Let us speak GNL and GTL

Unlike oil, gas is highly volatile and, consequently extremely difficult to transport. Therefore the most conventional way to valorize gas is to supply a close regional/local heating/electricity market. When it comes to valorize remote gas accumulations in uninhabited regions (steppes Amazon rainforest, arctic regions) located very far from potential markets, gas transportation becomes the key factor.

Over reasonable on-shore distances of a few hundred to a few thousand kilometers, the gas can be regularly re-compressed and transported by pipeline being. However, over greater distances and when it comes to cross seas or oceans, it is necessary to convert the gas into a liquid by cooling it at -160 ° C at atmospheric pressure. Another way consists in converting chemically the gas in a light oil through a process called "Fischer-Tropsch".

However, to be economic, these two processes require significant gas reserves produced at rates sufficient and for periods of time sufficiently long, in the context of long-term contracts.

LNG (Liquefied Natural Gas)
Liquefied Natural Gas or LNG consists of cooling the natural gas down to -160°C at atmospheric pressure to convert it into a liquid for easier storage or transport. In standard conditions (20°C, 1 atm), LNG takes up about 1/600th of the volume of the gas. It is odourless, colourless, noncorrosive and nontoxic. Neither LNG nor its vapor can explode in an unconfined environment. So it can be transported safely in specially designed cryogenic tankers (called “LNG carriers”) which are the most expensive ships in the world (150 to 200 million US dollars each). The LNG is then delivered to a re-gasification terminal where it is reheated and turned into gas to be sent to the distribution network. However given the amount of energy required for liquefaction and transport, LNG has poor GHG performances generating 20% to 40% additional CO_2.

The LNG process uses a similar principle to that of a domestic refrigerator (**Figure 1**). The gas is cooled by thermal exchange with a refrigerant fluid flowing through a closed loop which includes 4 phases: compression, isopressure cooling at room temperature by exchange with air or water, pressure release in a Joule-Thomson valve to cool the circulating fluid then liquefaction of the natural gas by thermal exchange with the refrigerant fluid.

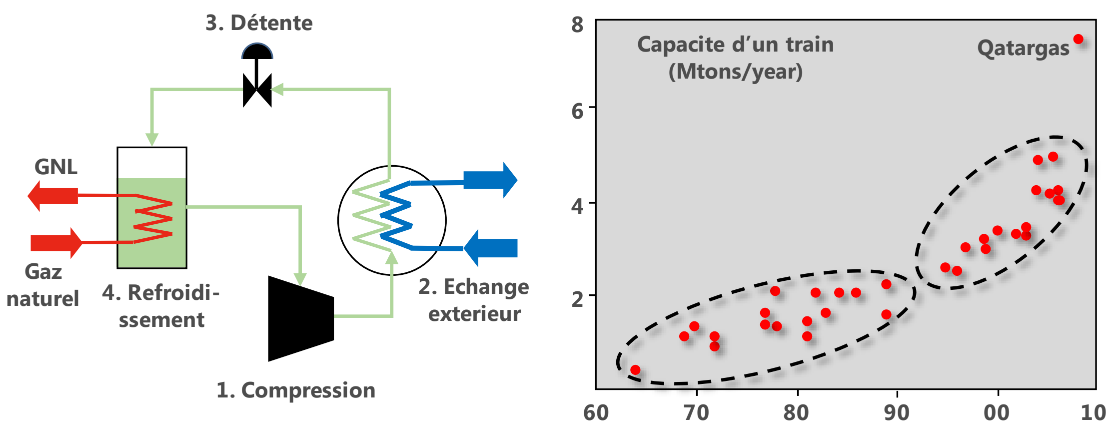

Figure 1 – LNG cooling cycle
Increase in the unit capacity of LNG trains

A LNG plant consists of one or more <u>LNG trains</u>, each of which being an independent unit for gas liquefaction. The LNG industry is by nature highly capitalistic and traditionally involves long-term contracts (20 to 25 years) between a provider and a buyer. The provider will invest massively in a liquefaction plant and will guarantee a continuous supply to the buyer whereas the buyer guarantees the provider the offloading and payment of a certain annual quantity of gas whether or not he has any use for it. To be economic, a LNG train will typically need to produce 4 to 5 Mtons of LNG/year over 20 years, which will correspond to a supply of between 15 and 20 Mm^3/day over 20 years, i.e. proved reserves of between 4 to 5 TCF.

The impact of scale on the cost of the plants has given rise to a race for outsizing. Starting from trains with a unit capacity of 0.3 Mtons/year in 1964 (Arzew in Algeria), the figures rose to 4.9 Mtons/year in 2005 (Damietta plant in Egypt) and 7.8 Mtons/year in Qatar in 2012 (**Figure 1**).

