Implementation Plan for Phase 2

July 8, 2009

Research Consortium for Methane Hydrate Resources in Japan
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(Reference) Review of Exploitation Program and Challenges for Phase 2
1 Research Background

1.1 Recent Energy Situation

Japan depends on imports from overseas for more than 80% of the primary energy the country uses, which is mostly fossil fuels such as crude oil, natural gas and coal. It is also characteristic that Japan is highly dependent on crude oil from the Middle East and natural gas from Asia and the Pacific area. Under these circumstances, from the viewpoint of securing stable energy supplies, it is a pressing issue for Japan to explore diversified supply sources as well as to improve the ratio of energy procured through independent exploitation efforts. In particular, as natural gas is a clean energy source compared to crude oil or coal, with low emissions of CO\textsubscript{2} and sulfur oxides, there are plans to actively accelerate its introduction in Japan. However, demands for natural gas are increasing worldwide with countries such as India showing the greatest growth in consumption, inviting steeper competition among procurers.

In this situation, considerable amounts of methane hydrate – an unconventional natural gas resource - are estimated to exist off the coast of Japan. When methane hydrate production technology is established and commercialization is realized, it is expected to become a new domestic energy source that will significantly contribute to the securing of stable supplies of energy for Japan.

1.2 Japan's Initiatives toward Methane Hydrate Research

In view of the significance of methane hydrate production technology in the energy policy as described above, the METI announced the "Japan's Methane Hydrate R&D Program" in FY 2001. This is an 18-year plan to be completed in FY 2018 (initially planned as a 16-year plan to be completed in FY 2016 but revised at the time of Interim appraisal in FY 2008). The basic policy for the plan is to "Methane hydrate, of which there is expected to be substantial amounts offshore Japan, is positioned as a future energy resource, and impelling technological developments into drilling, production and recovery of methane hydrate on an economical basis for future utilization will contribute to the acquisition of a long-term steady supply of energy." and the step-by-step objectives presented include the following six items:

(1) Clarification of MH occurrences and characteristics offshore Japan
(2) Assessment of methane gas amounts trapped in promising offshore methane hydrate bearing zones.
(3) Selection of methane hydrate resource fields from promising offshore methane hydrate bearing zones and deliberation of economic potential.
(4) Implementation of production tests in the selected methane hydrate resource fields.
(5) Improvement of technologies for the commercial production.
(6) Establishment of a development system complying with environment.

This program proposes a three-phase approach for accomplishing the above objectives. The eight years from FY 2001 to 2008 is Phase 1 to accomplish goals 1 to 3 above, followed by Phase 2, seven years from FY 2009 to 2015, to accomplish goal 4.

After that program was developed, public interest in methane hydrate as a future domestic energy source grew, and an April 2005 cabinet decision included reference to the promotion of methane hydrate-related technological development to be included in the plan for achieving Japan's Kyoto Protocol targets. Furthermore, the Basic Energy Plan established in a March 2007 cabinet decision and the Basic Plan on Ocean Policy established in a March 2008 cabinet decision included reference to efforts toward commercialization of methane hydrate. In addition to methane hydrate, for petroleum and natural gas resources and seafloor hydrothermal deposits, the Offshore Energy and Mineral Resources Development Plan was established in March 2009 under the Basic Plan on Ocean Policy.

1.3 Other countries' Initiatives toward Methane Hydrate Research

As a prospective future energy resource, some countries other than Japan have already initiated research and development of methane hydrate. The following describes major trends.

<The United States of America>
The Department of Energy (DOE) released "An Interagency Road Map for Methane Hydrate Research and Development" in 2006 for methane hydrate research to implement researches under the research system incorporating the DOE and other government organizations and the industrial world. Onshore in Alaska, methane hydrate research wells were drilled in 2007, and a long-term production test is being
considered for the future. Also in 2009, methane hydrate research wells were drilled in the Gulf of Mexico, which led to confirmation of the presence of pore filling type methane hydrate bearing sediment during geophysical logging.

<India>
The Ministry of Petroleum and Natural Gas released the "Natural Gas Hydrate Program" in 1997. The Directorate General of Hydrocarbons acted as the driving force for promoting the program. In 2006, they drilled 39 methane hydrate exploration wells off the coast of India and confirmed the presence of methane hydrate.

<South Korea>
In 2005, the Gas Hydrate R&D Organization was founded under the Gas Hydrate Development Project, in which the Industry and Energy of the Ministry of Commerce, KNOC, KOGAS and KIGAM jointed. In 2007, they found methane hydrate in the Sea of Japan.

<China>
The “10th Five-year Plan” in 2001 and the “11th Five-year Plan” in 2006 included implementation of methane hydrate investigations. In 2007, they discovered methane hydrate in the northern part of the South China Sea. In 2009, the research into methane hydrate in the South China Sea was included in the “973 Program” (the "National Program on Key Basic Research Project")
2 Accomplishments of Phase 1

2.1 Overview of Phase 1

In order to implement Phase 1 of the "Japan's Methane Hydrate R&D Program" developed in July 2001 by METI, the Agency of Natural Resources and Energy consigned the duties to three entities: the Japan Oil, Gas and Metals National Corporation, National Institute of Advanced Industrial Science and Technology and the Engineering Advancement Association of Japan, which organized Research Consortium for Methane Hydrate Resources in Japan (or MH21 Research Consortium) under the leadership of Professor Emeritus Shoichi Tanaka, University of Tokyo, acting as the project leader.

The "Japan's Methane Hydrate Exploitation Program" describes five areas (exploration, modeling, field production test, development and environment) of technological development required for accomplishing the six goals. The outline of the outcome of Phase 1 research is as follows.

<Exploration Section>
Using the Eastern Nankai Trough area as a model sea area, detailed surveys were conducted through MITI seismic surveys and MITI exploratory test well drilling. As a result, it has been found that methane hydrate in the eastern Nankai Trough area is mostly of the same type as that trapped in the sand layer within turbidite sequence and that methane hydrate concentrated zones are distributed. Also, a technique has been established to delineate a methane hydrate concentrated zone based on the seismic data. Thus, the original methane hydrate gas in place within the eastern Nankai Trough area has been evaluated with the probabilistic approach. Furthermore, concerning the 16 methane hydrate concentrated zones in the eastern Nankai Trough area, the original gas in place, reservoir characteristics and seafloor conditions were examined among other things to pick out three locations as candidate areas for offshore production tests.

