Natural Gas Processing and Handling

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After last year's US election and the high oil prices, the news has been filled with discussions about clean fuels, energy security, and environmental stewardship. Oddly, these public discussions have omitted natural gas as a clean, plentiful, and efficient energy source. The world's energy needs will continue to be met by fossil fuels in the near term. It is estimated that by 2030, fossil fuels will supply 75% of the world's energy—35% from oil and 22% from gas.

In reviewing articles for this feature over the last few years, it is clear to me that the industry continues to create technology and innovative methods to find and produce gas from both conventional and unconventional sources. Expanding the use of natural gas is clearly not a question of resources. Issues confronting expanded use of natural gas lie in transportation methods, expanding end-user markets, and finding alternative uses for gas. Its use as an energy source continues to evolve around getting the gas from its source to end user. As many gas reservoirs continue to be found in smaller volumes and in remote locations, the way we think about transporting natural gas, processing it, and delivering it to markets needs to go beyond traditional solutions and technology. The magnitude and time lines of new technology and project investments will need to involve not only oil and gas companies, but government co-operation to establish stable end-user markets and clear regulatory direction.

The articles selected for the feature this year provide tantalizing insight into new gas-transportation and processing technologies as well as managing investment in these technologies. The first large-scale commercial gas-to-liquid (GTL) plant being constructed in recent years and due to come on stream by the end of the decade may finally bring GTL to the forefront of alternative-use technologies. Natural-gas hydrates as an alternative transportation method could allow the transport of natural gas in a more economical and environmentally friendly manner. Rethinking decision processes to implement liquefied-natural-gas projects as well as other new gas technologies can minimize risk, shorten project cycles, and optimize economic value. In combination with the articles in the recommended reading list below, this year's feature offers some interesting discussion topics for both our industry and the public news forums. **JPT**

Natural Gas Processing and Handling additional reading available at the SPE eLibrary: www.spe.org

SPE 114921 *• "Gas Monetization for Sustainable Development, the Trinidad and Tobago Experience" by Timmy Baksh, Ministry of Energy and Energy Industries, Trinidad and Tobago.*

IPTC 12111 *• "LNG-Technology Advances and Challenges" by R.R. Bowen, SPE, ExxonMobil, et al.*

SPE 115295 *• "The Generic LNG FPSO—A Quick & Cost-Effective Way to Monetize Stranded-Gas Fields" by W. van Wijngaarden, SBM Offshore, et al.*

Additional reading available at OnePetro: www.onepetro.org

OTC 19551 *• "The Commercial Advantages and Limitations—Onshore vs. Offshore LNG-Import Facilities" by Hans Kristian Danielsen, Det Norske Veritas, et al.*

An Integrated Decision-Management Process Shortens Time to First Gas

The monetization of gas, particularly in liquefied natural gas (LNG) projects, requires large capital investment in most links of the gas value chain from production to end use. Companies that invest in a single component of the value chain, such as nonintegrated gas producers, must understand the value of and risks inherent in every link in the chain, because gas will be priced in relation to its final point of sale. Final sale price as well as the effects of processing and capacity limitations ripple their way upstream to alter the timing, demand, and viability of the upstream investment.

