GASES TO LIQUIDS (GTL)

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Summary

Natural gas reserves have significantly increased since about the 1980s. A remarkable fraction of this remote reserve remains too far from the international market to be economically transported using conventional technology limited to pipelines and LNG (Liquefied Natural Gas).

Global sources of remote natural reserves gas are identified along with the main options

to allow for the high amounts of energy contained in to be moved economically to the market. Among these options, chemical conversion-before transportation-of natural gas to liquid (GTL), using Fisher-Tropsch process, is reported to be most promising on the basis of its current level of development and its potential future improvements.

The two main components of Fisher-Tropsch process are carefully examined; namely synthesis gas generation and its subsequent conversion to clean petroleum fuels. Different methods of producing synthesis gas are described. This includes: steam reforming (SR), non catalytic partial oxidation (NCPO), auto thermal reforming (ATR) and combined reforming or two-step reforming (TSR) Chemical reactions underlying the Fisher-Tropsch process are presented with trends of developments in the GTL technology.

Commercial applications of GTL technology worldwide are cited. Positive impact of GTL on the environment is emphasized because of two reasons:1st the clean-burning properties of the produced diesel fuels, 2nd converting natural gas to liquid allows oil-producers to utilize the natural gas that would otherwise be flared and pollute the atmosphere

1. Introduction

Natural gas is four times more expensive to transport than crude oil. Converting remote sources of natural gas into liquids can reduce significantly the costs associated to the transport.

Natural gas can be used as a feed stock to produce bulk petrochemicals; in particular methanol and ammonia and other down-stream products. However, this approach represents a relatively small usage of the gas reserve with limited markets.

Liquid and other petroleum products, on the other hand are cheaper to transport and market using the existing system of shipping either by tanker or pipeline.

New technology is being developed and applied to convert natural gas to liquids, known as *GTL*. The key influences on the competitiveness of the GTL approach are the following factors:-

- Cost of capital investment.
- Operating costs of the plant
- Cost of feed stock
- Anticipated scale of production and the ability to achieve high utilization rates in production.

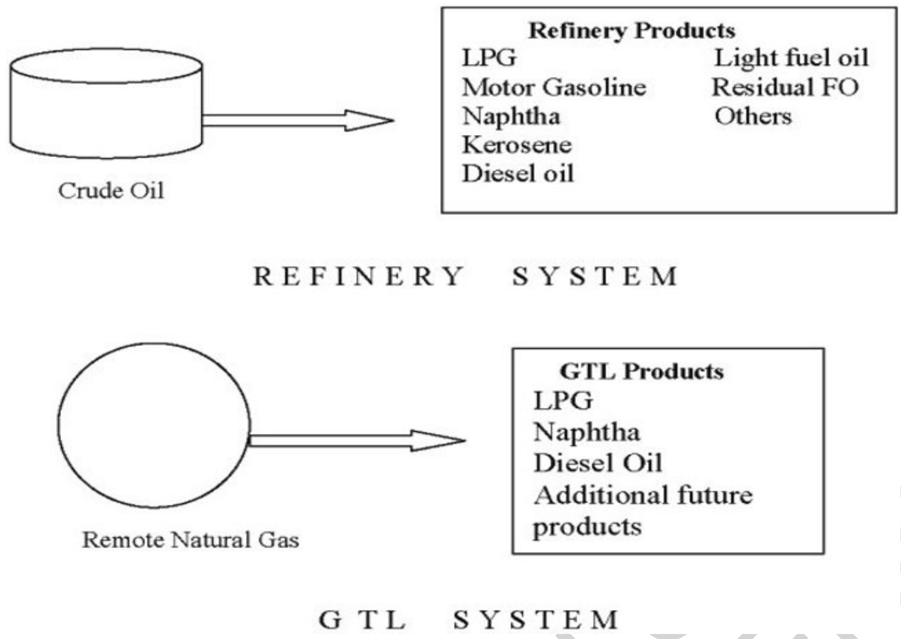

Figure 1. Comparison between Refinery Set-up and GTL System

GTL not only adds value by utilizing remote natural gas, but capable of producing superior products that can be sold or blended into refinery products. GTL, however, is not competitive against conventional oil production unless the gas has a low opportunity value and not readily transported.

A comparison between the output of a conventional refinery and GTL system is illustrated in Figure 1.

2. Exploitation of Remote Reserves of Natural Gas

2.1. Overview

The difficulty of moving remote natural gas to the market in a profitable way can be comprehended if we know that many important gas fields are very far from the main international market. The following are some specific examples:

1. Sakhalin area (Russia) is about 3,000 km from Tokyo (Japan)
2. Bonny area (Nigeria) is about 8,000 km from Rotterdam (The Netherlands)
3. Abu Dhabi fields (U.A.R.) are about 11,000 km from both Rotterdam and Tokyo

In addition, large gas reserves exist in Qatar, Iran, Saudi Arabia, Canada and Alaska.