In the areas off the coast of Japan other than the eastern Nankai Trough, the BSR (Bottom Simulating Reflector) distribution was reviewed based on existing seismic data, referring to the findings obtained from the eastern Nankai Trough.

<Modeling Section>
A mainframe production simulator (MH21-HYDRES) was developed, which can analyze
the performance of various production methods including the depressurization, thermal simulation method, and combine methods under the given conditions such as the temperature and pressure of the methane hydrate reservoirs. And by using a fundamental technology developed for testing the physical properties and dissociation behaviours of methane hydrate sediment under the in-situ conditions of the target methane hydrate resources, the reservoir characteristics of the eastern Nankai Trough area were evaluated.

Based on analyses of optimal production methods using the MH21-HYDRES it was cleared that the depressurization method was effective as a main method for production at the eastern Nankai Trough area. The advantage of depressurization method was verified through the second onshore gas production test, for which the test results were very similar to the prediction (predicted gas and water outputs, etc) from the production simulator.

<Field Production Test>
In order to verify the production method in the field, MH21 conducted the production test twice on methane hydrate trapped in the sand layer beneath the permafrost zone in the Canadian part of the arctic circle.

The First Onshore Gas Hydrate Production test conducted in March 2002 yielded methane gas from a methane hydrate-bearing layer for the first time in the world, using the "hot water circulation method" (the production period: five days, cumulative output: 470 m³). However, some issues were left to be solved later from the viewpoint of the recovery method, including issues of energy efficiency and production continuity. In addition, gas emergence was confirmed by monitoring the process of depressurization by the MDT. It was also found that the methane hydrate-bearing layer has permeability as a result of pressure analysis, etc.

After that, in the Second Onshore Gas Hydrate Production Test conducted in March 2008 (the second year), MH21 succeeded in continuous production of methane gas "by the depressurization method" for the first time in the world (the production period: six days, cumulative output: 13,000 m³), proving that the depressurization method does work as the production method. For this production test, MH21 installed sand screens to reduce sand production.

<Development Section>
Considering the results from the METI Exploratory Test Wells "Tokai-oki to Kumano-nada" and onshore gas hydrate production tests, MH21 examined the concept for the well-drilling plan aimed at offshore production tests. Through such examination, MH21 extracted technical issues to be solved toward the implementation of offshore production tests in Phase 2 (such as cementing and well completion in deep-water shallow formation zones, establishment of a downhole system subject to the implementation of the depressurization method with consideration of emergency disconnect case, etc.)

Also, MH21 conducted studies from the economic viewpoint using the production simulator and the economic evaluation program on the methane hydrate resource field selected in the eastern Nankai Trough area. These studies have indicated possibility of economic feasibility to be realized through studies continued into the future. Also, MH21 extracted technical issues from the viewpoint of improvement of economic performance (such as higher productivity, improved recovery rate, etc.)

<Environment Section>
MH21 conducted collection and compilation of basic information required for predicting environmental impact in methane hydrate exploitation as well as studies on technology elements.
MH21 conducted environmental investigation of the sea area for grasping basic information concerning the sea area hosting methane hydrate resources and studied the ground properties of the sedimentary layers beneath the seafloor by using core samples from an MITI exploratory test well. Furthermore, MH21 extracted environmental factors to be given particular considerations in methane hydrate exploitation, that is, methane leakage and ground deformation, created a model for predicting their behavior and developed sensors that would enable real-time monitoring of offshore production tests.

2.2 Project Evaluation
In FY 2005 and FY 2008, project evaluation was conducted by external well-informed individuals according to the METI guidelines for technical evaluation. In the evaluation given in FY 2008, at the end of Phase 1, it was recommended to proceed to Phase 2. The following summarizes major opinions and suggestions given in the FY 2008 project
evaluation.

<Major Opinions>
- This project is in line with the national energy policy, greenhouse gas reduction policy and ocean policy, and also helps satisfy the needs of the people from the viewpoint of securing of energy resources, attracting great interest and expectation. As for the accomplishment of the researches in Phase 1, the goals were virtually fully accomplished through extension of the period and other flexible efforts, which is to be highly appreciated.

- While certain achievements have been brought about in Phase 1, the project has not yet reached at a level where the private sector may consider participation with further technical or scientific challenges yet to be solved before commercialization, including the need for additional technological development and application and development of existing technologies. Therefore, it is appropriate to promote this research and development project under the initiatives of the state.

- As the goals of Phase 1 have been mostly accomplished as the research outcome has shown, it is appropriate to proceed to Phase 2. Note that it is difficult to evaluate the validity of commercialization at the present stage when the basic research is completed. It will be premature until MH21 sees the outcome of Phase 2.

<Recommendations>
- In offshore production tests in Phase 2, first of all, it is necessary to obtain adequate measurement data concerning the impact on the surrounding sediment layers as well as the maximum production ratio of a single well.

- In the future, it is important to cooperate with organizations and advanced companies around the world to facilitate efficient progress of the project. In order to facilitate international cooperation, MH21 needs to develop a basic strategy through reconfirmation of what resources (technology and funds) Japan has as well as understanding of its partners’ capacities and positions.

- In the future, MH21 will definitely be faced with an increasing number of practical challenges as the project is further directed toward goals such as verification and commercialization and grows in scale. It will be necessary to clarify and/or
redesign the targets in a flexible manner while fully examining results obtained step by step. In particular, it is desirable to clearly set out the goals of offshore production tests in conjunction with case studies by simulation.

- In the future research and development project, MH21 needs to prepare itself by extensively mobilizing engineers and other staff members from a broader range of areas. Also, it is important for the organizations responsible for the implementation of the national project to conduct detailed studies concerning environmental measures as well as to assume due accountability toward the public.

- Efforts should be made to bring about added effect by incorporating a broad range of related technologies, besides technologies specific to the area of oil and natural gas.

- Efforts are called for clear indication of unique classification and definitions according to the characteristics of hydrate, and for presenting such definitions as the world standards. Understanding among the general public and parties concerned is likely to be deepened along with clear representation of this development effort as a project focused on methane hydrate that has the highest potential for successful exploitation (within the country) among the categories under such classification.

