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Evaluation of utilization alternatives for stranded natural gas

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ABSTRACT

Options for exporting natural gas from stranded oil and gas fields to markets include pipelines, LNG (liquefied natural gas), CNG (compressed natural gas), GTL (gas to liquids), GTS (gas to solids), and GTW (gas to wire). Thus, the key question is which option is the most robust in ensuring the security of investment over a project life cycle against market fluctuations, trade embargos, political changes, technical advances, etc. Excluding pipelines, LNG, CNG, and GTL have attracted increasing investor attention during the last two decades. Although studies abound on economic comparisons of these processes, a systematic method to address this important problem in the presence of uncertainty seems missing in the literature. This work presents such a method based on decision analysis cycle and considers oil and gas prices as uncertain. Using NPV (net present value) as the decision criterion, it presents the computation of "expected NPV" of each gas utilization alternative to identify the best option. It includes the entire well-to-market supply chain, from extraction, conversion, and transportation, to re-conversion at the target market. Finally, it identifies the sweet spots for LNG, CNG, and GTL alternatives for different reservoir capacities and market distances.

1. Introduction

The world's primary energy demand is increasing at an accelerating rate. This has motivated extensive research on finding and developing new and better energy sources. Although the unconventional energy sources such as renewables will help in gradually shaking the world's reliance on fossil fuels; oil, gas, and coal will continue to dominate as the main energy sources for at least a few decades. Currently, these three resources account for more than 85% of the total world energy needs [1]. Of the three, NG (natural gas) is the cleanest. The lower C/H ratio and thus lower carbon emissions compared to oil and coal along with reduced emissions of oxides (nitrogen and sulfur) and particulates make natural gas environmentally very attractive. More importantly, the cost of processes based on natural gas such as power generation is much lower than those of coal and oil [2]. This economic advantage is growing as policies and/or mechanisms for carbon taxes/credits/penalties are getting implemented by several developed countries. These factors have led to a faster growth of natural gas exploration, processing, and consumption. In fact, they have made it feasible to exploit even the high-cost unconventional NG resources (e.g. CBM (coal bed methane), shale gas, tight gas, gas hydrates, etc.). It is projected that NG demand will dominate coal by 2035 [3].

The increased consumption of NG along with the reduction of the market share of existing sources such as oil have raised the specter of gas supply shortages in many regions. With the emerging demand and new market opportunities, the utilization of gas from offshore and/or stranded gas fields has generated tremendous interest.

The gaseous status of this fuel poses significant challenges in its transport to distant markets. In other words, the disconnection between remote and offshore gas reservoirs and markets has obstructed a fully developed market and globally traded commodity status for NG [4].

NG trade for a long time has been through pipelines and limited to supply countries and their neighbors [5]. Its transport in the liquefied form (LNG) as an alternative to pipeline began in 1960s mainly as a result of serious energy demand in countries (e.g. Japan) remote from the supply resources. The 600-fold volume reduction on liquefaction made it economical to ship NG to such countries using dedicated LNG carriers. In such instances, pipelines were either technologically impossible or economically unattractive [6]. The introduction of LNG as a new NG utilization alternative has significantly fostered global NG trade.

Although pipelines and LNG have been the two most common methods of natural gas transport from large gas reservoirs, a significant portion (between 30 and 80% of proven and potential NG reserves) of NG is still trapped in the so-called "stranded" category

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[7,8]. The utilization of gas from such fields is not economical due to the high investment required for pipelines and LNG. Besides, natural gas utilization is a “must” rather than an “option” for oil fields with associated gas [9]. Traditionally, the associated gas has been often flared and/or re-injected. However, due to the increasing awareness of environmental impact of flaring, the oil and gas industry has reached a point where developing a new field without solving the problem of associated gas is impossible. For this reason, extensive research is underway to develop alternative gas utilization options for monetizing remote NG. These alternatives include compressed natural gas (CNG), gas to liquids (GTL), gas to chemicals (GTC), gas to solids (GTS) and gas to wire (GTW). In this regard, a key question is how to select the best option that offers security of investment over the project’s life cycle against market fluctuations, trade embargos, political changes and/or technological advances [10]. In this work, we analyze and evaluate three options, namely LNG, CNG and GTL, which have increasingly attracted investor attention during the last two decades.

Thomas and Dawe [10] reviewed possible NG utilization and transport options. Their study was primarily a qualitative investigation of most the available alternatives and analyzed the pros and cons of each technology. Deshpande and Economides [11] compared CNG and LNG. They defined various thermodynamic scenarios for CNG compression and refrigeration, and studied their effects on the economics of the entire value chain. Subero et al. [12], using the available data on CAPEXs (capital expenditures) and OPEXs (operating expenditures), compared the attractiveness of CNG and LNG and identified the distance thresholds below which CNG was more attractive than LNG. In another study, Economides et al. [13] further developed the model by Subero et al. [12] to justify the attractiveness of CNG over LNG for small gas reservoirs.

