Prospectus

LNG: The Expanding Horizons of Liquefaction Technology and Project Execution Strategies

Nexant

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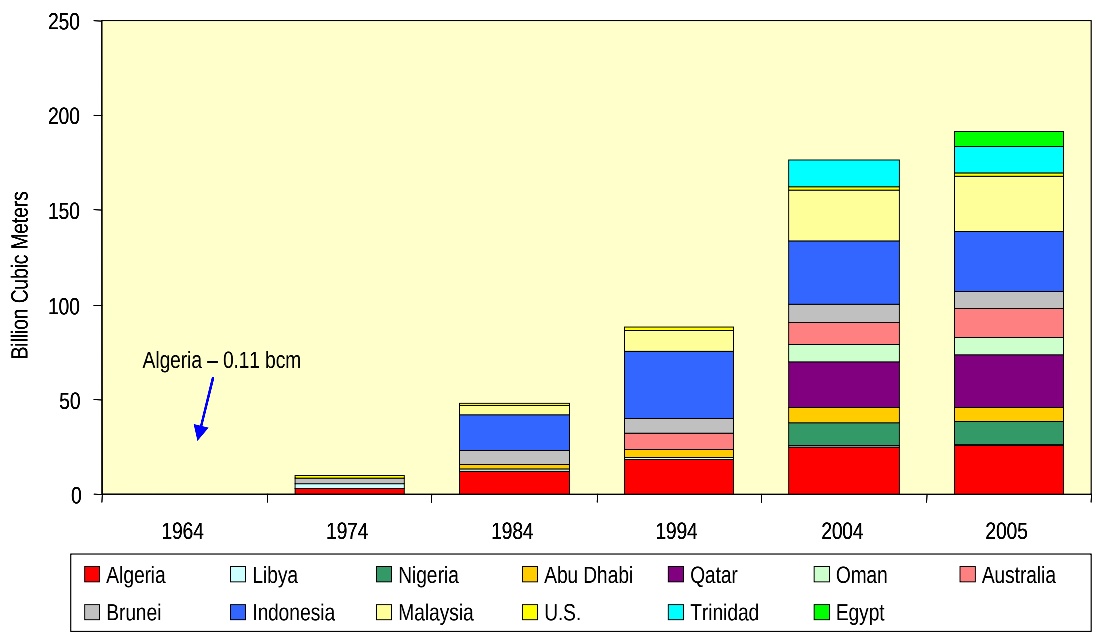
1.1 DEVELOPMENT OF THE LNG INDUSTRY

Methane was liquefied in the laboratory as early as 1877 and the U.S. Bureau of Mines demonstrated natural gas liquefaction in 1917 in association with helium recovery. A decade later, the first commercial liquefaction project was developed at the CAMEL (now GL4Z) plant in Arzew, Algeria. The first commercial LNG shipment from this plant was made in 1964 to the Canvey Island terminal in the United Kingdom. LNG has since developed into a global trade where LNG tankers move liquefied natural gas at -160°C between liquefaction plants and distant LNG terminals where the gas is revaporized for sale into local markets.

LNG is generally a more economic form of gas transportation than pipelines for distances over 3,000 km and is employed to move gas from reserves in distant or stranded fields to developed world markets.

Since its initial commercialization in 1964, the LNG industry has expanded significantly to the point today where it represents over 25 percent of the internationally traded volume of natural gas. LNG is currently produced in 13 countries, as shown in Figure 1.1, to supply markets in 15 countries.

