23rd World Gas Conference, Amsterdam 2006

ECONOMIC STUDY ON NATURAL GAS TRANSPORTATION WITH NATURAL GAS HYDRATE (NGH) PELLETS

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ABSTRACT

In view of remarkable growth of global natural gas demand and increasing geopolitical risks and concerns of naval accidents including terrorisms in this century, it is needed for us to develop diversified measures to transport natural gas economically and safely from remote gas fields to marketplaces by means of none pipeline technology. When the gas pipelines are not available, Liquefied Natural Gas (LNG) technology is preferably adapted to transport gas. However, in case of LNG, natural gas should be made cryogenic conditions of below minus 162 degree C, so total cost of LNG chain including liquefaction plant and LNG tanks becomes quite high particularly in case of medium or small lots gas transport projects, furthermore, LNG is dense light natural gas liquid so it has potentially risks in storage or transport against dangerous factors.

Many stranded gases and associated gases yielded with crude oil are not utilized and not monetized for economic reasons, and medium or small lot gas users such as independent power producers (IPPs) have not been able to access reasonable priced natural gas because small sized LNG chain is not economical. In addition although a lot of pipeline projects are planned, large part of that has not been materialized mainly because of political reasons. As the solutions of such issues, new economical, ecological and safe measure to transport gas instead of both pipeline and LNG is necessary.

It is well known that Natural gas hydrate (NGH) contains large amount of natural gas about 170 times as much as its volume and it is easy to be stored and transported safely at about minus 20 degree Celsius under atmospheric pressure due to so called “self-preservation effect”. Consequently, specifications of facilities including production plants are expected to be simpler and total cost of gas transport is lower in comparison with LNG case. Additionally to that, NGH is fundamentally safe substance against hazardous situations like fire bombs or leakages problems because it is solid crystalline bulk with water molecules. Focusing on such advantages of NGH properties Mitsui Engineering & Shipbuilding Co., Ltd. (MES) is working on the comprehensive NGH technology development to complete the gas transportation chain, such as NGH formation, dewatering, pelletizing, storage, sea transportation, loading/unloading and gasification. In particular MES has been developing the NGH “pellet” system, which is superior in many points including high filling ratio in ship cargo tanks, good fluidity and enhanced self-preservation effect, and that is one of the best solutions to make NGH transportation more feasible.

The feasibility study carried out by MES in 2004-2005 comparing with NGH chain and LNG chain in technical and economical respects with actual gas export terminals, carriers and receiving terminals. As the result of studies, MES found that NGH chain was better than LNG chain by 18-25% in total cost including capital and operational cost and 6-14% in energy required when transporting less than one or two million ton of natural gas for less than 3500 nautical miles in one way voyage between terminals.

MES has been working on the development of NGH total systems including NGH production process and so on since 2001. MES already constructed and now in operation process development unit (PDU) for 600kg of NGH per day at its Chiba works in Japan in order to obtain many engineering data supported by Japanese governmental bodies. As the result of MES’ feasibility study, it was suggested that NGH chain was more advantageous compared with LNG chain in economics and energy required in middle lots of gas transport for middle distance transportation. MES are accelerating the research and development on NGH chain aiming at the goal to get ready for actual NGH chain project starting in 2010.