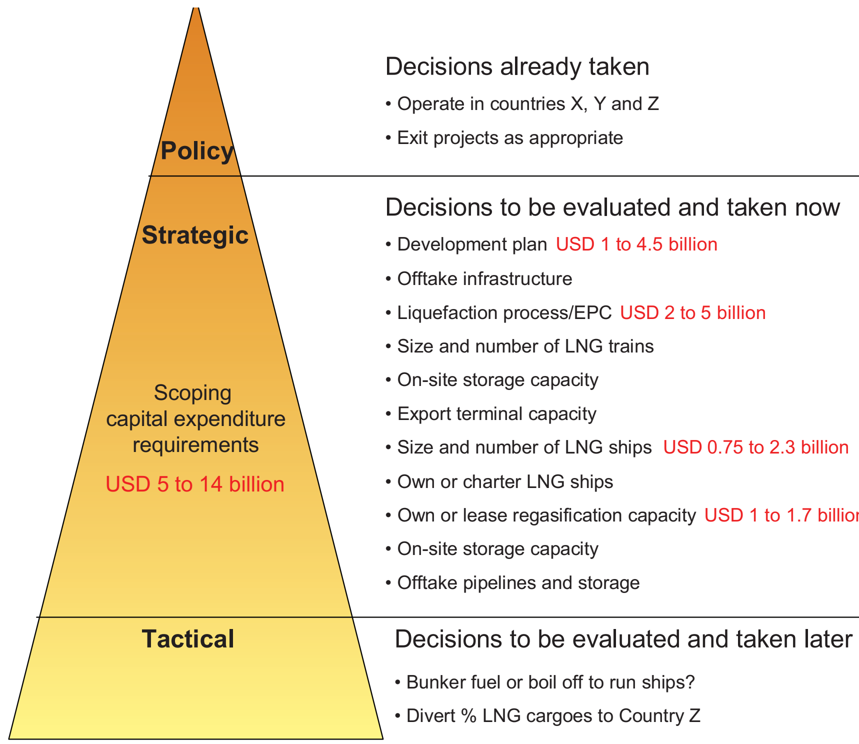

Fig. 1—Integrated LNG chain decision hierarchy; EPC=engineering, procurement, and construction.

Introduction

LNG projects are good examples of complex global gas-development projects with large capital-investment requirements. To build a commercial LNG project from gas production to point of final sale requires investment in and development of several capital projects. These linked or integrated projects serve to produce, treat, transport, and sell the gas in specific markets. These projects are joined in a value chain by at least 16 major commercial contracts, beginning with a production-sharing contract at the wellhead and ending with a gas-sales agreement in the end-use market. The entire set of investment decisions in the LNG chain can be driven by objectives such as the ability to book gas reserves by a certain date, optimizing the entire gas portfolio of assets, and in the case of companies with a portfolio of LNG assets, the potential for arbitrage and the ability to leverage and trade each LNG asset.

LNG projects now have even more complex business chains than 10 years ago, involving multiple investors in various parts of each chain. Successfully commercializing gas in integrated LNG projects and achieving acceptable returns requires numerous investment decisions. Building such a chain involves high-level coordination and integration of both technical and commercial processes, the option of reducing costs through increasing throughput, and leveraging economies of scale to reduce plant costs.

Companies participating in or operating the LNG chain also must have the financial strength to make the approximately USD 5 to 14 billion investment required to build out the gas business chain from discovery to delivering gas in the end-use market. Increasing project costs are adding uncertainty to already complex LNG value-chain projects. Uncertainties in costs, coupled with the ever-present uncertainties of gas price and changes in regulation in supply and receiving countries, increase the investment risk and can delay investment decisions. Additional delays in the time to first gas for an LNG project can affect the value of the project negatively and may result

This article, written by Assistant Technology Editor Karen Bybee, contains highlights of paper SPE 115251, "Reducing Time to First Gas: Lessons Learned in Expediting and Informing International Investment Chain Decisions," by ***Deborah D. Resley,*** *SPE, and* ***Christopher Reinsvold,*** *SPE, Decision Strategies, originally prepared for the 2008 SPE Asia Pacific Oil and Gas Conference and Exhibition, Perth, Australia, 20–22 October. The paper has not been peer reviewed.*

For a limited time, the full-length paper is available free to SPE members at www.spe.org/jpt.

