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Review

Review on global investment on liquefied natural gas (LNG) projects and development: Targeting on reduce flaring, cleaner and energy efficiency

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The importance of LNG to the global energy actualisation, maximisation and utilisation cannot be over-emphasised. These studies describe the liquefaction processes in a modern scope and LNG reviews on global investment and opportunities. The usefulness of this work is on reducing flaring of our abundant natural hydrocarbon that can be transforming into economy values and environmental friendliness. In Nigeria alone, the LNG projects assist the government to generate a huge sum of revenue that is over $200 - $300 million US in a month. While to the global world, the LNG and the reduced gas flaring has an approximate benefit to the tune of $5 billion US in a month. The interest on this study is to serve as an eye-opener to investors in the oil and gas projects because of its viability and high economic advantages in various ways over the conventional hydrocarbon products (gasoline and diesel oil etc.).

Keywords: LNG, NLG, MCHE and PMR, Investment and Flaring.

INTRODUCTION

Natural gases (NG) can be classified as associated or non-associated. The associated natural gases are those that are present with liquid fossil fuel, while non-associated gases are those that occur naturally without any impurities. The various importance uses of natural gas is in lighting cooker/stove and heating houses domestically and industrially use in the high powered engine etc. Interestingly, the exportation of natural gas is increasingly growing, as domestic production has lagged behind this growing demand for this clean fuel. Liquefied natural gas (LNG) processing is typically created using three-step processes Idris et al. (2007). Firstly, the subterranean gaseous-form natural gas is 'frozen' into a liquid state through a complex cryogenic process system (called '*liquefaction*'), this involve temperatures as low as -161 ^{0}C. The essence of the liquefaction process of LNG is to make transportation of natural gas easier, cheaper and convenient (Idris and Abowei 2004). Secondly, after the gas is liquefied, it can be stored in cryogenic holding tanks or pumped directly from the cooling vestibule into special insulated transportation vessels, such as railcars, trucks, or ships. Finally, upon delivery of the vessel to its final destination, LNG is pumped from the vessel into either another cryogenic storage tank for later delivery or directly into a re-gasification unit that uses sea water or air to reheat the LNG in order to convert it back into gaseous natural gas (Idris, 2003).

The LNG processing sounds fluid, but usually is not quite as simple. Raw natural gas can be 'heavy' (also called 'wet' or 'hot' gas) with various higher carbon molecules. These heavier particles create a higher heat content (ranging from 11.28 – 13.66 kWh/m^3) than permissible by many pipeline distribution standards (PDSs). Although this heavier form of gas can be frozen, stored and shipped, the extra heat content may have to be 'stripped off' prior to entering another distribution

Abbreviations

EIA – Energy Information Administration, **FERC** – Federal Energy Regulatory Commission, **HEAI** – Hybrid Energy Advisors Inc., **LNG** – Liquefied Natural Gas, **NLG** – Natural Gas Liquid, **MCHE** – Main Cryogenic Heat Exchanger, **PMR** – Propane Mixed-Refrigerant, **PUCs** - Public Utility Commissions.

Table 1. Comparison of natural gas with gasoline, diesel oil and liquefied petroleum gas, LPG.

Properties	Physical state	Boiling Range (^{0}C @ 1 atm)	Density kg/m^3	Net Content Energy *10^6 kJ/m^3	Auto Ignition Temperature (^{0}C)	Flash Point (^{0}C)	Octane Number Range N_R=(R+M)2	Flammability Limits	Volume % in Air	Explosive limit for Fuel (PPM)
Gasoline	Liquid	26.67 - 215.56	688.79 - 784.90	5.212 - 5.323	232.2 - 482.2	-42.7	87 - 93	L = 1.4	H = 7.6	500
Diesel No. 2	Liquid	160 - 382.2	784.90 - 881.01	5.268	204.4 - 260	51.67	n/a	L = 0.7	H = 5.0	n/a
LPG (HD-5)	Gas	-42 - 0.56	496.57^b	5.519	494.3 - 548.89	73.3 - -65.5	104^c	L = 2.4	H = 9.6	n/a
NG	Gas	-161.67	128.15	5.937	732.2	-148.89	120^c	L = 5.3	H = 14	nontoxic

Source: NRIS (2005)

system to conform to the gas heat standards of the pipeline network Idris (2003).