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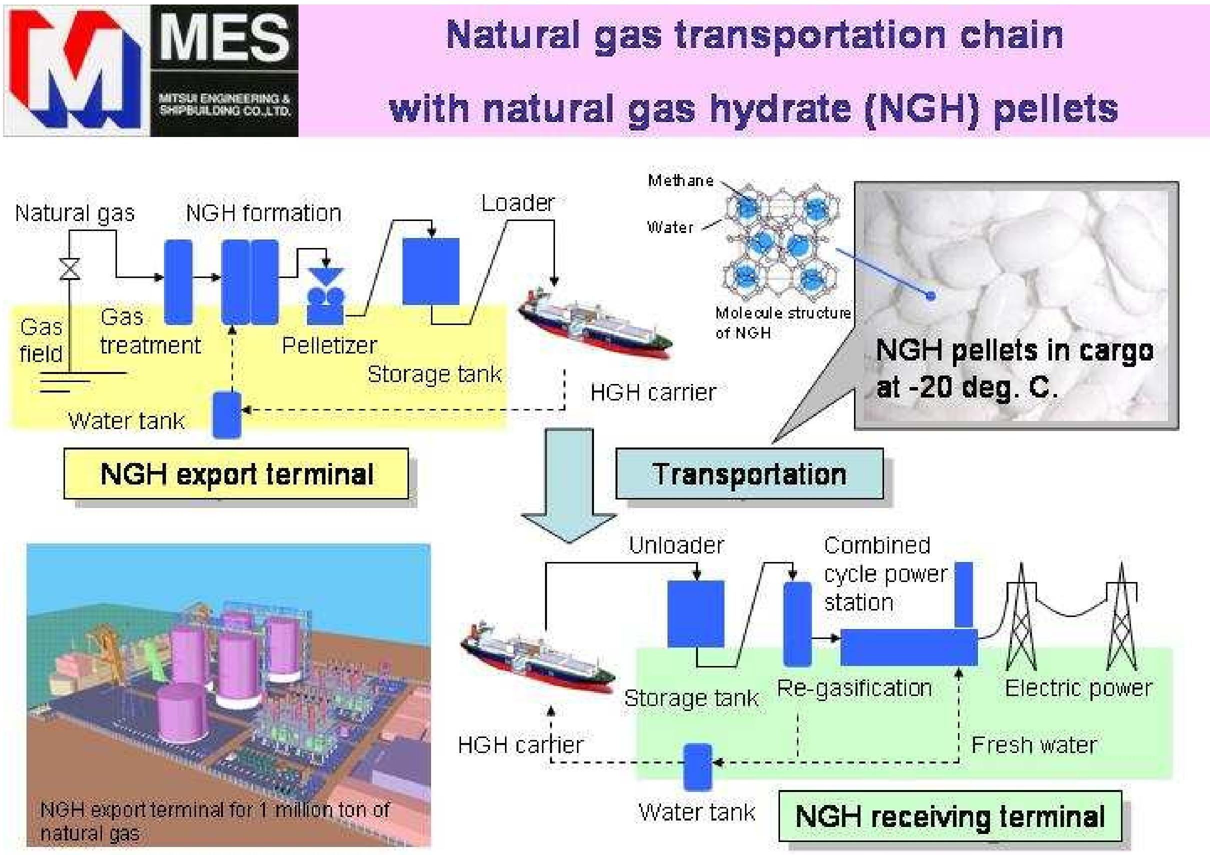
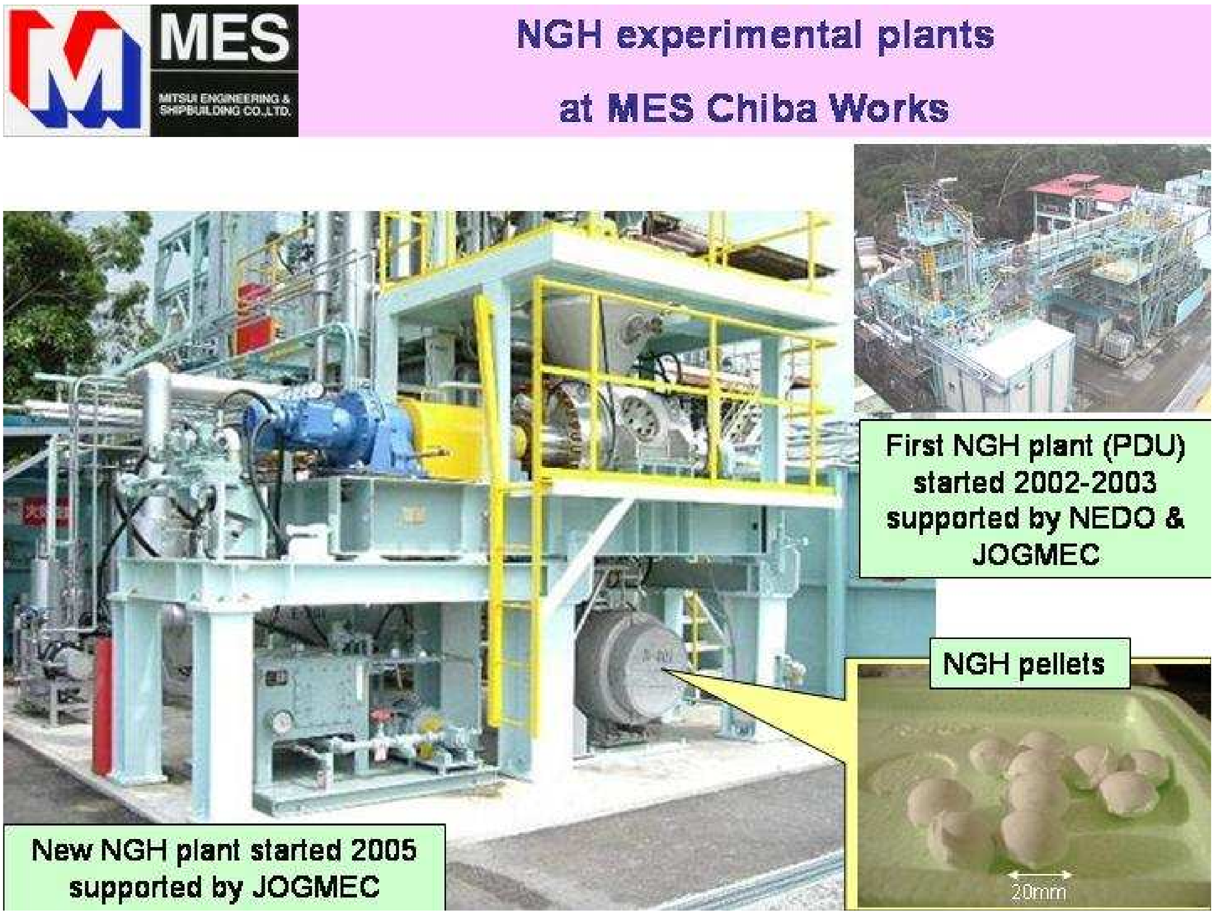
1. INTRODUCTION