Figure 1.1 Development of LNG Exports: 1964 – 2005



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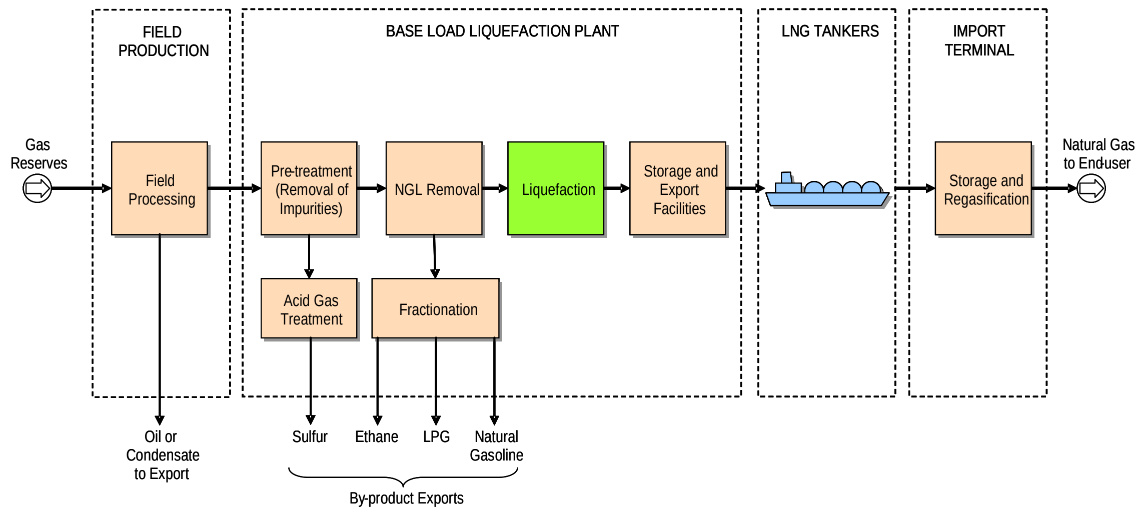
The international trade of LNG expanded at an impressive annual average growth rate of about 8 percent since the mid-1990s. During this time, LNG has moved away from being a niche premium fuel to a mainstream source of supply of natural gas.

Part of the reason for the growth of LNG has been attributed to advancements in liquefaction technology, a critical component of the LNG value chain and of this study.

1.2 GAS LIQUEFACTION

Liquefaction forms the central element in the LNG supply chain, as shown in Figure 1.2, although it should be recognized that all elements are critical in supplying gas to market.

Figure 1.2 The Role of Liquefaction in the LNG Chain



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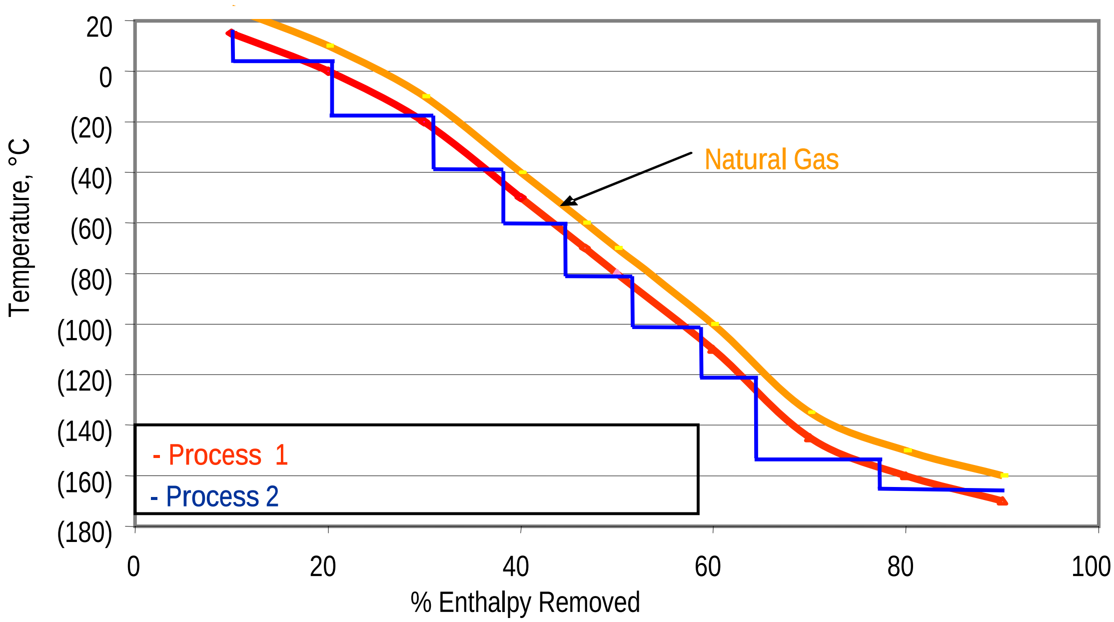
The fundamental process used for liquefaction of natural gas is mechanical refrigeration where the gas is cooled and liquefied by heat exchange with a separate refrigerant. A number of licensed processes have been developed over the last four decades based upon this fundamental principle. Besides seeking to reduce investment and operating costs, the primary objective of these technological innovations is to optimize the efficiency of the cooling or refrigeration process employed to liquefy natural gas. Figure 1.3 shows an indicative cooling curve of a natural gas with the temperature profiles of two routes to liquefaction superimposed (pure component cascade and mixed refrigerant).