- In order to move toward commercialization, it is necessary to encourage active participation of private oil and gas development companies with operating experiences and technologies.

### 2.3 Future Challenges based on Accomplishment of Phase 1

While the accomplishment described above has been obtained from the studies carried out in Phase 1, there are a number of technical issues to be solved before realization of future commercial production.

1. Evaluation of methane hydrate distribution in areas other than the eastern Nankai Trough

In Phase 1, MH21 grasped the state of methane hydrate occurrences in the eastern Nankai Trough area and established technologies, among other things,
for identifying methane hydrate concentrated zones. Based on the findings from
the assessment of the resource amounts in the eastern Nankai Trough, MH21
needs to expand the target area to areas off the coast of Japan other than the
eastern Nankai Trough to proceed with estimation of distribution of methane
hydrate concentrated zones.

(2) Implementation of longer-term production tests
While MH21 succeeded in continuous production of methane gas from methane
hydrate-bearing layers by the depressurization method in the onshore production
tests in Canada, the duration was for six days. Therefore, longer-term production
tests are needed to further verify issues related to long-term productivity of
methane gas production from methane hydrate-bearing layers as well as its
production behavior, production damages, etc.

(3) Implementation of offshore production tests
Japan can only find domestic methane hydrate resources off the coast of Japan.
Thus, it is essential to develop technologies that enable safe and economical
production of methane gas from methane hydrate-bearing layers, which
necessitates offshore production tests. As these tests should be conducted in
deep-water shallow formation zones, it is necessary to address technical issues
involved and develop preliminary environmental impact assessment and then to
prepare test planning to ensure safe implementation of the plan. Also, MH21
needs to verify gas recovery methods and production methods focused on
methane hydrate-bearing layers off the coast of Japan and extract technical
challenges.

(4) Investigation of advanced production methods and optimization of the
development system
In addition to field production tests, in order to produce/recover methane gas from
methane hydrate-bearing layers in economical manners, efforts for ensuring
ultimate cost-effectiveness are needed toward technological sophistication that
enables efficient production. For this purpose, MH21 needs to develop recovery
and production methods for improvement of productivity and recovery rate of
methane gas as well as examination of drilling/development systems for higher
cost-effectiveness.
(5) Grasping of environmental impact and establishment of the assessment method

While environmental impact is likely to arise from methane leakage, seafloor instability including landslides, etc., specific environmental assessment methods are yet to be established. On the other hand, Phase 1 has yielded geological findings concerning methane hydrate concentrated zones along with a direction of studies for production methods. Thus, it is now possible to investigate specific risks concerning environmental assessment accompanying hydrate resource development. For that purpose, it is necessary to study issues including extraction of environmental risks in offshore production tests, identification of characteristics and countermeasures. Also, MH21 needs to obtain data concerning seafloor environment required for such studies and to grasp environmental impact through actual monitoring of environmental impact as well as to establish the method of environmental assessment, looking to realize commercial production.
3 Overview of Phase 2

3.1 Approach for Phase 2

In Phase 1, as a result of the detailed investigation of the model sea area of the eastern Nankai Trough, MH21 has located the methane hydrate concentrated zones with a high saturation of methane hydrate deposited in pore spaces of sand layers in alternation of sand and mud, and figured out the amounts of original methane gas in place in the methane hydrate-bearing layers in that sea area. Furthermore, MH21 has confirmed through laboratory experiments and simulation that the depressurization method works well as the optimal production method for the methane hydrate-bearing layers in the eastern Nankai Trough, and also verified the validity of the method through onshore gas hydrate production tests. These results indicate the potential of methane gas in methane hydrate-bearing layers off the coast of Japan to become energy resources.

In Phase 2, recognizing the technical issues identified at the end of Phase 1, MH21 will evaluate the potential of methane gas in methane hydrate-bearing layers as an energy resource with higher reliability through research and development efforts including offshore production tests off the coast of Japan while extracting technical issues required to be addressed required for development of technologies to enable commercial development of the methane hydrate-bearing layers. Additionally, production tests may be implemented in a scale closer to cases of commercial production, depending on circumstances, via joint efforts of the public and private sectors in Phase 3, the final phase of the "Japan's Methane Hydrate R&D Program" developed by the METI while technologies for commercialization will be developed through presentation of measures for tackling technical issues and evaluation of cost-effectiveness.

Note that, in Phase 2, given that the project scale is huge compared to Phase 1 as exemplified by the implementation of offshore production tests, a greater number of practical challenges will be involved. Therefore, MH21 will build an implementation system via cooperation with the industry, academic and administrative entities such as the previous one, and aim to further deepen ties with companies developing oil and gas. In addition, MH21 will promote a range of publicity activities aimed at the general public so that the project will proceed with support of the people.
3.2 Goals of Phase 2

Phase 2 are aimed at accomplishing the following five goals.

(1) Verification of the production method through implementation of offshore production tests and extraction of technical challenges for commercial production
(2) Recommendation of economical and efficient recovery methods
(3) Evaluation of methane hydrate distribution off the coast of Japan
(4) Recommendation of environmental assessment methods through offshore production tests
(5) Recommendation of the potential for safe and economical development options for methane hydrate-bearing layers off the coast of Japan

3.3 Research Themes for Phase 2

In order to accomplish the goals of Phase 2, MH21 set out the following research areas and work on the research and development themes. For details, see "4. Goals and Research Themes by Area for Phase 2"

<Research concerning Field Development Technology>
- Implementation of offshore production tests
- Characterization of methane hydrate resource field
- Investigation of the offshore development system
- Analysis of the Second Onshore Gas Hydrate Production Test and implementation of long-term tests

<Research concerning Production Method Development>
- Development of technology for advanced production method
- Development of evaluation technology for productivity and production behaviors
- Development of evaluation technology for sedimentary characteristics

<Research concerning Resources Assessment>
- Evaluation of methane hydrate resources off the coast of Japan
- Investigation of the methane hydrate system

<Research concerning Environmental Impact Assessment>
- Environmental risk analysis and investigation of countermeasures
- Development of environmental measurement technology
- Environmental impact assessment in offshore production tests
- Comprehensive environmental assessment in methane hydrate development

<Assessment of Economic Potential>

<Other Challenges>
- Promotion of international cooperation

3.4 Period of Phase 2

The period for implementing Phase 2 extends for seven years from FY 2009 through FY 2015 as the METI's policy.