Since the idea of ocean transport of natural gas by means of natural gas hydrate (NGH) utilizing so called "self-preservation effect" was advocated in 1996 by Dr. Gudmundsson of Norwegian University of Science and Technology and Aker Kvaerner ASA, various kinds of research for NGH Ocean Transport Chain have been made in all over the world including Japan. Mitsui Engineering & Shipbuilding Co., Ltd. (MES) has executed a new conceptual design and economic feasibility study of the NGH chain by means of NGH pellet placing emphasis on its practical design and economy based upon enormous amount of knowledge obtained through the research and development strenuously continued since 2001 for NGH production process, carrier ship, re-gasification process etc. as well as through the demonstrational operation of large-scale experimental plant (PDU: Process Development Unit). In this study, overall energy consumption and CO_2 emission by the NGH chain were also assessed to compare those for the conventional LNG transport chain.



2. RESEARCH AND DEVELOPMENT

Since early 1990th MES has been working on comprehensive R&D of NGH value chain including formation, pelletizing, storage, carrier and re-gasification. Over 2002-2003 MES constructed PDU supported New Energy and industrial Development Organization (NEDO) and additionally Japan Oil, Gas and Metals National Corporation (JOGMEC), both are subsidiaries of Ministry of Economy Trade and Industry to confirm continuous NGH production, pelletizing, storage and re-gasification at Chiba Works, Japan. The capacity of PDU production is 600kg per day of methane hydrate. Subsequently in 2005 MES completed new NGH experimental production plant next to PDU supported by JOGMEC again to develop new and competitive process of NGH with "mixed gas" including methane, ethane and propane, where new dewatering, primary reactor and high-pressure pelletizer are adopted. As parallel R&D activities on NGH, MES have been also developing NGH carrier since 2001 in cooperation with Ministry of Land Infrastructure and Transport. In 2005, three year R&D on NGH carrier as second phase started testing with newly constructed 1/10 model of cargo tank with NGH pellets in Chiba Works. Not only before mentioned experimental plant operational studies, but also fundamental researches have been repeated by MES including NGH stability under self-preservation phenomena.