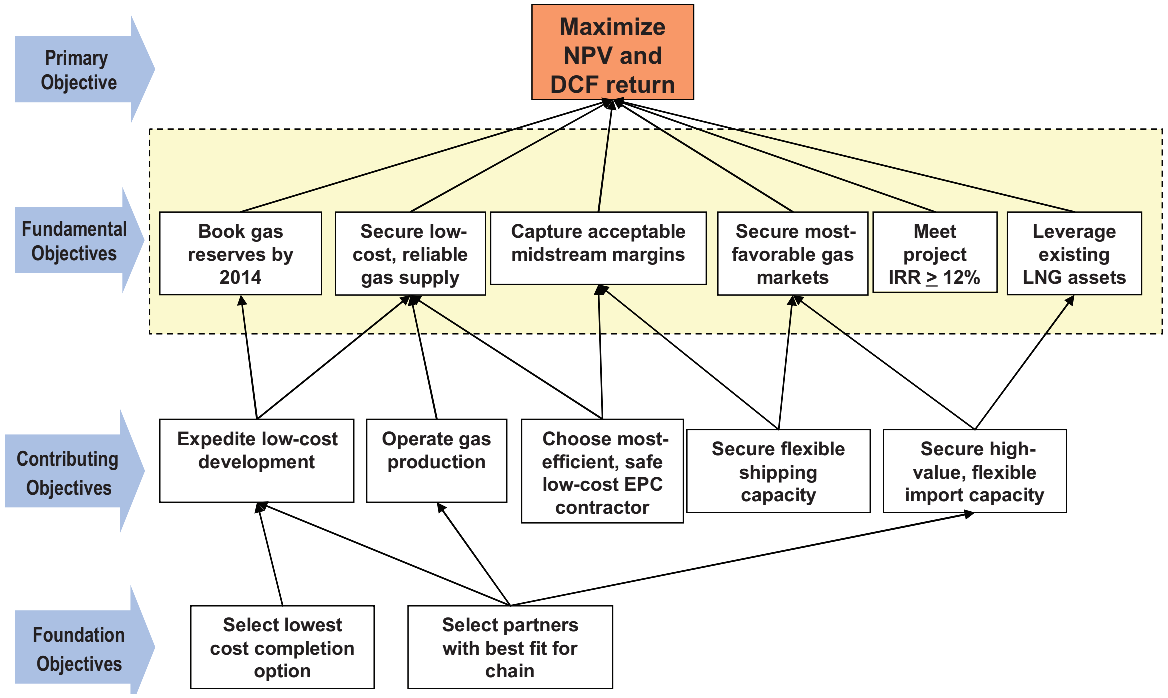

Fig. 2—Example objective hierarchy.

in missing a competitive gas supply or demand window.

The shortest time reported for a greenfield LNG project from gas-field discovery to end use of the gas produced is approximately 6 years, held by the Egyptian LNG Train 1 project for gas offshore Egypt sold into France. Most LNG projects take much longer, generally at least twice as long. The reasons for the extended time are numerous, involving technical and contractual alignment of all of the individual projects in the chain.

Major Investment Decisions

Decision Heirarchy. Decisions can be defined as the irrevocable actions that commit resources to either one course of action or another. To focus on the most important issues to be evaluated in any investment, decisions can be categorized and ranked in importance and immediacy as policy decisions, strategic decisions, and tactical decisions. These can be illustrated by a decision-hierarchy triangle, such as shown in **Fig. 1.** Policy decisions are made at corporate level. These decisions are ranked highest and normally have been made before the LNG project evaluation takes place, and they typically affect the balance sheet, and speak to the political and financial risk appetite of a company. Strategic decisions can be either at business-unit, portfolio, or project level, and have a capital- and operating-expenditure effect as well as a revenue component. Tactical decisions can be made at a later date, once the strategic decisions have been made because they are a level of detail below strategic-level detail.

Uncertainties are defined as quantities that currently are unknown and cannot be known for certain until sometime in the future, typically after the investment decision has been made. The effect of uncertainties on decisions is variable and can be quite high. In general, the single most-important factor influencing the decision to develop the integrated LNG project will be gas price at the end-use market. However, price will be the most uncertain and the least controllable factor in the entire project-development scenario. Considering the strategic investment decisions listed in Fig. 1, the uncertainties for each decision in each stage of the integrated gas chain can be identified.