The world's proven gas reserves are estimated at a value of 6000 trillion cubic feet (tcf); while the potential reserve is reported to be around 13,000 tcf. Only a small fraction of the world marketed production of natural gas is internationally traded today.

Of the proven and potential gas reserve, up to 80 % are too far from large markets to be transported by pipeline. Some remote gas reserves are shipped as LNG (Liquefied

Natural Gas) using cryogenic liquefaction which requires expensive insulated and pressurized vessels. Other option is to convert natural gas into chemical products such as methanol which is exported using conventional tankers.

2.2. Available Technological Options

As stated above, the technology currently used in transporting natural gas is limited to two options:-

1st- Shipping of the gas in a liquefied form known as LNG that requires special tankers for transportation.

2nd- Chemical conversion of the gas into a liquid product for example: methyl alcohol (Me OH) that can be shipped by regular tankers.

A different kind of technology for converting hydrocarbon gases to liquids, called gas-to-liquid (GTL) is on the verge of changing the exploitation of remote reserves of natural gas in the world. Many large oil and gas companies are developing expertise in this new field. A few already have commercially operating plants and many have initiated pilot projects.

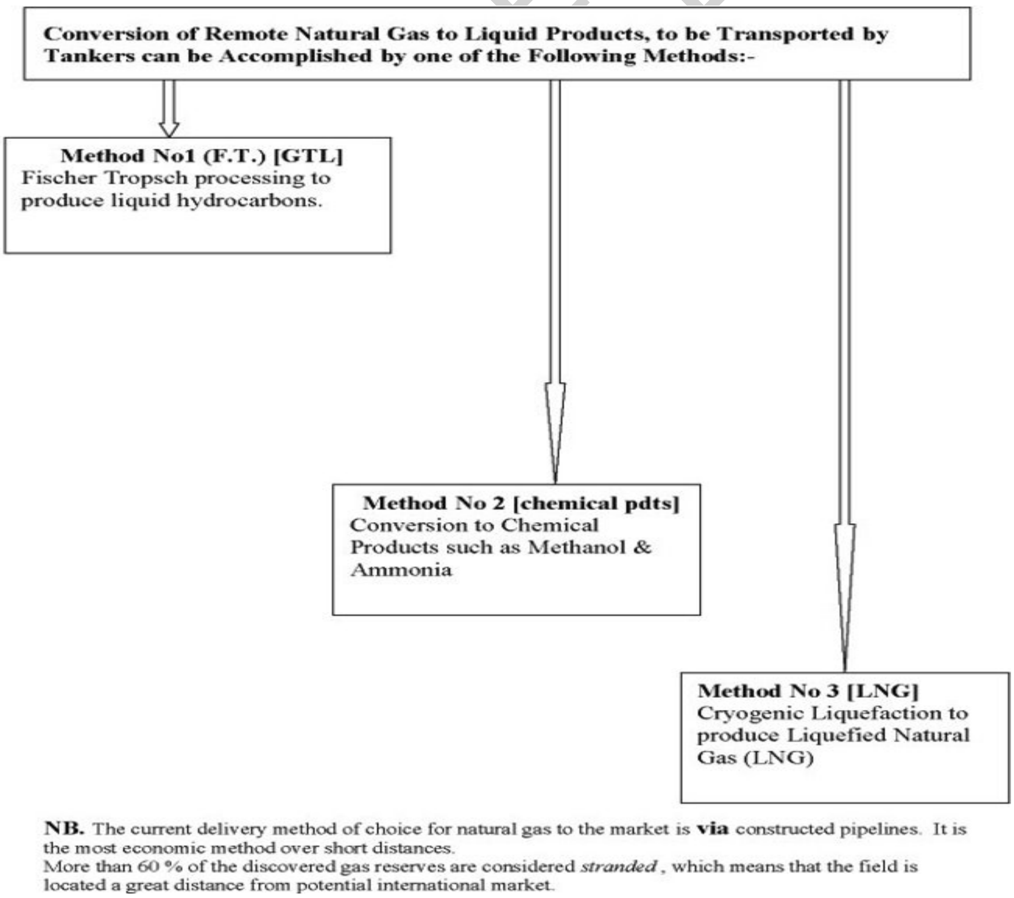

Figure 2. Options Available for shipping Remote Reserves of Natural Gas in Liquid Form

In summary, the conversion of remote natural gas reserves to liquid products to be shipped by tankers is illustrated in Figure 2.

3. GTL Technology

3.1. Thermodynamic Background

The primary objective of GTL technology is to convert natural gas into *clean petroleum products.* In principle, there are two broad technologies to convert natural gas to liquids as shown in Figure 3.