3. NGH PRODUCTION AND RE-GASIFICATION PROCESS

NGH Production

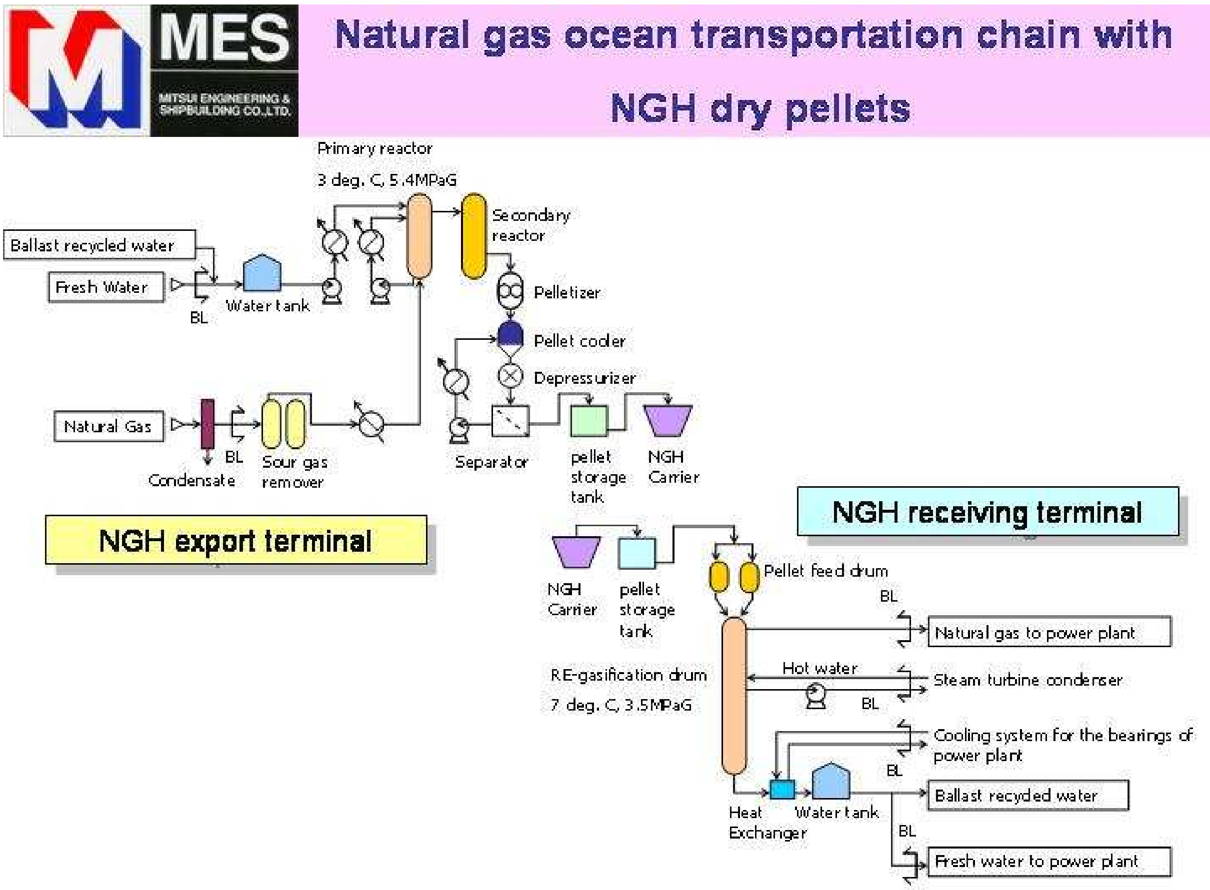
Raw materials for the NGH production plant are supposed to be the natural gas, from which the component heavier than C_4 and CO_2 are removed and the fresh water from the river and /or underground well. The associated gas from oil field contains a lot of heavy components and therefore is excluded from the study since such heavy components should be separately recovered and sold in the form of condensate. Sour gas such as CO_2 and H_2S are removed by means of MEA (Mono Ethanol Amine) method from the material gas and the lighter component than C_3 is used. Unlike LNG system, water removing process is not required for NGH formation.

In the NGH formation process of MES, high-density slurry is produced in high speed by means of mixing/bubbling method as a primary formation stage, and as a secondary formation stage, NGH from a primary reactor is purified. The purified NGH powder is then continuously shaped into NGH pellet of 5-70 mm diameter by the roll type pelletizer for storage in the pellet storage tank under atmospheric pressure at -20 degree C which is the temperature self-preservation effect appears.