For commercial liquefaction processes, the objective is to minimize the difference between the refrigerant curve(s) and the natural gas cooling curve in the most economical manner but yet will produce the most LNG from the plant over a period of time, taking into consideration plant availability and reliability issues.

Figure 1.3 Indicative Cooling Curves



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The first two base load LNG plants that were completed in 1964 and 1969 utilized variants of cascade liquefaction technology. From the early 1970s through the mid-1990s, the mixed refrigerant liquefaction technologies dominated the liquefaction market. Since the completion of the first train of the Trinidad Atlantic LNG project in 1999, however, the liquefaction technology market has been much more competitive, with an optimized cascade technology remerging as a viable route to liquefaction in recent years.

Over time, liquefaction process licensors have also implemented innovations in attempts to improve efficiency and optimize costs of the two dominant technologies. The most significant recent and emerging technological developments include:

- Mixed Fluid Cascade Technology (MFC). The first plant using this process is being installed on the island of Melkoya near Hammerfest in Northern Norway. This single train plant uses plate-fin and spool wound cryogenic exchangers. This will also be the first Base Load LNG plant to use electric motors to drive the refrigeration compressors.
- Dual Mixed Refrigerant Technology (DMR) This process will be used at the Sakhalin LNG plant in Russia now under construction and is employing spool wound cryogenic heat exchangers.
- Propane PreCooled Mixed Refrigerant Plus Nitrogen Expander Technology (AP-X™). This process is being used in mega projects that are presently under construction and will employ large LNG trains with 7-8 million tons per year of capacity.

At present, technological developments and project execution approaches to develop greenfield projects or to expand existing liquefaction capacity are focused on the following key issues:

1.2.1 Train Size Optimization

The size of the LNG liquefaction train has grown steadily over time as developers seek to realize economies of scale in order to achieve lower liquefaction unit costs (the same approach is currently pursued for LNG shipping). At the present time, the capacity of the largest train under construction is about 8 million tons per year (MTPA). These large sized plants will push turbine drive and compressors to their physical limitations using existing standard technologies. As these units have become larger, the risks associated with equipment mechanical reliability will also increase.

A key issue to be addressed in this Study is: "what is the optimal train size under the current industry standards and market conditions?"

1.2.2 Choice of Compressor Drivers

Many of the older liquefaction plants use steam turbines to drive refrigerant compressors. This type of driver is available in wide power and speed ranges and can easily be adapted to refrigerant compressors. Newer plants have opted for industrial gas turbine drivers primarily to reduce capital costs through the elimination of steam generation and boiler feed water treatment facilities. In addition, the widespread adoption of industrial gas turbines for power generation is such that their reliability has improved sufficiently for them to be considered for base load LNG plants.

However, gas turbines are only available in discrete capacity ranges, thereby forcing the refrigeration cycle to be designed around the available gas turbine power. More recently, in order to minimize the impact of discrete turbine sizes, there has been interest in the use of electric motors for driving the refrigeration compressors.

Therefore, the choice of compressor drivers is another important issue that must be addressed by project developers, and will be discussed in this Study.

1.2.3 Gas Quality

Considerable analysis is in progress to determine the optimum application of liquefaction technology according to the quality of the feed gas initially and over time. This analysis is closely linked to the C_{2+} content of the gas and the availability of refrigerants to be used in the gas cooling cycles.

Experience has demonstrated that a specific technology has a comparative advantage over other technologies when constrained by a gas supply of a certain quality/composition. Assessments have also demonstrated the possibility of improved project viability due to the availability of NGL recovery in some LNG plant designs as opposed to others that cannot justify extraction units because of the lean quality of the feed gas.

Technology choice as it relates to gas quality will be reviewed in this Study.

