 1948 Strizhov has published assumption about GHs spreading in permafrost areas. In 1959 van der Waals and Platteeuw have published first fundamental thermodynamic description of GH phase. In 1970 a group of Soviet researchers initiated by Yuriy Makogon has registered the discovery of the possibility of GHs existence in the Earth crust. In 1972 natural GHs for the first time have been recovered in the Black Sea (Yefremova, Dgidgenko, 1974).

What is MH?

Methane hydrates (MHs) are type of natural formation that contains water and large amounts of methane, in the form of ice. From a scientist's point of view, MHs are crystalline solids that form under moderate pressure (for the Black Sea pure MHs exist at water depths greater than 500 meters) and at temperatures above the freezing point of water.

Why is it important to study MHs?

Hydrates are potential future energy resource; factor for climate change (a source and a sink for atmospheric CH_4); seafloor areas with hydrates are less stable; hydrates cause blocking in underwater gas pipelines; could be used to increase the volumes of gas in storage; they are markers for oil deposits; may be an alternative to pipeline as a way to move gas; could be used to patch leaks in underwater pipelines; might be used as a vehicular fuel, especially for ships or to drive machinery without affecting the energy content of the gas…

How much hydrate is there?

There is no definitive answer to this question at this time. However, the worldwide amount of carbon bound in GHs is estimated to total twice the amount of carbon to be found in all known fossil fuels on Earth and measured in petatons (10^{15} tons). Theoretically, one volume of pure MH should yield about 164 volumes of methane and 0.8 volumes of water. In nature, it is more typical to get 158 or so volumes.

'Gasbergs': How do we study them?

Drilling and submarines are best, but expensive. Seismic is most popular. The contrasts in velocity created by the hydrate-cemented zone produces a strong reflection called BSR "bottom simulating reflection". "Blanking" is the reduction of the amplitude of seismic reflections that is caused by cementation by hydrate of the strata. The blanking can be quantified to estimate the amount of GH.

Questions

To understand the role of the Black Sea GHs must be found answer of many questions: When do MHs appear in the Black Sea? What is their evolution? Where to look for relict MHs? Is it possible to reconstruct a "frozen" geological history of the basin by analyzing their structure? What is their role in the carbon budget, hydrocarbon migration, sea bottom relief origin and contribution to the atmospheric greenhouse gases?

SUMMARY OF PROPOSAL FOR NPGHRD CREATION

Problem Description

Absence of information even in academic environment and eco-journalists about the nature of the gas GH and their importance. Absence of an evaluation for the GH deposits and their distribution area in the Bulgarian Black Sea part. And as a result - absence of a NPGHRD - foundation for significant social, structural, technological and economical progress.

Target Groups and Beneficiaries

- The Bg population (20%) and the civilian organisations (20%) and mainly from the beach districts (aims: eco-education and culture (EEC); civilian activity (CA));
- Representatives of the municipality, district and state administration (30 - 100) (aims: effectively utilization of nature resources (EUNR); improvement of the environment (EE); EEC; CA; structural and social changes planing (SSCP));
- Business Leaders (EEC; CA; SSCP);
- Academic environments and eco-journalists - (professional qualification; alternative energy and raw material sources research).

Project Goals and Objectives

- Foundation of a NP, which to be proposed to the Ministry of Environment and Water. Its approval and realization would secure a durable ecological, social, economical and re-structural effect for gradually increased parts of population and varied organizations.
- The program is a base for introducing an ecological alternative energy and raw material resource) and stable growth of new and restructuring organizations and revealing of new positions for various high skilled specialists;
- Execution of the Frame Convention of OON about global climate change (1995) and the Convention for public participation in the process of decision making (1998);

Project Activities

- Identification / Inventory / Archives creation / Inquiry
- Model quantitative predictions / Results acquaint / Public discussion
- Draft program / Social discussion / Standartization
- Working out project report

1. Identification / Inventory / Archives creation / Inquiry

- Creation of project library - sources inventory: bibliographical, data bases, video tapes, Internet resources (on the whole 3 months (m); will grow and after the project);
- Creation of data base with the addresses of interested persons and organizations (parliament commissions, ministries, state and private organizations, media - press, TV) - "participants" (on the whole 1.5 m);
- Carry out an inquiry to find out concepts of participants about the content of such NP. Analysis publication of results in Internet for discussion enrich (on the whole 1.5 m)