Out of the period, the first half of Phase 2 (from FY 2009 to FY 2011) is for preparation for offshore production tests and implementation of onshore gas hydrate production tests through international cooperation. The outcomes of these tests are subject to project evaluation by the METI scheduled in FY 2011 (at the mid-term of Phase 2).

In the latter half of Phase 2 (from FY 2012 to FY 2015) is for offshore production tests (two instances) and the outcome of these tests are subject to project evaluation by the METI scheduled in FY 2015 (at the end of Phase 2).

3.5 Research Structure for Phase 2

For implementing Phase 2 of the project, two parties, Japan Oil, Gas and Metals National Corporation and the National Institute of Advanced Industrial Science and Technology will form a new consortium named Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium) under the initiative of the project leader, Dr. Yoshihiro Masuda, Associate Professor of University of Tokyo to conduct the researches. Note that this consortium is named after the previous one for Phase 1, considering the existing recognition.

Under the MH21 Research Consortium, four groups are set up, besides the steering committee functioning as a decision-making organ, for promoting research and development (namely, Administrative Coordination Section, Research Group for Field
Development Technology, Research Group for Production Method and Modeling, and Research Group for Resources Assessment). As for research concerning environmental impact, the entire organization of the MH21 Research Consortium will be engaged in it under the control of the Administrative Coordination Section as the importance of that area is to increase in Phase 2 in which offshore production tests are expected. Furthermore, a structure will be created for seeking advice of external informed individuals as research and development proceed.

The planning, operation, publicity and other affairs within the MH21 Research Consortium are entrusted with the Administrative Coordination Section. Additionally, the Administrative Coordination section will be in charge of studies concerning environmental impact as well as supervision of economic potential evaluation. Moreover, in order to encourage open exchanges of opinions among engineers, technical meetings are to be held within the MH21 Research Consortium.
4 Goals by Area and Research Themes for Phase 2

4.1 Research and Development concerning Field Development Technology

Goals

In order to enable commercial production of methane gas from methane hydrate-bearing layers which are non-conventional type of resources, it is essential to conduct field production tests to verify the production method, assess the dissociation behavior of the methane hydrate-bearing layers, evaluate the development technology, and so on. As Japan’s methane hydrate-bearing layers lie in the deep-water shallow formation layers off the coast of Japan, MH21 also needs to promote technological development for coping with the situation. Recognizing the significance as described above, MH21 will conduct the following research and development activities related to field development technology so that MH21 will enable to isolate technical issues to be addressed for commercialization and to verify the production technology through implementation of production tests.

- Implementation of offshore production tests
- Characterization of methane hydrate resource field
- Investigation of offshore development system
- Analysis of the second onshore gas hydrate production test and implementation of long-term tests

Contents of the research and development

- Implementation of offshore production tests
  Two offshore production tests are scheduled in FY 2012 and FY 2014 in order to gain an understanding of the dissociation behaviors of methane hydrate-bearing layers, verify the development technology, acquire basic data for examining economic potential, and so on.

  Offshore production tests will be conducted for several days or up to several weeks using offshore drilling rigs and existing production facilities/equipment. For these tests, MH21 will develop and implement a test plan that enables it to acquire quantitative data
related to the soundness of the sediment layers and wells as well as dissociation behaviors of methane hydrate so that the test results will maintain the productivity and production of offshore wells and evaluate technologies for retaining the well integrity and economic potential. After the tests, analysis associated with the goals will be performed on the results and evaluation will be conducted on the reservoir layers in the area.

In order to facilitate planning the tests, necessary studies will be conducted including a preliminary investigation of the offshore environment, evaluation of the reservoir characteristics, prediction of methane gas production behaviors, investigation and designing of systems and facilities for enabling the well integrity to be maintained while maintaining productivity, selection of the optimal well completion method, dissociation monitoring technology studies, and so on whose research outputs will be applied to the offshore production tests.

Furthermore, along with the implementation of offshore production tests, adequate considerations will be given to possible impact of the production tests on environment in order to reduce environmental impact. At the same time, an environmental impact assessment will be conducted based on information obtained from the subject offshore areas and required for the environmental impact assessment. For that purpose, an investigation will be conducted on offshore environment that is required for analysis of environmental risks and examination of countermeasures. As part of the environmental impact assessment related to the production tests, existing data regarding the subject offshore area will be evaluated for assessing risks of methane gas leakage, landslides at seafloor, etc., the results of which will be reflected on selection of testing locations. Additionally, an investigation and measurement will be conducted regarding the seafloor environment and the ecological system in the vicinity of the testing locations before, during and after the tests.

(Major activities)

- Implementation of technological development
  - Development and evaluation of technologies for maintaining productivity and production of offshore wells, and for retaining well integrity
    - Research concerning zonal isolation such as shallow-layer cementing
    - Research concerning measures against sanding and reservoir damage
    - Research concerning downhole tools and flow assurance
- Research concerning geophysical exploration technology related to production and development
- Other technological development activities required for implementation of the tests
  - Formulation of implementation plan
  - Implementation of offshore production tests
  - Analysis of the test result and identification of issues to be addressed
  - Evaluation of reservoir at the test target area
  - Environmental impact assessment at the testing locations

○ Characterization of methane hydrate resource field
Detailed characterization on methane hydrate-bearing layers is an important research theme that will be the base for the creation of a development system aimed at commercial production and will affect the evaluation of long-term production behaviors and evaluation of economic potential with a higher reliability. Therefore, in Phase 2, MH21 will comprehensively analyze data obtained from offshore production tests together with the seismic data, the modeling data, etc. to develop a detailed reservoir model for the area surrounding the well for production tests, evaluate the characteristics of the methane hydrate resource field, and evaluate the production capacity.