The LNG world market has undergoes a high growth over the last 25 years passing from 50 million of tons in 1990 to 100 million tons in 2000 and 245 million of tons in 2014. Main LNG producer is Qatar with 76 Mtons, main consumers are Japan (88 Mtons) and South Korea (37 Mtons). Very soon USA will export LNG from Gulf of Mexico either to Europe either to South East Asia where it will challenge Russian markets. The LNG US production could reach 80 Mtons in 2030 that is 20% of the total world market.

However, conventional LNG infrastructures do not allow cost-effective monetization for fields that are too far from shore, difficult to access or of limited size. In order to valorize such resources, extensive research[1] has been conducted on the development of mini LNG floating units (1 to 2 Mtons/year) liquefying and tandem offloading[2] in open sea conditions directly on the gas production site (**Figure 2**).

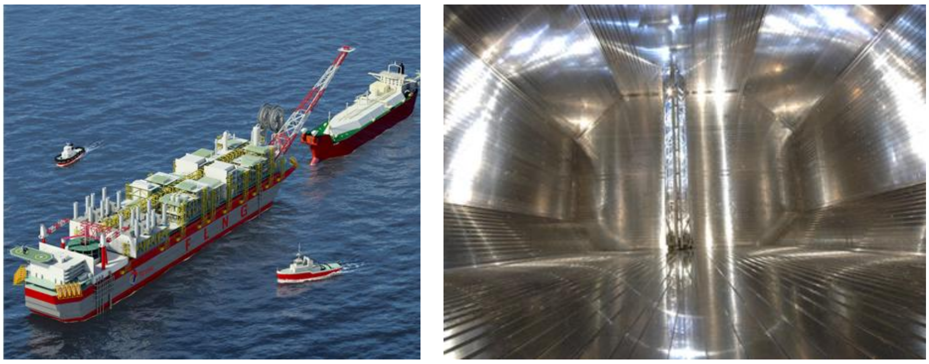

Figure 2 – Synthetic view of what could be a FLNG unit with tandem offloading. LNG storage chamber.

GTL (Gas to Liquid)
The chemical (by contrast LNG is a purely physical process) conversion of natural gas into liquid fuels is an alternative to LNG to possibly unlock remote gas reserves. The process was discovered in the 1920s by two German researchers Franz Fischer and Hans Tropsch. The aim was initially to produce liquid fuels from coal and not from natural gas. Many refinements and adjustments have been made since the original process, and the term Fischer-Tropsch[3] now applies to a wide variety of similar processes. The GTL process can be breakdown into two successive phases. The methane is first mixed with O_2 to produce via a partial combustion[4] a mixture of carbon monoxide and hydrogen which will

[1] P. Cox, E. Jeanneau and J. Eidem (2010) "*Tandem Transfer of LNG – Interface with the Operator*" PP Offshore Technology Conference 3–6 May 2010. OTC-20730

[2] D. Chretien and Th . Jeanneau (2012) "An operator approach to the floating LNG : process, selection and risk management" World gas Conference Kuala Lumpur

[3] http://en.wikipedia.org/wiki/Fischer_Tropsch - cite_note-2#cite_note-2

[4] $2CH_4 + O_2 \rightarrow 4H_2 + 2CO$

be the main reactants in the Fischer-Tropsch reaction according to the following stoechiometric equation:

$$(2n+1)\underline{H_2} + n\underline{CO} \rightarrow \underline{C_n}\underline{H_{(2n+2)}} + n\underline{H_2O}$$

The Fischer-Tropsch process generally takes place in the 150-300°C temperature range. Although the basic idea was launched in the early 1920s, the history of GTL is relatively limited insofar as the process has never been really competitive in an open oil market. During the 20th century, Coal To Liquid (CTL) was mainly developed industrially in countries under an oil embargo such as Germany (peak of 124 kbopd in 1944) during the Second World War and later in South Africa during the apartheid period. South Africa is still the main producer of synthetic fuels, through its company SASOL (160kbopd of both CTL and GTL).

The high cost of the barrel and the necessity to give value to giant remote gas fields should change the situation and make GTL (as well as CTL - Coal to Liquid- and BTL -Biofuel to Liquid-) an important alternative for the next twenty years.

After the medium-scale GTL plant in Bintulu Malaysia developed during the 1990s with a capacity to produce 15 kbopd of high-quality products, was launched in 2006, the "*Qatar Pearl project*" a giant GTL plant to be fed with the offshore natural gas resources of Qatar's North Field. Upon achieving its full capacity, it will convert 1.6 bcf/day of natural gas into 140 kbopd (two trains of 70 kbbls/day) of light liquids.

Compared to LNG, GTL has the major advantage of escaping the severe rules of the gas market and therefore adapts more easily to a discontinuous gas supply. Miniaturization of the GTL process using advanced microchannel reactor and catalyst technologies[5] could prove to be an attractive solution to unlock medium and small size remote gas reserves including flared associated gas which could represents by itself 3 Mbopd of synthetic fuel.

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[5] http://velocys.com/ocge04.php