In the United States, state public utility commissions (PUCs) oversee the gas pipeline heat content standards. It is estimated that the average heat content of current distributable gas in the United States is approximately 10.66 – 10.97 kWh/m^3, HEA (2011). Any gas disseminated into a system that does not conform to these independent standards will not be permitted into the inherent system without the heavier particles being stripped (through a process called '*fractionation*') or diluted with inert gas. This fractionation process is an additional cost to the overall LNG project. Fractionation can occur either upstream or downstream, but is usually contingent upon which location is most cost effective, politically sound, environmental-friendly or where there may be access to a viable purchasing market for the fractionated heavier gas, although guaranteed the economies and long-plant life. Fractionated gas products can either be marketed or injected back into the ground. Any marketing and sales of this heavier gas can serve as a revenue enhancement of or a contra-expense item to the total LNG projects.

In a similar vein, such adopted standards on gas pipeline heat content measurements can be initiated in the Nigeria LNG project through the appropriate Federal Ministries in order to establish resource data for future research and development on the LNG project and all other energy efficiency projects.

The primary aim of this study is to discuss the global investment opportunities in LNG projects and further buttress the cleaner and the environmental friendliness of natural gas over the conventional hydrocarbon products. Once this LNG turns into gaseous gas, it is pumped through a pipeline system that leads to an ultimate market. Natural gases have various important uses which are described as follows:

Domestically

They are use in heating building, heating water, cooking, drying clothes, lightning etc. Household appliances that use natural gas include: heater (furnace), pool and spa heaters, clothes dryers, outdoor lights, barbecues, water heaters, stoves etc.

Industrially

They are use in high powered engine, HPE; transport & locomotive engines etc.

Table 1 represent a detailed comparison of NG with other conventional fossil fuel. From this table it is clearly observed that NG is easy on engine with non-toxic explosive limit. NG gives a longer service life with lower maintenance costs involved. In addition, NG is the least expensive alternative fuel (except electricity) and it has a higher octane rating (Idris et al., 2006).

Table 2 expresses the thermo-physical properties of methane, ethane and ethylene. This comparison is to further represent qualitatively the high grade and environmental acceptability of methane with other conventional fuel products.

THE LNG PROCESS AND OPERATIONS

The Main Cryogenic Heat Exchanger (MCHE) and LNG Production

The MCHE is the liquefaction unit in an LNG process that cryogenise the treated natural gas from -32 ^{0}C to the desirable temperature -161 ^{0}C by a physical process using the principles of appropriate simulation model. The MCHE is the most important and delicate unit of LNG

Table 2. Thermophysical and chemical properties of methane, ethane and ethylene.

Property	Methane	Ethane	Ethylene
Chemical Symbol	CH_6	C_2H_6	C_2H_4
Molecular weight	16	30	28
Normal boiling point (K)	111.7	184.6	169.3
Freezing temperature (K)	89.9	90.6	104.2
Critical temperature (K)	191	305	283
Critical pressure (bar absolute)	47	49.7	52.5
Expansion ratio-increase in volume as liquid as 1 bar abs boil to gas as 1 bar, 15^0C	626	437	489
Density of standard liquid at 1 bar abs (kg/m^3)	424	546	565
Latent heat of vaporisation (cooling potential of phase change) (kJ/kg)	512.4	488.3	483.4
Relative gas density (referred to dry air at 1 bar abs,) 15^0C at density 1.21kg/m^3	0.56	1.05	0.97
Air liquefaction hazard	No	No	No
Spontaneous ignition temperature in air (K)	813	783	753
Flammability limits in air (K)	5 - 15	3 - 12.4	2.7 - 36
Minimum ignition energy (MJ)	0.28	0.24	0.085
Flame temperature (K)	2153	2168	2248
Limiting oxygen index (vol %)	11.5	11.0	11.5

Source: Tiratsoo (1979) and BCC (2004).

process plant, because of it significant values in the LNG processing. The treated and dried natural gas (NG) from the mercury removal unit is further processed and liquefied in the liquefaction unit. The processing includes removal of heavy ends in the natural gas section, to help preserve the life of the process equipment and the quality of the LNG. The essence of the MCHE unit helps in liquefaction of the LNG by one-six hundredth of the ideal volume of treated natural gas for economic and easy transportation overseas (Idris et al., 2006).

However, the LNG production from every process train is strongly influenced by the ambient air and the cooling water temperature. At high site temperatures, the power required to produce a quantity of LNG is greater than that required to produce the same quantity at lower site temperatures. Also, at a high site temperature, the power available from the gas turbines to drive the refrigerant compressor is less than that available at lower site temperatures. These factors result in variations in the maximum LNG production rate from day to night and from season to season Idris and Abowei (2004). Figure 1 represents the flow sheet of the Main Cryogenic Heat Exchanger MCHE) or liquefaction unit of LNG Train, while Figure 2 depicts the existing train of the Nigeria LNG Production unit.