(Major activities)
  - Implementation of detailed geological modeling and reservoir characterization at test location
  - Reservoir assessment in the resource field

○ Investigation of the offshore development system
In Phase 2, MH21 will conduct conceptual design development for an offshore development system in accordance with the technologies validated in the offshore production tests, the resource field characteristics and the predicted production characteristics. Also, a technical study will be carried out regarding the measures for reducing costs and risks in relation to drilling, well stabilization, production, well completion, and so on, in order to acquire an outcome useful for the realization of the offshore development system to be accomplished in Phase 3.
(Major activities)
- Conceptual design of the offshore development system
- Technical study on drilling, well stabilization, production and well completion, etc.

○ Analysis of the second onshore gas hydrate production test and implementation of long-term tests
MH21 will conduct detailed analysis and evaluation of the results of onshore gas hydrate production tests conducted in Phase 1 and compile information required for offshore production tests. In the second onshore gas hydrate production test, MH21 could not conduct a long-term test, one of the initial objectives, as the test period was limited to about six days. Toward the establishment of the production method, it is necessary to verify that the depressurization method enables to provide long-term and stable production. For that purpose, MH21 will work on long-term onshore gas hydrate production tests through cooperation with the METI and in the form of an international joint project. By conducting long-term onshore gas hydrate production tests, MH21 will grasp long-term production behaviors and isolate problems, aiming to obtain data that help establish the methane hydrate production method suited for areas off the coast of Japan.

(Major activities)
- Analysis of the second onshore gas hydrate production test results
- Implementation of long-term onshore gas hydrate production tests (international cooperation)
4.2 Research and Development concerning Production Method Development

Goals

For commercial production of methane gas from methane hydrate-bearing layers, a production method with stable and massive production of methane gas from methane hydrate-bearing layers, evaluation technology for predicting and analyzing with a high precision the production behaviors of the target methane hydrate resource field and the gas production capacities of wells, and evaluation technology of sedimentary characterization for ensuring long-term safety of sedimentary deformation and consolidation behavior as following production, are required to be developed. From such significance, the research and development activity concerning development of the production method including the following R&D objectives, will be conducted to establish an economical and efficient production method.

○ Development of technology for advanced production method
○ Development of evaluation technology for productivity and production behaviors
○ Development of evaluation technology for sediment characteristics

Contents of the research and development

○ Development of technology for advanced production method
The higher the initial reservoir temperature, the higher rates of methane gas production and recovery are expected when the depressurization method is applied to a methane hydrate-bearing layer with alternation of sand and mud. However, the production rate gradually decreases due to reduction of the reservoir temperature during the production process. Therefore, the research includes development of a composite production method (combined method) for recovering the reservoir temperature. Also, the other production methods including a sediment-thermal stimulation method for economic and efficient heat supply, an accelerated recovery method focused on the reservoir characteristics providing high permeability layers after production, a method for improving the permeability factor that contributes to initial productivity, and so on, will be developed. Furthermore, in order to ensure long-term stable methane gas production, MH21 will conduct quantitative analyses of productivity impediments through the development of numerical models, which includes production-impeding impact of sand
production, reductions of permeability due to skin formation, flow obstruction due to methane hydrate reproduction, and so on, and develop technologies to counter and control the production damages.

(Major activities)
- Development of technology to enhance productivity
- Development of technology to counter/control production damages.
- Verification with large-scale laboratory test equipment

○ Development of evaluation technology for productivity and production behaviors
MH21 will develop a technology for providing more reliable productivity and predicting production behaviors by adding the models such as variations of reservoir characteristics owing to the production process and so on into the production simulator developed in Phase 1 (MH21-HYDRES). For that purpose, MH21 will work on upgrading the production simulator, by developing an analysis routine for evaluating changes following production in relation to permeability of the reservoir, thermal characteristics, consolidation properties, etc., and for evaluating production damages through verification of onshore gas hydrate production tests and offshore production tests. As for the three-dimensional reservoir models to be loaded into the production simulator, MH21 will aim to evaluate production behaviors in wider-area, sediment characteristics, etc., in long-term production by considering introduction of discontinuity such as faults, heterogeneous reservoir parameters, and so on. Based on these results, MH21 will conduct a comprehensive evaluation of the production method and system for optimizing economic potential according to the reservoir characteristics.

(Major activities)
- Functional improvement of production simulator (MH21-HYDRES)
- Development of three-dimensional reservoir model for production behavior evaluation
- Prediction and verification of production test
- Productivity evaluation of commercial-scale production

○ Development of evaluation technology for sediment characteristics
Through advancing sets of formulas in the sediment deformation simulator developed in
Phase 1, an evaluation routine will be developed, which enables assessment of environmental impact such as probability of landslide, a risk of methane gas leakage, and so on that may follow methane gas production. Also, by using the above routine, MH21 will comprehensively evaluate mechanical properties peculiar to methane hydrate development of deep-water unconsolidated sedimentary layers and verify the geo-mechanical stress around wells relating to the methane gas production, boarder-area sediment deformation accompanying long-term production, and so on.

(Major activities)

- Functional improvement of sediment deformation simulator
- Evaluation of well integrity
- Evaluation of sediment deformation in boarder area
4.3 Research and Development concerning Resources Assessment

Goals

In Phase 1, as a result of case studies conducted in the eastern Nankai Trough, MH21 secured great achievements with respect to a technology for identifying a methane hydrate concentrated zone, a promising resource field, a technology for evaluating the amount of the original methane gas in place contained in methane hydrate-bearing layers, and a technology for obtaining findings on the characteristics of methane hydrate-bearing layers in the alternation of sand and mud. Also, MH21 revised the methane hydrate-originating BSR distribution zones in order to identify sea areas bearing methane hydrate distributed off the coast of Japan.

In Phase 2, utilizing the technologies and findings accumulated in Phase 1, MH21 will expand the research target areas to other than the eastern Nankai Trough and proceed to estimate the distribution of methane hydrate concentrated zones while obtaining data from reprocessing/reanalyzing existing or new geophysical data acquired by a seismic vessel “Shigen”. Moreover, MH21 will conduct a comprehensive evaluation of the state of methane hydrate deposits off the coast of Japan through basic research on the mechanisms in relation to the generation, migration, and accumulation of methane, the generation of methane gas-bearing layer, and so on (as a whole, a methane hydrate system).