Evaluating Investment

Two distinct approaches to the problem of investing in major capital projects such as an integrated LNG project are the traditional, or advocacy approach and the decision-centric approach.

Advocacy Approach to Investment. The traditional approach to decision making is to "forecast the future" through the use of a business case with specific fixed assumptions and business context. An advocacy-led analytical approach typically relies on a project sponsor who champions a proposed solution on the basis of a situation analysis of the problem. Then a discrete value for the decision is calculated on the basis of assumptions and forecasts and by use of a discrete discount factor. The resulting business case for solving the problem is presented to decision makers in an advocacy style, where the project sponsors advocate their choices of the input parameters used to measure the value of the investment to justify the business case.

Often, decision makers ask for a review of the assumptions and forecasts, plus other performance-related input variables, and a new evaluation or set of evaluations is required. The re-evaluation process can be and often is repeated until agreement is reached by the decision maker. Some of the adverse tendencies in using the traditional advocacy-led approach can include diving into a solution without first understanding the problem, solving the wrong problem or failing to explore options, centering on suggested numbers or events, relying too heavily on recent information or events, not seeing or understanding the real level of uncertainty, generalizing a decision on the basis of similar situations, the inability to estimate correctly the probability of occurrence, and failing to manage the group decision process around traps.

Decision-Centric Approach to Investment. In the decision-centric approach to investment, the range of important alternatives and the value of each are evaluated before seeking agreement. The discovery and screening of the investment opportunity is done up front to clarify the situation, define the investment opportunity, and clarify the objectives. Alternatives are created by subject-matter experts within the investing firm, and their value is evaluated. With each stage of the process, insights are created that help to focus the evaluation. Unlike the advocacy approach to investment, which assumes a discrete outcome, decision, or inquiry-based analysis, decision-centric-based evaluations generally use a probabilistic, or stochastic, approach that uses a range of values and associated probabilities for each input parameter as identified by subject-matter experts. The value of the investment is measured against its likelihood or probability.

Methodological decision-analysis processes form the basis of the decision-centric approach. These processes uncover interests and goals of all stakeholders, identify the key uncertainties and decisions to be made, generate creative alternative approaches, evaluate these alternatives in such a way as to identify the key risks and uncertainties, and implement the approach with the highest chance of achieving the objective or objectives. Decision quality is achieved when the decision being made is appropriate in scope and perspective; it compares several real alternatives, not just justification of a predetermined decision; it incorporates credible, honest information from appropriate experts, recognizing their degree of confidence and uncertainty; it has the appropriate balance of cost vs. benefits, risk vs. return; it uses a logical analysis that is comprehensive, insightful, but focuses on critical questions; and it gets organizational "buy-in" and a commitment to implementation of the final recommendation. Decision analysis should align with other business processes in an overall integrated-decision-management approach.

Recommended Approach for LNG Chain

In integrated LNG projects, the conditions for justifying an advocacy-led approach to investment cannot be met because of the multiple and dependent, or interrelated, uncertainties inherent in each decision. A clear, unbiased, and integrated decision-centric approach both optimizes the investment and shortens the time to first gas because it eliminates recycling and re-evaluation of each investment decision as well as other "analysis/paralysis" type of traps.

Both the investment objectives and strategic decisions in an LNG project are examined in the earliest stages of the decision-centric approach. Following construction of the decision hierarchy (Fig. 1), an objective hierarchy for the investment can be produced **(Fig. 2).** In this example, the primary objective is to maximize both net present value (NPV) and return on discounted cash flow (DCF) to the project sponsors. Underpinning the primary objective are contributing or fundamental objectives. These objectives include securing a low-cost, reliable gas supply; capturing acceptable midstream margins; securing the most-favorable gas markets; keeping the project internal rate of return (IRR) greater than or equal to 12%; and leveraging existing LNG assets in the portfolio of the project sponsors through arbitrage or trading the LNG assets.