1.2.4 New Project Execution Strategies

The present critical shortage of engineering and project management services, skilled labor, equipment, materials, and commodities are having a serious impact on the execution of projects. As a result, project developers are seeking alternative strategies and approaches for contracting and implementing engineering, procurement and construction (EPC) services. These include:

- Lump-sum turn key bids
- Cost reimbursable bids
- Cost reimbursable with bonus/penalty
- Bid cost reimbursable front-end with conversion to open book lump sum
- Negotiated Awards
- EPC Management

In the current environment of tight engineering contracting and equipment supply and the corresponding cost challenges that this creates, the need to sustain the competitiveness of LNG supplies to gas markets requires a closer, critical look at the technology and execution strategy employed in every segment of the LNG value chain.

The volatility in commodity and equipment pricing and the high level of worldwide engineering and construction activity is placing unprecedented strains on available EPC (engineering, procurement, and construction) resources, which affects more than LNG project costs and economics. Thus, proper planning and implementation of large projects, such as baseload LNG complexes, are more important than ever.

The alignment of the objectives of the project owners with those of the contractors must address factors such as local client needs, gas composition, and labor availability and contractibility, in addition to project budget, schedule, design, and turnover.

While there are advantages and disadvantages to each approach, it is imperative that all stakeholders understand and thoroughly review the premises that must be tailored to project specific objectives and constraints. That is, the owners, EPC contractors, and LNG technology licensing teams must ensure that the engineering designs meet project intentions while remaining within the boundaries of project constraints.

The gas liquefaction technology developments and the search for competitive LNG project EPC contracting strategies are among some of the key issues that this study will focus on.

2.1 STUDY OBJECTIVES

The objectives of this new Nexant LNG study are to undertake the following:

- Technology Review – A review of several of the liquefaction technologies available and a comparison of technologies on a like-for-like basis.
- Commercial Assessment – Comparative breakeven of LNG prices for each of the evaluated liquefaction technologies.
- EPC Contracting Strategy Review - A review of project execution approaches to establish whether these can reduce cost and/or schedule.

2.2 SCOPE AND ISSUES ADDRESSED

The scope of the study is outlined below.

2.2.1 Technology Evaluation

Nexant will undertake a detailed review and assessment of the status of the various process routes. The study will provide a simplified process flow sheet, brief description of liquefaction technologies currently available, and provide some in-depth investigation to the following liquefaction technologies for larger size trains (the basis for any technical comparisons will be the utilization of a lean feed gas with the plant set in a tropical environment):

2.2.1.1 Review of Liquefaction Technologies

Cascade Process

- Optimized Cascade

Mixed Refrigerant Processes

- Dual Mixed Refrigerant
- Multiple Mixed Refrigerant
- Mixed Refrigerant with Propane Precooling and Nitrogen Sub-cooling

A technology evaluation will be undertaken using representative values for such parameters as gas composition, feedstock volume, ambient conditions, operating envelope, etc. The effectiveness of each technology will be evaluated based on non-confidential information.

Review of LNG Train Optimization

Nexant will undertake a review of the latest developments in LNG technology and the associated equipment supply. This analysis will include a review of the following aspects:

- The choice of compressor drives – large single shaft gas turbines versus electric drives
- An evaluation of the impact of LNG train size to establish the trade off
  - Do the proposed mega trains truly exhibit economies of scale when step out in equipment sizing for the trains and associated infrastructures (shipping and receiving terminals) are considered?
  - Is there a "sweet spot" in regard to LNG train size?

2.2.2 Commercial Assessment

Nexant will provide a general overview of the international LNG market, identifying and discussing the manner in which unique supply and demand characteristics, such as market size and resource endowment, could potentially impact the liquefaction technology selection process, as well as project execution strategies.

Drawing on the technical evaluation and corresponding equipment and features unique to each process, an assessment will be undertaken based on the investment and operating costs developed for each technology. Costs will be developed on a stand-alone basis, and will be based on a representative base load LNG plant with a dry gas feed in a tropical location (e.g., West Africa).