- Evaluation of methane hydrate distribution off the coast of Japan
- Investigation of the methane hydrate system

Contents of the research and development

- Evaluation of methane hydrate distribution off the coast of Japan
Utilizing the technologies and findings accumulated in Phase 1, MH21 will expand the research target sea areas to other than the eastern Nankai Trough to proceed to estimate the distribution of methane hydrate concentrated zones which consist of sand layers as reservoirs while obtaining data from reprocessing/reanalyzing existing or new geophysical data acquired by a seismic vessel “Shigen”. Also, MH21 will proceed with
studies including methane hydrates in other forms of deposits, using existing data and information on geological conditions, and provide comprehensive evaluation of the distribution of the methane hydrate resources off the coast of Japan with focusing on the feasibility as a resource development.

(Major activities)

- Estimation of the distribution of methane hydrate concentrated zones with enlarging the target areas other than the eastern Nankai Trough
- Comprehensive evaluation of methane hydrate resources off the coast of Japan

○ Investigation of the methane hydrate system
Basic research will be continued concerning geophysical, geological and geochemical characteristics of methane hydrate-bearing layers, aiming to contribute the estimation of methane hydrate-bearing layer distribution, reservoir evaluation, and offshore production tests and environmental impact assessment. In addition, MH21 will aim to create a methane hydrate system model (including generation, migration, and accumulation of methane gas and formation and dissociation of methane hydrate) that explains the formation of methane hydrate concentrated zones in the eastern Nankai Trough, and gather and analyze the necessary data. By utilizing results of the above studies, MH21 will examine methods for estimating the development of methane hydrate concentrated zones in areas with limited data.
4.4 Research and Development concerning Environmental Impact Assessment

Goals

In order to provide scientific explanation concerning environmental impact from the development of methane hydrate that is a non-conventional resource and explore an offshore development system for minimizing the risks of environmental impacts, MH21 will carry out development activities concerning environmental impact assessment subsequent to Phase 1. Although the studies in environmental areas have been conducted by individual groups in the consortium so far, in Phase 2 and on, MH21 Research Consortium will conduct such study by gathering comprehensive and overall knowledge inside the consortium. Also, in order to provide comprehensive and neutral assessment on environmental impact of methane hydrate development, MH21 will construct a system for receiving consultations from external well-informed individuals and promote the research and development. At the same time, in order to show its accountabilities as the undertaker of the project, MH21 will publicize the obtained findings and knowledge in an active manner and promote to expedite the understanding toward the project.

- Analysis on environmental risks and investigation of countermeasures against them
- Development of measurement technology for environment
- Assessment of environmental impacts in offshore production tests
- Comprehensive assessment of environment and optimization of assessment methods in development of methane hydrate-bearing layers

Contents of the research and development

- Analysis on environmental risks and investigation of countermeasures against them

Based on the knowledge on conventional oil/natural gas resource development with considering the characteristics specific to methane hydrate development in deep-water shallow formation layers, MH21 will extract risks that may be imposed by methane hydrate offshore production tests and the offshore development system for
commercialization, and conduct quantitative risk assessment through identifying the characteristics of such risks. Furthermore, based on results of the above studies, MH21 will develop a risk management plan including measures for reducing the impacts, countermeasures against risk manifestation, and so on.

○ Development of measurement technology for environment
MH21 Consortium will continue to study on developing measurement technology for environment for long-term and broad-area application in deep-water areas, including modifying the methane leakage sensor improved in Phase 1 into a unit capable of operation in the actual sea areas, in order to assess the environmental impact in offshore methane hydrate development. By combining devices to be developed and existing devices, MH21 will also proceed to develop a concept for measurement method for environment which is optimized for the environmental risks in relation to the offshore development system.

○ Assessment of environmental impacts in offshore production tests
As a model case of assessing environmental impact accompanying development activities, MH21 will specifically assess the impacts imposed by offshore production tests. For that purpose, based on data obtained from the investigation of the seafloor environment and ecological system conducted during offshore production tests, MH21 will proceed to develop an environmental database, conduct preliminary environmental impact assessment, provide comprehensive evaluation of results of environmental monitoring during and after the tests, and publicize such results from time to time.

○ Comprehensive evaluation of environment and optimization of assessment methods in development of methane hydrate-bearing layers
MH21 will continue to study long-term and overall impact on ocean and global environment by development of methane hydrate-bearing layers, including positive aspects, and continue information collection and evaluation for that purpose. In addition, MH21 will conduct a study to optimize assessment methods for the environmental impacts applicable to the offshore development system for commercial production of methane hydrate while considering economical feasibilities through comprehensive assessment of environmental impacts during offshore production tests.
4.5 Assessment of Economic Potential

Goals

MH21 will present economical feasibility of developing methane hydrate-bearing layers off the coast of Japan and identify technical challenges in order to improve the economical feasibility.

Contents of the research and development

By using the evaluation tool for economical feasibility developed in Phase 1, and based on the results obtained by the MH21 Research Consortium, MH21 will study technical challenges for improving the economical feasibility as evaluating economical feasibility assumed for developing methane hydrate-bearing layers off the coast of Japan. This study is planned to be conducted in FY 2011 and FY 2015 when project evaluations are scheduled.

4.6 Other Challenges

<Promotion of international cooperation>

Through participation in overseas projects, etc., MH21 will grasp the trends of overseas studies on exploration, development, and basic research on methane hydrate. Furthermore, with recognition that outcomes and progress of overseas studies will in turn utilize and contribute to methane hydrate development promotion projects in Japan, MH21 will promote technical exchanges with overseas researchers in view of academic achievements, information, human resources, etc. while fully considering creation and enhancement of mutually beneficial relationships.
## 5 Goals of Phase 2