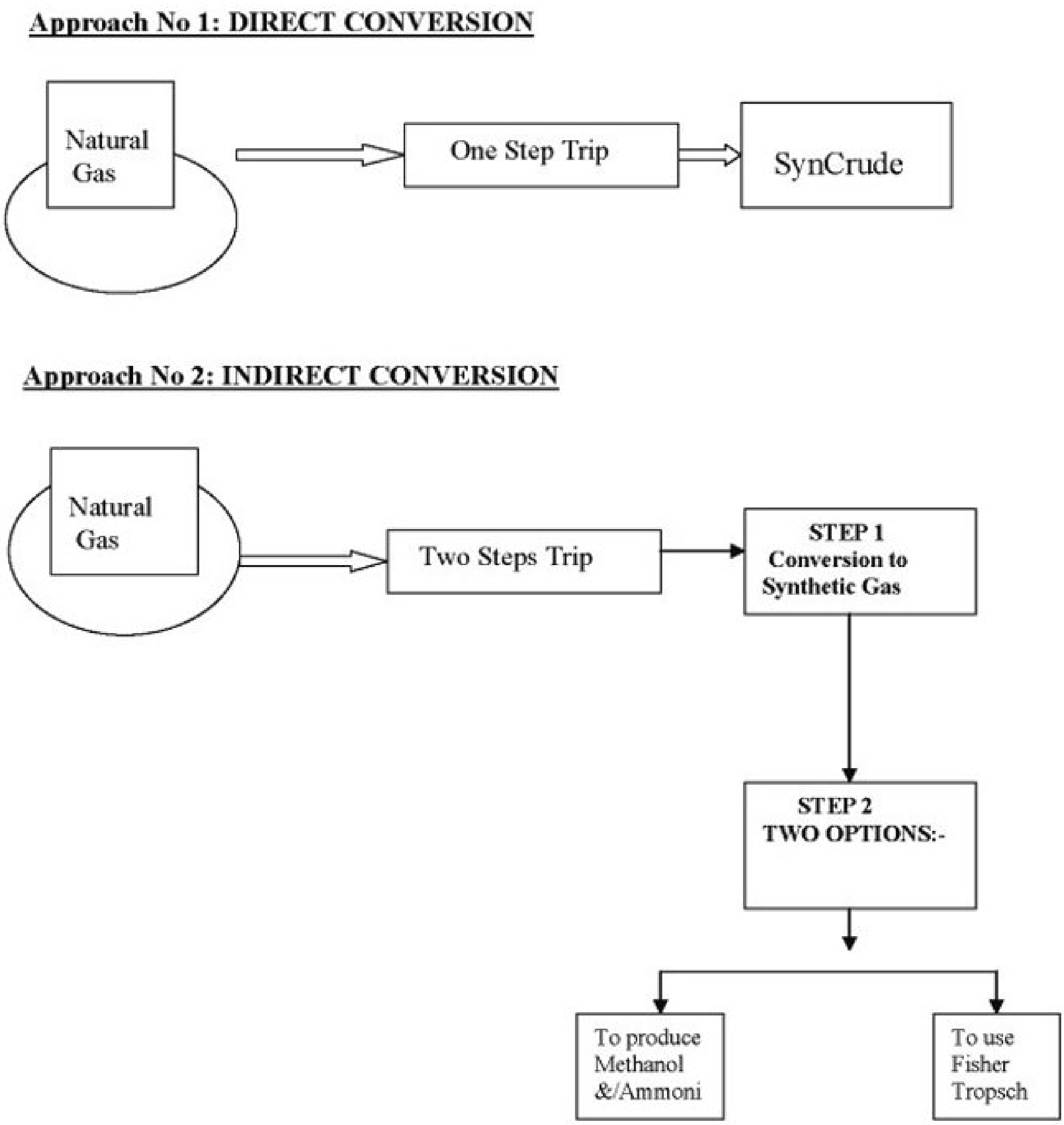

Figure 3. Current Approaches for GTL Technology

These processes are known as:-

A. Syncrude: the direct approach to convert natural gas into what is known as "syncrude"

The direct conversion of natural gas (typically from 85 to 90 % methane), eliminates the cost of producing synthesis gas as intermediate step, but it involves high activation energy and is difficult to control .Several direct conversion processes have been launched, but none have been commercialized; being economically unattractive.

There are a number of problems in turning this direct theory into chemical reality. The catalyst used in the conversion process needs to break the *tight* carbon-hydrogen bonds in the methane. It is known that methane has one of the strongest bonds among hydrocarbons and its reaction products usually have a weaker bond. Consequently, it is rather difficult to stop the reaction at the desired product. The search for a perfect catalyst is continuing. From the thermodynamic point of view, the chemical potential of methane is a significant factor in this domain, as shown in Figure in 4.