Some studies have compared GTL with LNG. Economides [14] performed an economic comparison between LNG and GTL considering different crude oil and gas price scenarios. Some distant markets were used as case studies. Dong et al. [15] compared GTL and LNG then concluded on the commercial viability of GTL, but did not report their economic model. They claimed that while a GTL facility is more complex, less efficient and more expensive than an LNG facility, their end-to-end supply chains are quite comparable and, thus, a decision to invest in either is challenging. They suggested that other factors besides CAPEX, such as technology risks, plant availability, local markets, political considerations, etc., may also be important in LNG vs. GTL decision-making. Recently, Al-Saadoon [16] considered different CAPEX and OPEX scenarios and assessed the economic viability of GTL plants. However, the study did not link oil and gas prices to CAPEX and OPEX, and thus did not result in an integrated economic model.

Several studies have focused on specific regions such as Canada’s Newfoundland [17], USA’s Gulf of Mexico [18–20], Iran’s South-Pars [21–23] and Russia’s Sakhalin Island [24]. These studies considered the markets around these specific regions and investigated the feasibility of various gas utilization options and developing a utilization strategy.

Other studies have focused on deep offshore gas reservoirs requiring floating production units such as FPSOs (Floating Production Storage and Offloading) [25–27]. They have investigated the feasibility of different gas processing options overboard of floating platforms. In contrast to onshore development, offshore field development faces the extra constraints of weight and layout. Alvarado et al. [25] evaluated a combined oil/gas production FPSO with LNG, CNG, and GTL. The study investigated the weight of each process and the feasibility of integration with oil production. As explained earlier, this is essential for preventing undesirable gas flares. Wagner [26,27] technically and commercially compared LNG-FPSO and CNG-FPSO development for a specific gas reservoir capacity. He used a simple payback approach with a wide range of assumptions and reduced accuracy. His analysis exhibited the highest ROI (return-on-investment) for CNG.

While several other case-based publications [28–33] addressing gas utilization or monetization alternatives are available, a systematic approach for quantitatively analyzing these technologies under uncertainty and considering reservoir capacity, distance-to-market, CAPEX & OPEX, oil/gas price uncertainty, etc. does not exist in the literature. The main aim of this paper is to develop a decision analysis (DA) approach for assisting gas reservoir owners to identify the most appropriate gas utilization option for a specific field. In this study, we carry out a comparative feasibility analysis of LNG, CNG, and GTL using cash flow NPV calculations. We use the DA cycle method to link the various stochastic parameters (e.g. oil/gas prices) and other variables.

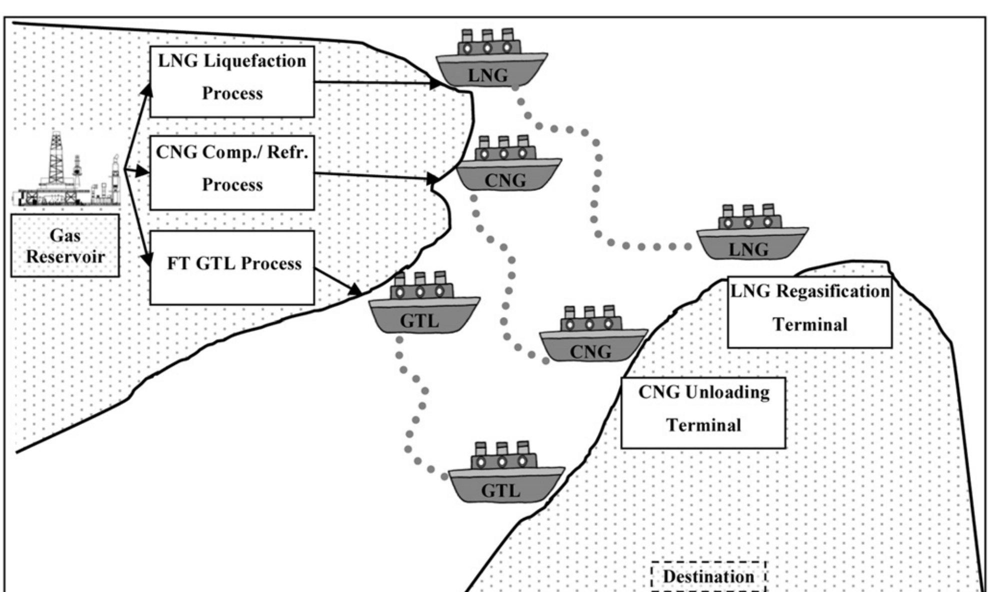

Fig. 1. A remote gas reservoir with three potential utilization alternatives.