<table>
<thead>
<tr>
<th>Item</th>
<th>Goal (FY 2011)</th>
<th>Goal (FY 2015)</th>
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<tbody>
<tr>
<td>4.1 Research and Development concerning Field Development Technology</td>
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<tr>
<td>1</td>
<td>Implementation of offshore production tests</td>
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<tr>
<td>(1) Implementation of technological development</td>
<td>Since this is considered as the first offshore gas hydrate production test in the world, the safety during the test period must be ensured and the methane gas production behavior must be defined as well. For this reason, plan the production test using conventional technologies, at the same time, identify the issues which require technological developments including the offshore well productivity, the well stabilization technologies, the geophysical exploration technology related to production and development and so on, present solutions to the issues and proceed such technological developments. For particularly important issues, complete the preparation through verification by laboratory or field experiments. Specifically, implement the following items. - Conduct research regarding the zonal isolation such as shallow cementing. Study the well</td>
<td>Based on the results of the two offshore production tests, identify the technical issues toward commercial production.</td>
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<tr>
<td>(2) Formulation of implementation plan</td>
<td>Formulate the basic policy for the first and second offshore production tests. Plan the first test to obtain the data which will enable to evaluate the offshore well productivity and well stabilization technology. Formulate the concrete test program to be implemented in FY 2012. Select the equipment used in the bottom-hole, seafloor and surface, select and design devices, and be ready for procuring them.</td>
<td>Plan the second offshore production test based on the result of the first offshore production test. Formulate the concrete test program to be implemented in FY 2014. Select the equipment used in the bottom-hole, seafloor and surface, select and design devices, and be ready for procuring them.</td>
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<tr>
<td>(3) Implementation of offshore production tests</td>
<td>To implement offshore production tests, select the operator and drilling rig, and be ready for the test.</td>
<td>Implement two offshore production tests safely, and obtain the necessary data. More precisely,</td>
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<tr>
<td>(4) Analysis of the test result and identification of issues</td>
<td>Based on the analyzing process of the second onshore gas hydrate production test implemented in Canada in Phase 1, prepare the flowchart for analyzing the test result.</td>
<td>Complete the basic analysis of the offshore production test through the management and processing of the obtained data, comparison with the dissociation monitoring result and verification with the simulator. In addition, understand the gas and water flow condition inside the well, and evaluate the reservoir with reference to the production method.</td>
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<td>(5) Evaluation of reservoir at the test target area</td>
<td>Based on the existing seismic data, well log data, core analysis result, etc., construct a reservoir model of the test location, estimate the gas and water flow rate using the production simulator, and identify the production risks.</td>
<td>Using the well log data and others obtained through the offshore gas hydrate production test, verify the reservoir parameters around the well again.</td>
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<td>(6) Environmental impact assessment at the test location</td>
<td>Prior to the offshore gas hydrate production test, investigate the offshore environment and ecological</td>
<td>During and after offshore gas hydrate production tests, investigate the offshore environment and</td>
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<tr>
<td>Table 8</td>
<td>Characterization of methane hydrate resource field</td>
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<tr>
<td>(7) Implementation of detailed geological modeling and reservoir characterization at test point</td>
<td>Based on the seismic data, well log data, core data, etc. formulate the reservoir model in the vicinity of the well which is required to predict the reservoir behavior of the first offshore production test.</td>
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<tr>
<td>(8) Reservoir evaluation in the resource field</td>
<td>Update the reservoir model based on the new data of reservoir parameters obtained in the offshore production tests, production data of two offshore production tests, and the results analyzed by the simulator.</td>
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<td>(8) Conceptual design of offshore development system</td>
<td>Apply the reservoir model at the test point, which was updated in offshore production tests, to the concentrated zone and the entire resource field utilizing the reflection seismic data, and so on.</td>
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<tr>
<th>Table 9</th>
<th>Investigation of offshore development system</th>
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<tr>
<td>(8) Conceptual design of offshore development system</td>
<td>Identify the issues on the offshore development system which were studied in Phase 1, assess the validity and feasibility, and progress the study on the development potential. Also, examine the up-to-date Based on the results of offshore gas hydrate production tests, review the offshore development system, and complete the realistic conceptual design suitable for the resource</td>
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<td>Analysis of onshore gas hydrate production tests and implementation of long-term tests</td>
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<td><strong>(9) Technical study on drilling, well stabilization, production and well completion</strong></td>
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<td>Apply the results of the technical study on offshore gas hydrate production tests to the study on the offshore development system. In addition, identify the technical issues related to reducing development risk and cost, and gather the most recent findings.</td>
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<td>Based on the results of offshore gas hydrate production tests, move the technical evaluation forward, and study the method to optimize each kind of technologies.</td>
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<td><strong>(10) Analysis of the second onshore gas hydrate production test results</strong></td>
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<td>Complete the comprehensive study on the result of the second onshore gas hydrate production test that was implemented in Phase 1 in Canada. Summarize the result to contribute to the development of hydrate off the coast of Japan, and publish the result if necessary.</td>
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<td><strong>(11) Implementation of long-term onshore gas hydrate production tests (international cooperation)</strong></td>
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<td>Through international cooperation, identify the site where a long-term onshore gas hydrate production test may be conducted by the depressurization method, and aim to obtain its long-term production behavior data.</td>
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<td>Analyze the result of the long-term production test, and incorporate the data to the production simulator and reservoir model in order to evaluate the long-term offshore production behavior.</td>
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<td>Item</td>
<td>Goal (FY 2011)</td>
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<tr>
<td>4.2 Research and Development concerning Production Method Development</td>
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<td>1</td>
<td>Development of technology for advanced production method</td>
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<tr>
<td>(1) Development of technology for enhancing gas productivity</td>
<td>Develop the technologies for enhancing gas productivity per well through the methane hydrate sedimentary core testing, by combing depressurization method and thermal stimulation methods, by increasing the methane gas production rate with effective thermal supply, by improving the permeability, etc..</td>
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<tr>
<td>(2) Development of technology to counter/control production impediments</td>
<td>Through the methane hydrate sedimentary core testing, clarify the mechanism of gas production impediments and assess its impact on gas production by analyzing the production impediments such as skin formation around the production well, accumulation of moving fine-grained sands into the pore of sandy sediment, ice formation/methane hydrate regeneration at a strong depressurization, production impediment such as lowering of permeability due to consolidation, and the flow obstruction due to regeneration of methane hydrate in the tubing.</td>
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<td>Development of evaluation technology for productivity and production behaviors</td>
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<td>Verify the technology to enhance gas productivity and control production impediments, and present an effective production method through overall evaluation of the developed technology, verification with offshore production test, and so on.</td>
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<td>Verification with large-scale laboratory test equipment</td>
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<td>Design and construct a large-scale laboratory test equipment to quantitatively evaluate the gas productivity and production behavior, and verify the technology to enhance the gas productivity and the production impediment mechanism.</td>
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<td>Development of evaluation technology for productivity and production behaviors</td>
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<td>Enhance the function of the production simulator (MH21-HYDRES) by adding a routine which is able to evaluate various production impediment factors such as flow obstruction due to skin formation. Also, accelerate the processing speed of the simulator by developing the parallel computing method and implementing it into the system. Also, develop the upscale method which ensures efficient simulation while maintaining accuracy to estimate the productivity and production behavior at the field.</td>
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<td>4</td>
<td>Functional improvement of production simulator (MH21-HYDRES)</td>
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<td>Improve the accuracy through verification of the result of the field test. Also develop a practical simulator that combines the production simulator with the sediment deformation simulator.</td>
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<td>5</td>
<td>Development of three-dimensional reservoir model for production behavior evaluation</td>
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<td>Obtain the sedimentary parameters which can describe sediment heterogeneity and discontinuity due to fault through experiments, etc. Develop a modeling procedure for the three-dimensional reservoir models which enables to evaluate the long-term gas productivity and sediment</td>
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<td>By introducing the sediment stochastic method, develop a modeling procedure for the three-dimensional reservoir models which is able to evaluate the gas production behavior and sediment deformation in wide area during the long-term production period.</td>
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<td></td>
<td>Development of evaluation technology for sediment characteristics</td>
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<tr>
<td>3</td>
<td><strong>Estimation and verification of production test</strong></td>
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<td>Estimate the productivity and production behavior of onshore gas hydrate production tests and offshore production tests, and incorporate the result to the test plan. Also, verify the reliability of the production simulator.</td>
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<tr>
<td></td>
<td>Estimate the productivity and production behavior of offshore production tests, and incorporate the result to the test plan. Also, verify the reliability of the production simulator.</td>
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<tr>
<td>7</td>
<td><strong>Prediction and verification of production test</strong></td>
</tr>
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<td>Predict the gas productivity and production behavior of onshore gas hydrate production tests and offshore production tests, and incorporate the prediction to the test plans. Also, verify the reliability of the production simulator with the result of the production tests.</td>
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<tr>
<td></td>
<td>Predict the gas productivity and production behavior of offshore production tests, and incorporate the prediction to the test plans. Also, verify the reliability of the production simulator with the result of the production tests.</td>
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<tr>
<td>8</td>
<td><strong>Functional improvement of sediment deformation simulator</strong></td>
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<td>Develop the sediment deformation simulator for analyzing broader area of sediment stress distribution, deformation behavior and consolidation behavior in the methane hydrate-bearing reservoir consisting of alternation of sand and mud. Also, develop the analytical simulator for geomechanical behavior which enables to evaluate the detailed dynamic behavior around the well and evaluate the long-term stability of the well.</td>
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<td>Develop the sediment deformation simulator for the reservoir model including the discontinuity and heterogeneity which enables to evaluate stress distribution and deformation of the sediment, subsidence behavior of the seafloor, possibilities of landslide, and gas leakage both around the well and broader area during the production.</td>
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<tr>
<td>(9) Evaluation of well integrity</td>
<td>According to the reservoir characteristics, evaluate the sediment deformation around the well, stress distribution of sediment on the wellbore wall, and possibility of gas leakage during the gas production process</td>
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<tr>
<td>(10) Evaluation of sediment deformation in broader area</td>
<td>Examine the subsidence of seafloor, deformation of sediment, possibilities of landslide, and gas leakage in broader area during the gas production. Also, summarize the geomechanical characteristics of deep-water shallow formation unconsolidated sedimentary layers.</td>
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<tr>
<td>Item</td>
<td>Goal (FY 2011)</td>
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<tr>
<td>1</td>
<td><strong>Evaluation of methane hydrate resources off the coast of Japan</strong></td>
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<td>(1) Estimation of the distribution of methane hydrate concentrated zones with enlarging the target areas other than the eastern Nankai Trough</td>
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<tr>
<td>2</td>
<td><strong>Investigation of the methane hydrate system</strong></td>
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<td></td>
<td>(3) Investigation of methane hydrate system</td>
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</tbody>
</table>
methane hydrate concentrated zone in the eastern Nankai Trough. examine the method for estimating the development of methane hydrate concentrated zones in the areas with limited data.