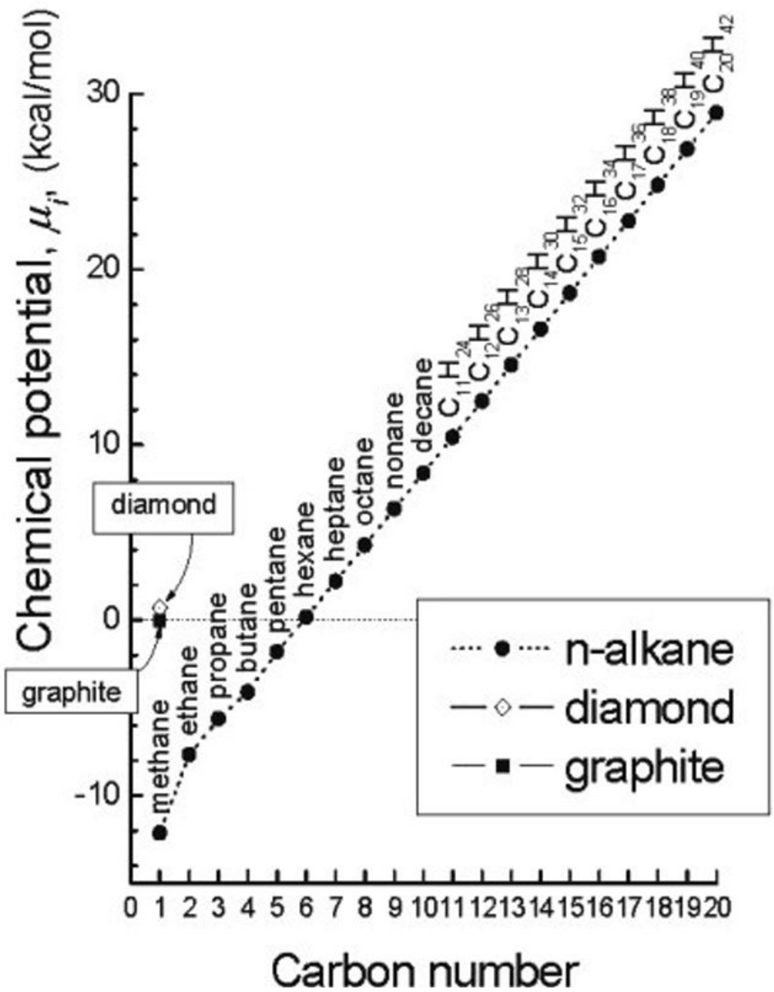

Figure 4. The Chemical Potentials of the n-alkanes at standard T&P

Gibbs defined the chemical potential U of a pure component in the following manner:-

$$U = F = H - TS$$

Where, the enthalpy H and entropy S refer to a single mole of the material. The free energy F for one mole is equivalent to the chemical potential and is perhaps more generally used. However, the latter term emphasizes the existence of a *potential* for the transfer of mass between phases, just as there is a potential (temperature) for the transfer of energy as heat. The activation energy, on the other hand, is given by the well-known Arrhenius equation:-

$$k = (A)\left(e^{-E/RT}\right)$$

Where, k is the rate constant for a chemical reaction, A is the frequency factor having the same units as k and E is the activation energy, which was considered by Arrhenius as the *amount of energy in excess of the average energy level which the reactants must have in order for the reaction to proceed.*

B. Synthesis gas (syngas): the indirect conversion of natural gas to liquids

Instead of carrying a heavy load in one trip, divide it and make two trips. .In principle, the process of converting natural gas into clean petroleum liquids involves basically two steps:-

1st Generation of synthesis gas
2nd Conversion of synthesis gas to petroleum fuels via Fisher-Tropsch (F-T) synthesis.

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Biographical Sketch

Hussein K. Abdel-Aal, born in Egypt, 1935, B.S. CH E, Alexandria University, 1956, M. S. & Ph.D, Ch E, Texas A.& M., TX, USA, 1962,1965. Major field of study: Chemical Engineering.

He has more than 50 years of industrial experience, academic research and university teaching. He was a faculty member at NRC, Cairo, Egypt, 1965-70, Post-Doctoral fellow at UMIST, England, 1970-71, Visiting Professor, Texas A.& M., College Station, TX, 1980-81, Professor at KFUPM, Dhahran, Saudi Arabia, 1971-98. Currently, he is Emeritus Prof., NRC, Cairo, Egypt. He is the author of more than 50 journal publications and two text books: Petroleum Economics & Engineering, Marcel Dekker Inc, 1992 and Petroleum & Gas Field Processing, Marcel Dekker Inc, New York, 2003.

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