2. Model quantitative predictions / Results acquaint / Public discussion

- Developing mathematical model for GH reserves prediction and data base with the necessary input information (6 m);
- Programming, tests, numerical experiments and graphical visualization of the results. Model accuracy estimation through re-interpretation of seismic records (on the whole 12 m);
- Building up academic report:"Model Estimation of GH reserves and distribution in the Bulgarian Black Sea Part", 20 copies preparing and sending to participants (2.5 m); report publication in Internet (0.5 m);
- Design, printing (500 - 1,000 copies) and distribution of a booklet (A4, 2 sided, color) with general results, Internet links and addresses for opinions and discussions (3 m).

3. Draft program / Social discussion / Standartization

- Study of the existing programs and creation draft NP GH (1st edition) through compilation and render an account of collected information. Copies preparation, sending; Internet page; discussion, analysis (2 m);
- Creation draft NP GH (2nd edition); copies; sending; Internet; discussion, analysis (2 m);
- Organize and carry out a work meeting for creation NP GH (3rd edition) with presence of representatives of applicants and media. Copies; sending; Internet publication (2 m)

Expected Results

Social Heighten civil knowledge for local and global factors determined the environmental quality; heighten the ability to affect; cultivate tolerance between social groups and organizations; heighten civil responsibility of the municipality and ministry administration; stimulate the dialog citizenship - NGO - academic sphere - media - authority; overcome apathy and desire for anonymous of participants and heighten their citizen activity.

Intellectual Product Project library; published materials; GH model and results; Draft Bg NPGH in the Black Sea.

ESTIMATION OF BULGARIAN BLACK SEA GHs

4D model of the MHSZ in the Black Sea during the Quaternary realized a simplified paleo-climate, focusing on the abrupt temperature and sea level changes. Major model advantages are the long period (allowed correct initial thermal conditions setting), detail 1' calculation and bottom depths grid (for better relief effect accounting), reinterpreted data from heat flow measurements (for possible hydrate existence), non-stationary processes equation accounting the heat of hydrates creation and dissociation.

The data are processed by applying different parameters depending of the geology and tectonic evolution of the area; sedimentation rates; submarine fans and canyons; and evidences of gas seepages, pockmarks and mud volcanoes. The equations governing the MH stability curve are also conformable to Hydrogen Sulphide content and salinity of the bottom and pore waters.

The estimations are based on the two main theories of GH formation - in situ bacterial production and pore fluid expulsion models. The implications of these models on atmospheric methane release or massive slumping and liquefaction, are briefly examined.

Models (Vassilev, Dimitrov, 2000;2002; 2003; Dimitrov, Vassilev, 2002; Poort, Vassilev, Dimitrov, 2002) predict the volume of MH stability zone (MHSZ) in the Black Sea of about 100,000 km^3, or 77-350 km^3 pure MHs with 10-50.10^3 km^3 of gas Methane. This amount seems to be too high, even the total Black Sea resources of conventional hydrocarbons are in magnitude lower - about 3.5.10^3 km^3.

The equilibrium model for the Last Glacial Maximum (LGM) suggests a drastic reduction of the reservoir volume (15-62%) since the LGM. Taking into account the process of climatic heat wave propagation in the sediments, the model predicts a present MHSZ enlarging in the frame of method accuracy. However, the temperatures at depth of 200 and 500 m under the bottom will reach 90 % of the temperature equilibrium 200 to 1,000 Ky after LGM and we must run models for longer time periods.

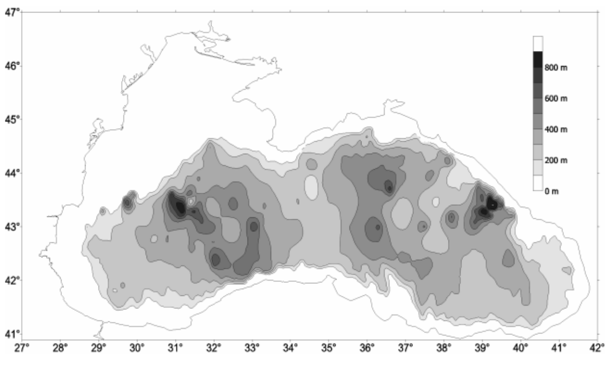

Figure. 1. The Black Sea hydrate stability zone thickness (m) calculated with in situ *measured temperature gradients*

Bulgarian natural gas consumption

In May 2001, Bulgaria signed a 25-year concession agreement with Patreco of the United Kingdom for exploration and extraction of natural gas. The area covered by the agreement is Bulgaria's sector of the Black Sea, including the Galata deposit which has estimated reserves of 53 Bcf. Beginning with 2002, Patreco plans to extract 14 Bcf of gas per year.