Conclusions

Given the complexity, integrated nature, large number, and the high impact of uncertainties in investing and developing a greenfield LNG project, assessing or planning investment by use of an advocacy-led approach is not optimal. A decision-centric approach that considers each of the strategic investment decisions against the overall objectives and uncertainties can align these decisions and demonstrate the risk/reward of each. Further, this approach is best used in the early stages of LNG project development to manage and evaluate uncertainty, particularly uncertainties that are outside of the direct control of the investor. Such a process gives stakeholders the ability to gain additional insights before committing contractually. The key investment decisions and their attendant uncertainties require full analytical rigor and then can be ranked and prioritized to expedite development and preserve value. In approaching the LNG project-investment issue in this way, project stakeholders profit from a strategic, holistic approach that clarifies the decisions that need to be made and considers their uncertainties and alternatives. **JPT**

Pearl GTL—Assuring Success From the Beginning

The Pearl gas-to-liquid (GTL) plant will be the largest energy project in Qatar. In spite of various challenges that are intrinsic to such a project, Shell and Qatar Petroleum are confident of managing construction successfully. Offshore activities include drilling wells and constructing platforms and pipelines. Onshore, the detailed design is nearing completion, and procurement activities are proceeding.

Introduction

The Pearl GTL project is fully integrated upstream/downstream in Ras Laffan Industrial City, 80 km north of Doha. It will have capacity to produce 140,000 B/D of GTL products, including fuel oil, naphtha, kerosene, normal paraffin, and lubricants, as well as 120,000 bbl of oil equivalent per day of ethane, liquefied petroleum gas (LPG), and condensate. The project is being developed in two phases, with the first phase expected to start up in 2010. Overall, it is more than 50% complete.

Project Description

Upstream, the project involves offshore development of a North Field block to produce approximately 1.6 Bcf/D of gas. The offshore scope includes 22 development wells, two unmanned wellhead platforms in 30 m water depth and two 60-km-long 30-in. pipelines to shore. Onshore gas-processing facilities will treat the sour, rich wellhead gas to produce a sulfur-free, lean-gas feedstock for the GTL plant and treated ethane, LPG, condensate, and pure elemental sulfur as a by-product.

The project uses proprietary Shell GTL technology, with 15 years of operational experience at the Bintulu, Malaysia, GTL plant. Although Pearl is approximately 10 times the size of Bintulu, scaleup was achieved by replicating smaller units, such as multiple parallel reactors, to minimize technical risk. A startup methodology has been applied from the outset, whereby potential problem conditions and flaws are identified and addressed.

Work began in February 2002 with a scoping study. Project authorization was granted in July 2006. To counter constraints in the engineering, procurement, and construction, including a shortage of capacity in many areas and rising prices, a contracting strategy was applied that aimed at giving access to a wider range of contractor resources and creating competition, while retaining close control over areas in which proprietary technology was involved.

Offshore Development

The engineer, procure, construct, and install contract for two wellhead platforms was awarded in June 2006. The main initial focus was on the jackets and temporary drilling decks, which were installed in 28 to 35 m of water in March/April 2007 to allow early drilling activities. Meanwhile, work continues on fabrication of the two 2000-tonne topsides to meet the planned offshore-installation schedule once drilling is completed. Trenching/dredging began in 2008, and a pipe-laying barge is expected in early 2009.

Offshore development drilling began mid-2007 and uses sequential batch-drilling. A newly built and fully automated drilling rig is designed to support simultaneous drilling and perforating/stimulating that should result in significantly fewer rig days per well compared with conventional drilling.

Onshore

The onshore project represents approximately 90% of the scope. The onshore project is split into 13 asset-development teams, each working with a different contractor. In executing this design, the technical and process interfaces between the packages, approximately 3,500, must be managed. A Web-based system has been crucial in identifying and closing these interface issues.

The quality of the design has been scrutinized in 3D-model reviews through the various stages of design development. Factory acceptance testing has started in Scotland, where 900 control cabinets will be tested with logic comprising 600,000 software-tag points and 120,000 physical inputs and outputs.