NGH re-gasification

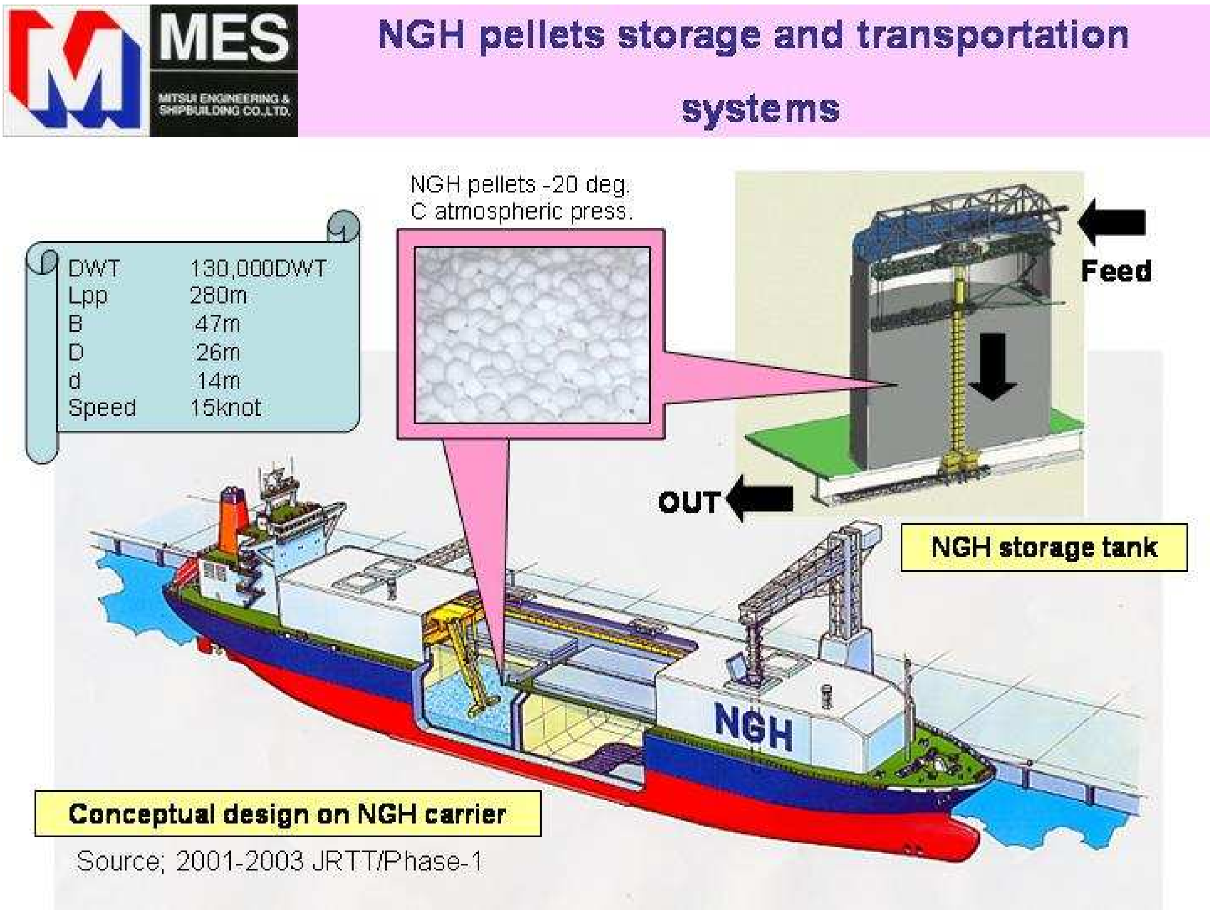
After the NGH carrier arrives at the jetty, NGH pellet is unloaded by a ship unloader on the jetty through a specialized hatch on the cargo hold at -20 degree C under atmospheric pressure and is further transferred to a NGH storage tank by the pipe conveyor. Afterward, the pipe conveyor carries out NGH pellet continuously from NGH pellet storage tank to a re-gasification plant.

The NGH pellet of -20 degree C under atmospheric pressure is supplied to pellet feed drums by gravity-type hopper and is further supplied to a re-gasification drum after being pressurized. Latent heat occurs when NGH dissociates is exchanged in the outer heat exchanger with heat of a steam condensate from the customer's GTCC power plant. NGH is decomposed into natural gas and water in the high-pressured gasification drum. After the gas-liquid separation, the high-pressured natural gas of 3.5MPa is supplied to a customer's GTCC power plant. Dissociated water of low temperature, after being met with cold-heat recovery for cooling of turbine shaft bearing of power plant, is collected to a dissociated water tank. Such dissociated water is loaded by a ballast pump into the ballast tank of the NGH carrier to be recycled at the loading port as NGH formation water. Remaining water can be sold to the power generating plant as an industrial water to be used for boiler water and/or cooling water.



4. STORAGE AND TRANSPORT SYSTEM OF NGH PELLETS

The produced NGH pellet is continuously conveyed by a pipe conveyor in enclosed natural gas of -20 degree C under atmospheric pressure into an enclosed pellet storage tank of -20 degree C under normal pressure for storage until the loading to the NGH carrier. Loading of the NGH pellet is made by ship-loader installed on the jetty down to the cargo hold of specialized NGH carrier. The storage tank is a silo type tank in which a pellet catcher collects the necessary amount of pellet. The collected pellets fall down to a passage at the center of the tank for discharge from its lower part. Mechanical system in the tank is of hydraulic system from the viewpoint of explosion proof. MES carried out a conceptual design of NGH carrier from 2001 to 2003 as a government-commissioned research by the Ministry of Land, Infrastructure and Transport. The concept of NGH pellet carrier is based upon a refrigerated bulk carrier and has an enclosed cargo hold system to store NGH pellet in the natural gas at -20 degree C under atmospheric pressure. As NGH pellet dissociates slightly in the cargo hold, its amount is not much enough for driving propulsion machinery. The dissociation gas from NGH pellet is used for driving the generator engine of the carrier.