But Bulgaria is dependent on imports for 70% of its energy supplies. With virtually no supplies of oil and small reserves of gas, Bulgaria has had to pay for energy in hard currency at world market prices, resulting in less reliable supplies.
In 2000, oil production was 1,000 barrels per day (b/d) (159 m3 – 58,000 m3/y – 0.057 km3/y gas) and 0 gas, Petroleum consumption in Bulgaria in 2000, was 117,000 b/d (or equivalent gas – 6.64 km3/y) and gas 0.193 Tcf (5.5 km3/y).

So, in 2000, total oil and gas production and consumption in equivalent natural gas are 0.06 and 12.14 km^3. If the production of methane is economically viable, a long-term energy security for centuries would be ensured, and environmental quality would be improved.

DRAFT NPGHRD – 1ST EDITION

The author offer as first Bulgarian NPGHRD to be used the US National MHs Multi-Year R&D Program Plan from 1999 as most detail and logically linked. It would be edited taking in account Bulgarian peculiarities.

The US Plan illustrates how technology is expected to proceed to achieve Program goals. The Federal role provides for the coordination, integration, and synthesis of research efforts to:
(1) estimate gas resources from MHs;
(2) develop the technology for commercial production of methane;
(3) understand the dual roles of MHs in the global carbon cycle and their relationship to global climate change; and
(4) respond to industry concerns the safety, seafloor stability and pipeline plugging which are currently associated with the exploration, production, and transportation of conventional hydrocarbons.

The R&D Program is framed as four technology areas which will share data, theoretical concepts, and results.

The position of the President's Committee of Advisors on Science and Technology (PCAST) in its 1997 *Report on Energy Research and Development for the Challenges of the Twenty-First Century* was that MHs were not being addressed adequately in Office of Fossil Energy (FE), or in other Department of Energy (DOE) R&D programs, and that more emphasis through applicable R&D was needed.

The PCAST suggested first-year funding of $5 million, rising to $12 million in the fifth year. The current consensus of DOE is that a MH R&D program of $150 to $200 million over a ten-year period will be needed to accomplish mission goals.

The relative level of effort in the four technology areas and their changes are depicted in Fig. 2.

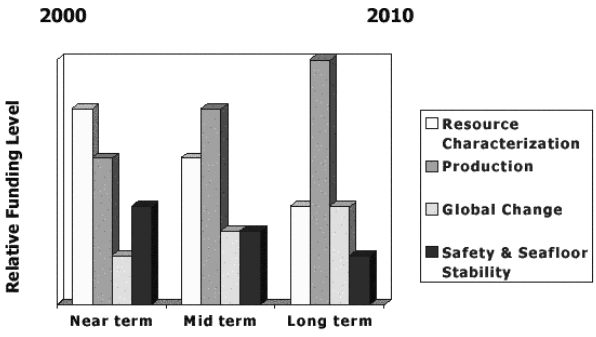

Figure 1 – R & D Funding Evolution

Figure. 2. R & D Funding by technology areas

Near-Term Benefits/Products (Within 5 Years)

- Assessment of the location and volume of MH resources for use in energy policy decision making;
- Techniques to mitigate methane hydrate formation in pipelines and production facilities offshore;
- Improved seismic and other geophysical tools for hydrates identification and characterization for use by the petroleum industry, military, etc.;
- Engineering concepts for production of gas from natural GH deposits;
- Databases containing ocean and atmospheric changes and coupling, for use in global climate modeling, including thermodynamic data applicable to CO_2 sequestration; and
- P-T-controlled sampling devices (which could be a prototype for NASA samplers).

Mid-Term Benefits/Products (5 to 10 Years)

- Improved estimates of recovery potential from the natural GH useful in guiding energy policy and planning;
- Advanced techniques to detect and analyze formation and reservoir systems;
- New or advanced production technologies, including tests of engineering concepts, for production of natural gas.