The economic estimates will include:

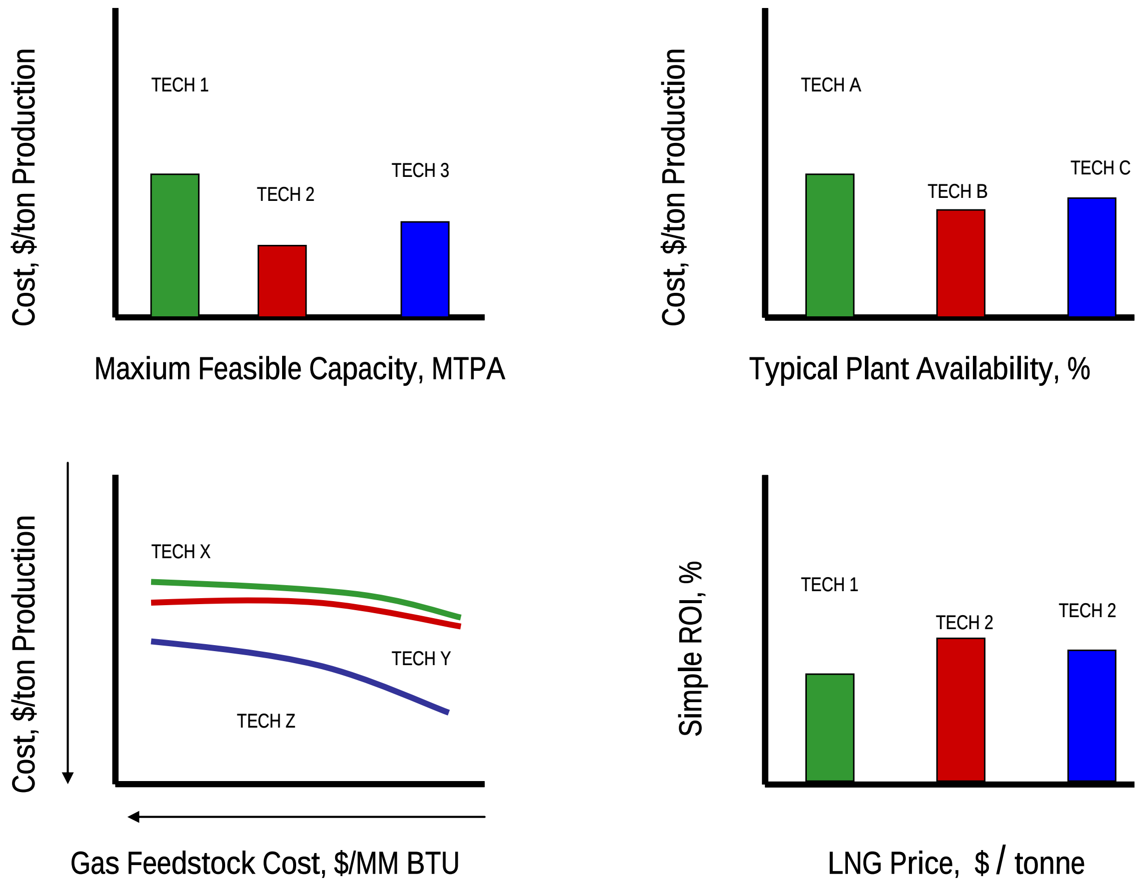
- Installed Capital Costs
  - Direct Costs (major equipment, bulk materials and labor)
  - Indirect Costs
  - Contingency

  EPC Overhead
- Operating and Maintenance Costs (cost of feedstocks and services)
  - Feed Gas
  - Other Materials and Supplies
  - Utilities
  - Labor Costs (operations and maintenance personnel)
  - Maintenance Material
  - General Plant Overheads and Insurance

  Technical and Administrative Service
- ROI and breakeven LNG prices on FOB basis

An analysis of the key advantages and disadvantages of each process according to a variety of operating conditions, such as plant size and gas feed prices, will be carried out in the Study. Illustrative types of sensitivities that may be carried out are shown in Figure 2.1.

Figure 2.1 Sensitivities of the Various Technologies to Commercial Parameters



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2.2.3 Review of Project Development Approaches

Nexant will review the contracting strategies available for the execution of LNG liquefaction projects and the recent trends that have developed in an attempt to optimize the development costs and project schedules.

- Innovative schemes for project planning and execution
- Strategies for aligning project objectives with stakeholder needs
- Templates for replicating successful projects
- Concepts that blend lessons learned with the advantages of new technologies
- Advantages and disadvantages of different approaches
- Rewards and risks

2.3 PROPOSED STUDY CONTENTS

The proposed contents of the study are presented below.