5. ECONOMIC FEASIBILITY STUDY

For study of overall LNG transport chain, MES assumed Japanese electric power companies having natural-gas-fired Gas Turbine Combined Cycle (GTCC) power station as the consumer of natural gas, and material gas was assumed to be the gas from smaller gas fields and/or associated gas from oil fields which are to be transported over the sea for about 1,500-3,500 nautical miles.
Main flow of the chain assumed the project to produce NGH pellet out of material gas and water at a loading port and such pellet is transported over the sea by a specialized NGH pellet carrier to be re-gasified at an unloading port for supply of natural gas to power stations along the sea coast. Conceptual design and economic feasibility study were made for two different cases with different transport scales and transport distances. The study was made for an ocean gas transport of about 0.4-1 million tons per annum (MTPA) in terms of natural gas. Although plural transport patterns can be thought for the future, the study was made based upon one (1) loading port and one (1) unloading port

For studying the economical feasibility of NGH ocean transport chain, investment cost and operation cost were calculated in two cases for comparison with an LNG ocean transport chain of same scale and with gas market price. Especially as for decision of ship size, over 200,000DWT (Dead Weight Tonnage) ship was originally envisaged in Case 2. However, after overall consideration of loading/unloading speed, on-land storage amount which is expected to increase, ship's draft etc., and the fleet plan is now composed of 4 ships each of max. 130,000DWT in Case 2.
Initial cost for the NGH chain was calculated based upon the precise planning of the actual plant and carrier ship utilizing up-to-date knowledge and expertise owned by MES. The cost for small LNG chain was assumed from general LNG chain of 3-5MTPA, because currently there is no such small LNG chain of 0.4-1MTPA available.

The study shows that initial cost of the NGH transport chain (as a whole) is lower than the LNG transport chain of the same scale by 23-27 % of which main reasons are supposed to be as follows:

1) Elemental equipments of NGH production plant are composed of general merchandized products and can relatively easily be procured although they are for high pressure use. Meanwhile, LNG production plant needs special compressors and heat exchangers suitable for cryogenic temperature.
2) Although the medium volume of NGH is about 3-4 times the volume of LNG for a same amount of gas, the storage temperature of NGH is -20 degree C, closer to room temperature than -162 degree C of LNG and therefore the storage cost of NGH especially at unloading terminal is much lower.
3) The small LNG carrier, which is appropriate for 0.4MTPA chain, comes higher in the unit cost than normal sized LNG carrier.

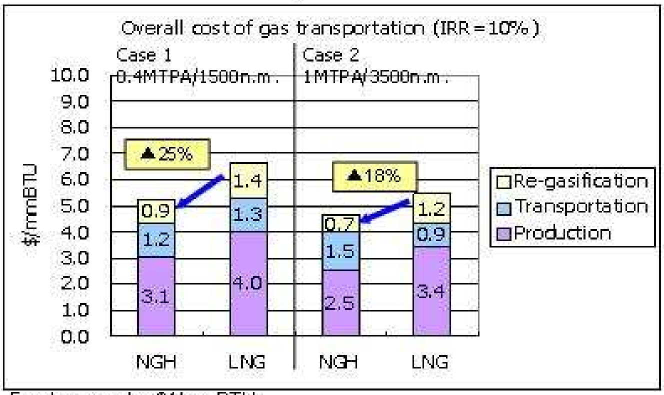
NGH has, if conditions permit, certain competitiveness in terms of total gas cost including operational cost, because such cost of NGH is lower than that of LNG of same scale by 18-25% when the IRR (Internal Rate of Return) is 10%.

	Case 1		Case 2	
	NGH	Small sized LNG	NGH	Small sized LNG
1.Natural gas value chain				
Natural gas source	Natural gas	→	Associated gas	→
Site of gas well	Close to Japan	→	Southeast Asia	→
Voyage distance	1,500N.M.	→	3,500N.M.	→
Production Capacity (gas)	0.4MTPA	→	1MTPA	→
Production Capacity (NGH/LNG)	3MTPA	0.4MTPA	8MTPA	1MTPA
Storage tank (Loading site)	50,000m3 x2	30,000m3 x1	55,000m3 x4	125,000m3 x1
Shipping Carrier	60,000DWT x2	30,000m3 x1	130,000DWT x4	125,000m3 x1
Storage tank (Unloading site)	50,000m3 x2	30,000m3 x1	55,000m3 x4	125,000m3 x1
Re-gasification Capacity	0.4MTPA	→	1MTPA	→
Receiving terminal	GTCC power station (Japan)	→	→	→
Electric power capacity	400MW	→	1,000MW	→
2.Capital cost (million US$)				
Production and storage	180	230	330	450
Sea transportation	80	100	240	180
Re-gasification and storage	60	110	110	250
Total	320	440	680	880