Long-Term Benefits/Products (10 to 15 Years)

Long-term, the Program will lead to an increased supply of cleaner fuel through development of technologies for commercial production of methane from marine hydrates, based on field testing and verification of improved geophysical technologies, production concepts, and reservoir model development for natural GH recovery.

PLAN-PROGRAM ELEMENTS

Resource Characterization

This key activity will involve the data compilation, field and laboratory studies, and model development necessary to understand and measure natural GH deposits and to assess the methane resource. This work will provide information to all program areas: resource characterization, production, sea floor stability, and environmental issues.

Table 1. Resource Characterization

RESOURCE CHARACTERIZATION

Activities & Sub-elements	**Y00**	**Y01**	**Y02**	**Y03**	**Y04**	**Y05**	**Y06**	**Y07**	**Y08**	**Y09**
Resource Assessm. (Near-Term)										
Historic / Bibliographic / Contractor Information										
Geologic Information										
Physical Property Information										
Location Map										
Laboratory Studies										
Hydrate Analysis										
Crystallography Studies										
Pore Water Chemistry										
Biochemistry and Natural Gas Hydrates										
Temporal History Studies										
Geo-Strata Water Movement and Behavior										
Thermodynamic Studies in Porous Media										
Kinetic Studies										
CO2 Hydrate Study Results Integration										
Field Geophysical, Geochem., & Microbial Studies										
Seismic Interpretation										
Well Logging										
Geophysical										
Geochemical										
Microbial Processes										
Novel Well-logging Techniques										
Model Hydrate Properties										
Physical / Chemical Properties										
Geological Modeling										
Geophysical Modeling										
Resource / Reserve Assessm. (Mid-Term)										
Reservoir Natural Gas Quality										
Reservoir Natural Gas Quantity										
Associated Free Gas										
Multi-disciplinary Interaction										
Economic Validation (Long-Term)										
Production Cost Estimates										
Impact of Resource Development Economics										
Field Validation										
Technology Development										
Development of Seismic, Sonar, & Well-Logging Technologies										
Develop P-T Controlled Coring										
Dev. of Monitoring Sensors and Samplers for Subsea Hydrates										

Production

The goal is to develop the knowledge and technology necessary for commercial production of methane from oceanic hydrate systems.

Specifically, the Program will:

- Develop a basic information necessary for production;
- Conduct reservoir and process engineering and economic analysis;
- Develop and test conventional recovery technologies and evaluate alternative recovery technologies.

Table 2. Production

PRODUCTION

Activities and Sub-elements	**Y00**	**Y01**	**Y02**	**Y03**	**Y04**	**Y05**	**Y06**	**Y07**	**Y08**	**Y09**
Primary Production Research (Near-Term)										
On-Line Production Database										
Sample Characterization & Ident. of Technology Gaps										
Obtain Input and Update with Drilling/Program Results										
Physical Process Modeling										
Sample Review and Lab Measurements										
Develop Production Models										
Preliminary Reservoir Engineering										
Onshore Site Selection & Test Design										
Offshore Site Selection & Drilling Criteria Specification										
Preliminary Production Modeling and Demo. Design										
Analyze Prior/Collaborative Production Test Results										
Prelim. Pilot Facility Development										
Preliminary Commercial & Alternative Methods Evaluation										
State-of-the-Art and Innov. Prod. Methods Evaluation										
Drill Exploratory Onshore Well										
Reservoir Simulation and Process Design (Mid-Term)										
Reservoir Engineering										
Select Offshore Sites										
Develop Field Test Reservoir Model										
Pilot Reservoir Studies for Model Verification										
Commercial/Alternative Process Design										
Develop Downhole Instrumentation for Logging Deposits										
Establish Alternative Production Technology										
Preliminary Economic Analysis										
Prod. Testing: Demo. Well & Alt. Prod. Evaluation (Long-Term)										
Process Model Validation										
Calibrate Model with Field Results										
Predict Demonstration Well Results										
Evaluation of Commercial Potential of Demo. Well Sites										
Drill Sampling Wells to Evaluate Potential Demo. Sites										
Tech. and Economic Analyses of Potential Demo. Wells										
Demonstration Well Site Selection Assistance										
Support for Industry Demonstration Well										
Demonstration Production Analysis										
Evaluate Program Accomplishments										
Select Novel Technology Facility Fabricator										
Tech. and Economic Analysis of Industry Demo. Well										
Final Calibration of Production Model										

Global Carbon Cycle

Releases of methane from hydrates add to the atmospheric carbon budget, either as methane, or indirectly as carbon dioxide through chemical/biological oxidation.