The LNG Energy Efficiency and Opportunity

The LNG energy efficiency can be easily being compared with the conventional gasoline and diesel oil as represented in Table 3. The natural gas which is being liquefied in the LNG plant is an emergent fuel of choice, and considered environmentally friendly, higher economic value and reduced hazard effects.

From Table 3, it is clearly observed that the natural gas production has various advantages over the conventional gasoline and diesel oil. Therefore, for economics, environmental and health advantages, increase in global production of natural gas could give the energy consumption markets greater opportunities.

OPPORTUNITIES AND CAPITAL INVESTMENT IN LNG PRODUCTION

The LNG and the Global Investment

In the year 2012 and beyond, it has been reported that the new LNG-related capital investment would be above $62 billion US as LNG becomes a significant component of the energy industry's marketing strategy HEA (2011). Historically, the price of LNG has been prohibitive when compared to United States (US) gas prices reference. The costs of delivery ranged are $0.726 to $0.871/mkWh range (not including the netback price to the owner of the stranded gas reserves from which the gas was initially purged). Assuming a $0.363mkWh netback to such owner, a total deliverable gas price of around $0.726 to$0.871/mkWh could possibly be attained on a cost

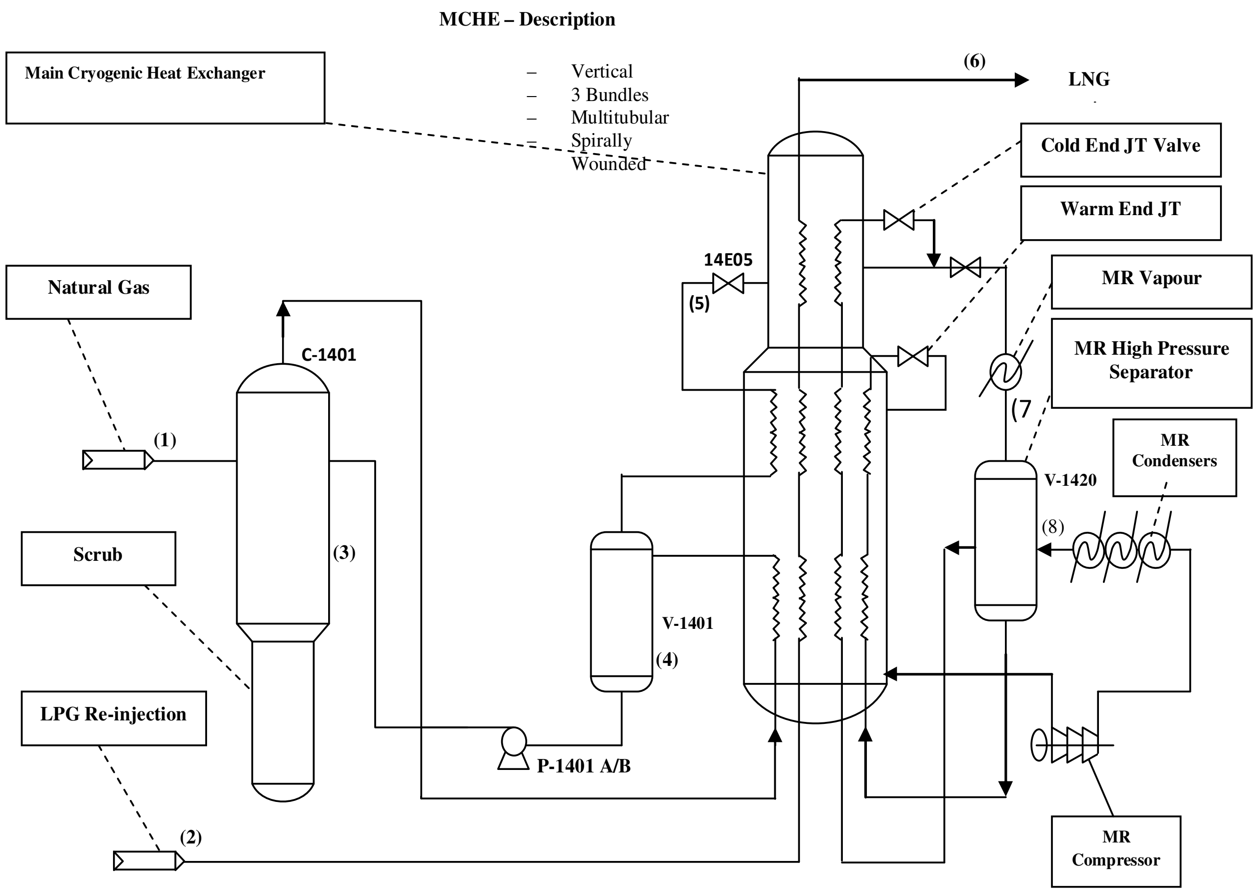

Figure 1. Flow sheet of the Main Cryogenic Heat Exchanger MCHE) or liquefaction unit of LNG Train.

Figure 2. LNG Production train, the Nigeria LNG Ltd. Source: http://www.nlng.com/

Table 3. Fossil fuel consumption per 1.05587×10^{-9} kg of gas emission.

Gases	Natural Gas	Gasoline Oil	Diesel Oil
Carbon Dioxide	52.153	74.828	95.235
Carbon Monoxide	7.710	14.966	9.070
Hydrocarbons	0.635	2.2675	10.431
Nitrogen Oxide	45.350	149.655	378.219
Sulphur Dioxide	0.272	453.500	770.950
Particulates	2.268	37.641	1405.850

Sources: Modified approach to GEH (1965) and HEA (2011).

basis HEA (2011).

In the 1970's and 1980's, physical gas prices had spiked in the US and Europe, feeding fears of gas shortage. This phenomenon inspired the construction of four major LNG import re-gasification terminals, all on the United States East Coast (Everett, Massachusetts MA, Elba Island, Georgia GA, Cove Point, Maryland MD, and Lake Charles, Los Angeles LA, in total constituting approximately 1.05×10^2 billion m^3/day of installed capacity).