To facilitate the logistics effort, a material-offloading facility was constructed by Pearl GTL in the Ras Laffan harbor. This facility avoids considerable road transport. Some equipment, such as the giant GTL reactors, requires special transport provisions. Twenty-four 1200-tonne GTL reactors are required. Each reactor contains 29,000 1-in. tubes, a total length of 340 km per reactor.

In total, more than 35,000 people are working on the Pearl GTL plant, drawn from more than 50 nations. Early in the project, it was identified that looking after the construction workers was a priority, and hence a residential area, Pearl Village, was constructed, capable of accommodating in excess of 40,000 workers. It has been crucial to ensure that every worker is fully aware of the safety standards expected on site. Therefore, a safety-training center was built in Pearl Village. Safety training involves induction for everyone and

This article, written by Senior Technology Editor Dennis Denney, contains highlights of paper SPE 118290, "Pearl GTL—Assuring Success From the Outset," by ***Andrew Brown,*** *Qatar Shell GTL, prepared for the 2008 Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, 3–6 November. The paper has not been peer reviewed.*

specific skills training for life-critical activities. Also, a behavioral-safety program called Incident and Injury Free was launched, involving everyone on site to ensure that everyone goes home safely every day. Reinforcing safety, but also quality and productivity, a 9-day supervisor leadership training course has been established, targeting the 5,000 supervisors on Pearl GTL.

Progress

Achieving a smooth transition from construction to commissioning and startup, followed by ramp-up to full capacity and achieving the operational performance set out in the project economics, is a challenge for any large oil and gas project. To meet the challenge, lessons learned from Bintulu GTL were used. Several proved industry best practices and proprietary methodologies also were deployed. These include

- Standardizing the preparation of commissioning, startup, and production processes
- Full and rigorous implementation of established startup procedures through all project phases
- Implementation of operational-excellence programs before startup

An extensive flaw database, containing lessons learned from all kinds of projects (including the Bintulu GTL project), complemented by the experience of the contractors involved, has been applied through all project phases. More than 3,000 flaws are scanned systematically and more than 10,000 known root causes of failures have been eliminated. These concepts have been applied deep into the supply chains in response to the overstretched markets where quality assurance is under pressure.

Detailed commissioning and startup-testing programs aimed at achieving a faster startup were defined. These programs cover specific items of equipment, as well as entire systems, and include testing on benign fluids such as water before the introduction of hydrocarbons. To understand system design and functional integrity, the performance requirements and characteristics of each system were defined in an asset-information database. Structured reviews for all conceivable operating conditions are carried out to assure the functional integrity of each system. A high-quality, multipurpose dynamic simulator was developed to verify design-control strategies, pretune controllers, and identify critical dynamic tests in commissioning. This simulator will be used to train panel operators. The asset-work register defines all critical activities that must be performed during the lifetime of the project to ensure safe and reliable operation. It includes the asset-reference plan, which describes the turn around cycles. The asset-work register sets out required procedures and routines, including job aids, checklists, and step-by-step work instructions.

Summary

The project remains on track, despite its size and complexity. Care for the welfare and safety of the workforce is a key value to the project team. Meanwhile, a rigorous approach to prepare for startup as well as an early focus on recruitment, training, and development of operators and technicians provides confidence to expect the project to produce as planned after startup. **JPT**

NGH Chain: Gas-Transportation Concept

In general, long-distance liquefied natural gas (LNG) transportation projects are economically feasible for very large natural-gas reserves volumes. Japan Oil, Gas, and Metals National Corporation and Japanese engineering companies have focused on natural-gas hydrate (NGH) as a gas-transportation concept. It is important to consider optimizing the process and to understand the effect on the chain and optimize the entire NGH chain.