Utilization of this resource would provide additional low-carbon fuels - part of a strategy for reducing atmospheric anthropogenic greenhouse gases. This activity seeks to understand and quantify the dual roles of hydrates in the global carbon cycle and their relationship to global climate change.

Table 3. Global carbon cycle

GLOBAL CARBON CYCLE

Activities and Sub-elements	**Y00**	**Y01**	**Y02**	**Y03**	**Y04**	**Y05**	**Y06**	**Y07**	**Y08**	**Y09**
Mechanisms and Processes of Hydrate Flux (Near- to Mid-term)										
Evaluation of Dispersed Hydrates										
Site Monitoring										
Measurement and Protocol Development										
Impact of Climate Change on Hydrate Stability										
Seafloor Stability and Release of Trapped Free Gas										
Consequences of Methane Release from Hydrates (Mid- to Long-Term)										
Ocean/Atmospheric Studies										
Biological Studies										
Application to Ocean and Climate Models										
Methane Release in the Geologic Record (Near- to Mid-Term)										
Compilation of Existing Data										
Development of New Proxies										
Application to Ocean and Climate Models										
Integrated Model Development (Long-Term)										
Use Modern and Geologic Data in Ocean and Climate Models										
Greenhouse Gas Mitigation (Near- and Long-Term)										
Environmental Benefits and Impacts										
CO_2 Storage Options										

Safety and Sea Floor Stability

This activity will be co-developed and integrated with the Resource Characterization effort.

Early emphasis will be focused on near-term solutions of both safety and sea floor stability, due to natural GH occurrence associated with the exploration, production, and transportation of conventional hydrocarbons.

These preliminary models will be upgraded in the mid-term to incorporate subsurface hydrate data obtained from early stage hydrate production modeling efforts.

Findings will be documented in a report on Advanced Mitigation Recommendations, which would conclude the Government's principal research effort to define safety and sea floor stability problems and offer practical solutions (if possible, offering low-cost problem recognition/avoidance solutions.)

Field demonstration and testing of both safety and sea floor stability mitigation technology is envisioned as a cooperative/co-funded effort with the oil and gas industry.

Possible and unpredictable future trends in global warming effects, that could exacerbate safety and/or sea floor stability due to hydrate dissociation, will be monitored and activities adjusted accordingly.

Table 4. Safety and sea floor stability

SAFETY AND SEA FLOOR STABILITY

Activities and Sub-elements	Y00	Y01	Y02	Y03	Y04	Y05	Y06	Y07	Y08	Y09
Basic Research in Safety and Seafloor Stability (Near-Term)	Изследване Високо ниво			Изследване Ниско ниво						
Safety/Risk Factor Research										
Devel. Database of Safety Issues/Incidents										
Devel. Preliminary Models and Predictive Tools										
Devel. Preliminary Mitigation Recommendations										
Seafloor Stability Research	Изследване Високо ниво			Изследване Ниско ниво						
Geological/Geophysical Studies										
Integrate Studies (w/Resource Characterization in 1)										
Develop Prelim. Seafloor Stability Models										
Advanced Safety & Seafloor Stability Model. Devel. (Mid-Term)										
Gas Hydrates Safety/Risk Factor Research Model Devel.										
Develop Advanced Seafloor Stability Models										
Develop Advanced Mitigation Recommendations										
Development & Field Demon./Testing of Safety and Seafloor Stabilty Mitigation Techniques (Long-Term)										
Development of Seafloor Safety Technology										
Field Testing of Safety Technology										
Development of Seafloor Stability Mitigation Tech.										

END OR START?

Look for additional information at http://www.io-bas.bg/gh/

Please, send ANY files to A. Vassilev at gasberg@io-bas.bg:

- Opinions, advices, web links
- Your new or edited parts of the National Program
- CVs of persons or organizations, etc.

Please, send post materials to:
Dr. Atanas Vassilev, IO-BAS, PO Box 152, Varna 9000

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