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<tr>
<td>4.4 Research and Development concerning Environmental Impact Assessment</td>
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<tr>
<td>Analysis on environmental risks and examination of countermeasures against them</td>
<td>Complete the identification of the risks associated with offshore production tests. Understand the property of the risks associated with offshore production tests, and prepare a risk management plan for the possible risks.</td>
<td>Based on two offshore production test results, complete the identification of commercial production risks, and propose countermeasures against the possible risks in commercial production.</td>
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<tr>
<td>Development of measurement technology for environment</td>
<td>Identify the necessary monitoring sensors, and plan for developing them. Establish the monitoring concept for offshore production tests, and prepare an optimal system accommodating the risks and the operation.</td>
<td>Identify the necessary sensors for commercial production, and propose a concept for the optimal monitoring system accommodating the risks in commercial production.</td>
</tr>
<tr>
<td>Assessment of environmental impacts in offshore production tests</td>
<td>Conduct a preliminary assessment of the methane gas leakage, sediment deformation, etc. Based on the investigation of the seafloor environment and ecological system, estimate the environmental impacts and establish corresponding countermeasures by using a model. Prepare the environmental impact assessment procedure for offshore production tests, and conduct an internal assessment.</td>
<td>Based on the evaluation of offshore production test results, evaluate the validity of the estimation method, and optimize the assessment method of environmental impacts for the offshore development system.</td>
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</table>
**Comprehensive assessment of environment and optimization of assessment methods in methane hydrate development**

Collect the latest information on the research related to methane hydrate, and study the environmental impact assessment.

Based on the result of offshore production tests and the past achievements, propose an assessment procedure for the environmental impacts in the commercial production.

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<th>Item</th>
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<tbody>
<tr>
<td>4.5  Evaluation of Economical Feasibility</td>
<td>Based on the achievement of the research of the first half of Phase 2, review evaluation of economical feasibility of the methane hydrate development off the coast of Japan which was conducted in Phase 1.</td>
<td>Present the economical feasibility of the methane hydrate development off the coast of Japan, based on offshore production tests, the study on the offshore development system, and so on, and identify the technical issues to improve economical feasibility.</td>
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</table>