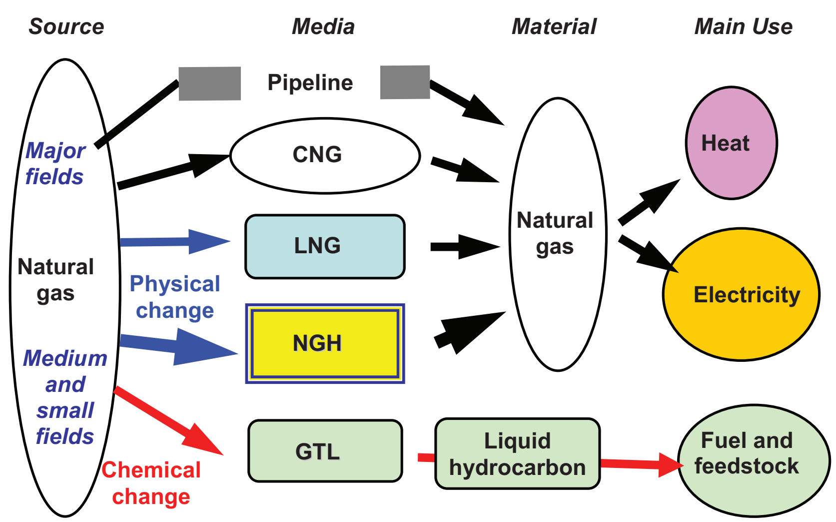

Fig. 1—Gas-transportation concepts. CNG=compressed natural gas. GTL=gas to liquids.

Background

Many medium and small gas fields within 6000 km of Japan are difficult to develop by conventional techniques, such as LNG and pipelines. NGH may be an economical gas-transportation method. NGH contains 170 times the gas volume compared with liquid or gaseous states. Therefore, initial cost of the NGH process is estimated to be less than that for LNG.

LNG transportation is economically feasible for long-distance transportation. Pipelines are suitable for relatively-short-distance transportation because of higher capital cost. NGH transportation is a solution for small-to-medium-scale or remote gas fields, as shown in **Fig. 1.** Feasibility studies shown in **Fig. 2** indicate that NGH transportation has an economic advantage for suitably sized gas reserves and transportation distance.

Several systems have been developed to form NGH, including the bubbling/stirring-type formation reactor, the water-spraying-type formation reactor, and a hydrate-formation system that uses microbubbles with a tubular reactor, which obtains a higher formation rate than the other systems. Further improvement is needed in the precision of the feasibility study along with advances in technology.

This article, written by Senior Technology Editor Dennis Denney, contains highlights of paper IPTC 12807, "NGH Chain: A New Gas Transportation Concept," by ***T. Kawasaki, K. Bando,*** *and* ***Y. Suehiro,*** *SPE, Japan Oil, Gas, and Metals National Corporation, prepared for the 2008 International Petroleum Technology Conference, Kuala Lumpur, 3–5 December. The paper has not been peer reviewed.*

Conceptual Design

The purpose of this study was the life cycle carbon dioxide ($LCCO_2$) analysis of natural-gas transportation to Japan as NGH. In the selected model, natural gas is converted to NGH at the production plant and delivered to Japan by an NGH-carrier ship from existing undeveloped natural-gas fields in coastal areas of Southeast Asia. The base case production rate was 1×10^6 tonnes/a of LNG equivalent with a transport distance of 6000 km. The study presumed that the gas would be used in a power plant.

$LCCO_2$ Analysis

The scope of investigation includes processes between the production facilities (including inlet-gas treatment) and the regasification facilities.

$LCCO_2$ Emissions of LNG Chain. The scale of 1×10^6 tonnes/a of LNG equivalent is so large as not to be considered a proven LNG project. On the basis of previous reports, the carbon dioxide emission is linear with respect to the scale of LNG volume. The $LCCO_2$ emission of 1×10^6 tonnes/a LNG chain was extrapolated from data of $LCCO_2$ emission vs. LNG volume. The $LCCO_2$ emission of 1×10^6 tonnes/a LNG chain was determined to be 0.574×10^6 tonnes/a.