MTPA: Million Ton Per Annum, N.M.: Nautical Mile, GTCC: Gas Turbine Combined Cycle

Notes;
1.Content of Natural gas; CH_4 91%vol., C_2H_6 7%vol., C_3H_8 2%vol.
2.Ambient temp.; 30 degree C, Sea water temp.; 28 degree C.
3.Hydration Ratio; 90%
4.Filling ratio of NGH pellets; 78%vol. per tank volume

Feasibility study of natural gas ocean transportation chain



Feed gas cost = $1/mmBTU
IRR; Internal Rate of Return (after tax basis)

The advantage of NGH chain over LNG chain in terms of total cost is kept even if the transport amount increases in this study. However, since NGH chain handles bulky cargo, it is considered not so feasible advantageously compared with LNG chain in case of large amount gas transport. When the gas transport amount is more than 2MTPA (3,500 nautical miles), in NGH case, number of the ship is more than 10 units and the navigation interval is less than 3 days, all of which make the transportation pitch narrower.

According to the above findings, gas transport of comparatively smaller amount (less than 1MTPA) by NGH is advantageous over LNG, even more so for the project with smaller demand in the unloading port. NGH, therefore, will provide incentives to the development of smaller gas fields in South East Asian area. NGH pellet, because of its easy handling at -20 degree C, needs smaller cost of storage and acceptance, and is a very appropriate method of supplying natural gas to smaller customers such as independent power producers (IPPs) lying scattered along sea coast and other small gas providers in small cities.

6. UTILIZATION OF DISSOCIATED FRESH WATER

Research was also made for the economical effect of sales on dissociated water from NGH at the unloading port on the total gas cost. It was found that such sales of dissociated water would decrease the total gas cost by $0.1-$0.2/mmBTU based upon $1 for one ton, the international price for fresh water. Use of the dissociated water as supplement boiler water in the power generating plant, industrial water such as washing/cleaning water and tap water can be expected.

7. CHALLENGES

Although the relative superiority of NGH system to LNG system for transport of smaller amount natural gas (of less than 1MTPA) was reconfirmed through this study, some challenges are identified to be solved before the commercialization such as:

1) To establish a method of formation of mixed gas hydrate of higher quality
2) To establish a method of formation of higher density pellet
3) Optimization of decompression system
4) Optimization of pellet cargo handling system
5) Necessity of construction of a pilot plant for confirmation of total system
6) To establish a total cost down for development and spread of NGH system