1. Executive Summary
2. Introduction
3. LNG Marketing Overview
4. Methodology
5. LNG Technologies
   - 5.1 Overview of LNG Technologies
   - 5.2 Comparative Technical Analysis of Selected Technologies
   - 5.3 LNG Production to Storage
6. LNG Economics
   - 6.1 Capital and Operating Costs
   - 6.2 Comparative Economic Analysis
7. Project Execution Strategies
   - 7.1 Contractual Approaches
   - 7.2 Project Risks

3.1 NEXANT

Nexant, a leading, global provider of consulting services to the energy and chemicals industries, was established on 1 January 2000. Originally formed from a core group drawn from Bechtel's Technology and Consulting Group, the company has since grown organically and through acquisitions and now totals over 350. In 2001, Nexant acquired the leading refining and chemical consultancy, Chem Systems, which is now fully integrated into Nexant's Oil and Gas, and Chemicals Business Units.

As an independent company with a number of shareholders, Nexant provides impartial advice to clients in the energy sector.

Nexant offers global coverage through its major offices in London, White Plains (New York), Houston, San Francisco, and Bangkok, with project offices in New Delhi, Abuja (Nigeria) and representatives in Singapore, Tokyo and Seoul.

Nexant's consulting services cover all areas of the natural gas business and our gas specialists have a strong track record throughout the LNG chain, both technically and commercially. We have successfully completed a large number of key LNG assignments and are very familiar and up-to-date with recent technical and commercial developments taking place in the different segments of the LNG chain.

3.2 NEXANT'S LNG EXPERIENCE

The following is a shortlist of recent Nexant studies in support of LNG projects.

3.2.1 LNG Liquefaction Experience

- Due Diligence Assessment of Base Load LNG Project – West Africa
- Benchmarking LNG Base Load Capital and Operating Costs – Latin America
- LNG Liquefaction Feed Gas Techno-Economic Assessment
- Advances in LNG Technologies – PERP multi-client study
- Advances in Gas Processing Technology – PERP multi-client study
- LNG Technology Comparison Study – Latin America
- LNG Supply Feasibility Studies – Various countries
- Gas Quality Deliverability Forecasts – Various countries

3.2.2 LNG Terminal Experience

- LNG Terminal Due Diligence Project – Asia Pacific
- LNG Terminal Feasibility Study – Spain
- LNG Terminal Development – Eastern Mediterranean

- LNG Terminal Technical Review - Korea
- LNG Supply Feasibility Studies – Various countries

3.2.3 LNG Project Sponsors and Lenders

Nexant has been the Technical and Market Consultant to the sponsors and lenders on numerous projects, including:

- Gas Consultant – International Gas Tender – India
- Gas Advisor – International Gas Tender - China
- Gas Market Advisor – Middle East LNG export project
- Technical & Commercial Advisor –West African LNG Liquefaction Plant Due Diligence
- Market Advisor – Future LNG development at Ras Laffan for Qatar Petroleum
- Technical and Market Advisor – LNG terminal development – S.E. China
- Technical & Market Advisor – LNG terminal development - Spain

3.2.4 LNG Market Experience

- LNG Transport Study - India
- LNG Competitiveness for South East Asia LNG Supply
- Expert Witness - Commercial Value of Gas Supply – Gulf of Guinea
- LNG Market Evaluation – South Asia

4.1 TIMING

Anchored with Nexant's extensive experience and in-house database, the Study is estimated to be completed by the end of Q1, 2007.

4.2 SUBSCRIPTION PRICE

If subscribed to by/on October 31, 2006, the cost of the report, ***"LNG: The Expanding Horizons of Liquefaction Technology and Project Execution Strategies",*** will be US$19,000.00 (nineteen thousand U.S. dollars). If subscribed to after October 31, 2006, the price will be US$23,000.00 (twenty-three thousand U.S. dollars).

Each subscriber will receive two (2) hard-bound copies of the Report accompanied by an electronic version of the Report presented in PDF format and available by password from www.nexant.com. Additional copies of the Report can also be ordered for a cost of US$500.00 per copy, which represents the costs associated with producing and delivering additional copies.

5.1 CONTACT INFORMATION

Please visit www.nexant.com to authorize engagement of the study or return the following authorization form to one of Nexant's offices listed below.

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1. The undersigned (hereafter "Client") hereby subscribes to purchase from Nexant, Inc. ("Nexant"), Nexant's study, "***LNG: The Expanding Horizons of Liquefaction Technology and Project Execution Strategies"***, in accordance with the following terms and conditions.

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