$LCCO_2$ Emission of NGH Chain. The $LCCO_2$ emission of NGH was split into three major components: NGH

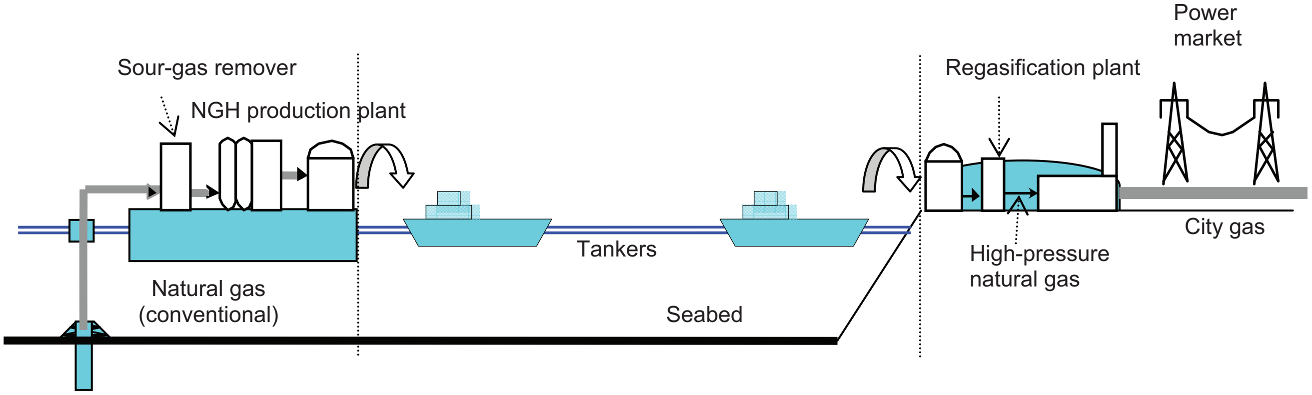

Fig. 2—Concept and research system of NGH transport chain.

production systems, including inlet-gas treatment; NGH transportation; and NGH regasification systems.

NGH production systems include production and loading processes of NGH onto an NGH carrier at the loading jetty. The NGH-carrier concept is based on a refrigerated bulk carrier, which has an enclosed cargo-hold system to store NGH at –20°C under atmospheric pressure. NGH regasification systems include an unloading process of NGH from the NGH carrier and a regasification process.

Results

The study showed that the total $LCCO_2$ emission for the NGH chain would be 0.479×10^6 tonnes/a, 17% lower than for a similar LNG chain. Elemental facilities of the NGH production system are composed of general-purpose equipment for high-pressure use, but can be procured with relative ease. Although $LCCO_2$ emission from NGH carriers is 4 times that of an LNG carrier for an equal amount of natural gas, the higher storage temperature of NGH pellets enables the use of a less expensive carrier.

Sensitivity Analysis

It was recognized that there is large uncertainty in the generating efficiency, transportation distance, hydration ratio, refrigerating system, and NGH formation facilities, in descending order. Although each parameter range has a different feasibility risk, the focus was on enhancement of the parameters of transportation distance, hydration ratio, refrigerating system, and NGH formation in the feasibility study and the development of technologies of NGH chain to achieve the practical use of NGH chain.

Conclusions

In this study, the advantage of an NGH chain was confirmed under certain conditions. The chain included NGH production facilities, four carriers, and regasification facilities. The transport distance was 6000 km. The total $LCCO_2$ emission for the NGH chain was 17% lower than for a similar LNG chain.

NGH technology has interesting potential for monetizing small-to-medium-scale or remote gas fields in the range of $1–3\times10^6$ tonnes/a gas production and transport distance to the user of less than 6000 km. In the near future, improving the precision of the feasibility study will be needed along with advancing technology development to determine the extent of NGH-technology potential to compete effectively with LNG technology. Therefore, it is important to consider optimizing the production process and to understand the effect of the process on the chain and optimization of entire NGH chain. **JPT**