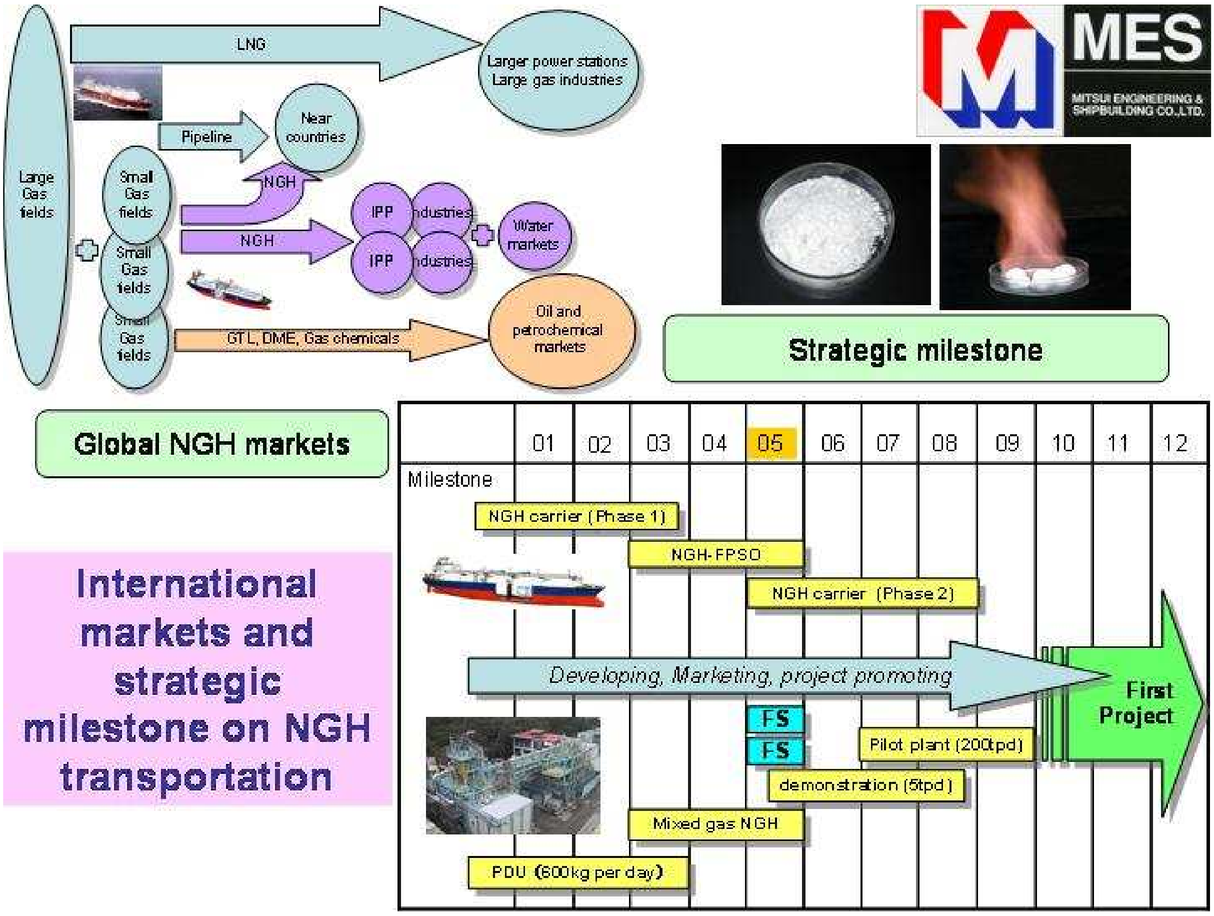
In order to solve the above-mentioned challenges, MES is committed to expedite the development of NGH chain for its commercialization after 2010 through the construction and operation of pilot plant using actual natural gas after 2007 including various kinds' element research and development.

8. DEMONSTRATION OF NGH LAND TRANSPORT IN JAPAN

Agency for Natural Resources and Energy and NEDO are planning to demonstrate NGH land transport system where NGH produced in an LNG receiving terminal is delivered for 50-100km each to small gas customers such as a co-generation system or a community gas company with NGH lorry. This plan is scheduled to start in 2006 up to 2008 (3 years). The main purpose of this project is to expand natural gas use in the rural areas where gas pipelines are not well constructed, and to reduce national CO_2 emissions targeting global worming commitment on Kyoto Treaty.

9. CONCLUSION

As seen from the above, the specific comparison of NGH chain with LNG chain in two cases has proved the advantage of NGH chain in terms of cost by 18-25% in case of transport of 0.4 MTPA (1,500 nautical miles)-1MTPA (3,500 nautical miles).
As the natural gas demand increases worldwide in the future, the development of many small gas fields in South East Asian area etc. is expected to be expedited by the application of NGH system, and further a direct delivery of natural gas to smaller IPPs and other customers is also expected to start.
NGH cold-heat at -20 degree C level is most appropriate for air conditioning and for cooling of shaft bearing and can also be used by gas customer at an unloading port for power plant, clean room etc. Dissociated water, which is a freshwater of relatively high purity, can be used for various industrial purposes and even for tap water after appropriate process treatment including disinfections. NGH will be applied to various projects in the future as a clean urban infrastructure medium in developing countries.
NGH has smaller transport gas density than LNG and is a solid matter containing much water, which fact turns out be fundamentally safe against accidental fire, leakage accident etc. It can be called a safe medium for transport and storage from the dangers of natural disaster such as earthquake, tsunami, typhoon etc. and also from human act disaster such as terrorist attack, military action etc.
As this study has confirmed the economic efficiency of NGH system in certain market, it is the desire of the author that various new projects will be created utilizing the inherent safety and cold-heat characteristics of NGH in the future.



10. ACKNOWLEDGEMENT

We highly appreciate Mitsui Oil Exploration Co., Ltd. (MOECO) for knowledge of the upstream of gas field, Chubu Electric Power Co., Inc. for knowledge of natural gas utilization by GTCC power plant in Japan and Nomura Research Institute (NRI) for comprehensive economical assessment.

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