However, deregulation led the producers of natural gas to become motivated to explore and develop newer, easy access gas reserves in the mountain states and the Gulf Coast, flooding the market with excess gas inventory. This was exacerbated by Canadian policy changes that allowed increased gas exports, in effect emigrating additional low-cost gas from the Western Canadian Sedimentary Basin (WCSB) to compete for demand in the United States. The result was a gas supply 'bubble' which kept prices very low for quite some time. Imagine how times have changed. Based on the Department of Energy's Energy Information Administration (EIA), it was anticipated in 2011 medium-term Henry Hub gas prices to range from $0.769/mkWh to $0.726/mkWh, and long-term gas prices to be close to $0.871/mkWh.

In analytical forecasting of natural gas prices, one can label the expected gas price a 'dependent' variable and the underlying fundamentals as 'independent' variables that influence the dependent variable. Using quantitative techniques, Hybrid Energy Advisors, Inc. (HEAI) predicted in the spring of 2002 that Henry Hub financial prices, the dependent variable, would range between $3.35 and $4.10 through the winter months of 2002/2003. They also calculated ten-year price forecasts of $0.5445 - $0.6776/mkWh during the summer months and $0.8954 - $1.0285/mkWh during the winter months. HEAI believes that ten-year city gate prices of gas on the West Coast and Midwest United States will trade approximately equivalent ('flat') to Henry Hub prices, and upper East Coast prices to trade at approximately 13.06 – 18.87 basis points (cents/mkWh) above Henry Hub prices HEA (2011). These forecasts include a greater gas import as a percentage of total domestic gas. HEAI forecasted that by the year 2011, approximately 6 - 10% of the total US gas supply will come from LNG produced from foreign stranded gas reserves. In a similar vein, a forecast in the European and Asian gas consumption of similar trend has been predicted.

Today the total cost of LNG production has been quite streamlined and reduced to approximately $0.484/mkWh due to competition and improvements in technology. Much of the technology pertaining to lower-cost land-based terminals and offshore and ship-board re-gasification units are still relatively unproven. However, major energy industry players and engineering firms do not foresee problems with the design and implementation of these methods HEA (2011).

Therefore, assuming a netback of $3.44/mkWh, the total delivered price of approximately $10.45/mkWh can now be theoretically achieved. This LNG price is almost $3.44/mkWh less than a decade ago. When comparing this new price to industry average price forecasts for Henry Hub and East and West coast city gates, LNG can certainly be considered an economical source of natural gas supply.

The Nigeria LNG Gas Reserve and Reduce Flaring

Nigeria is highly blessed with massive reserves of associated and non-associated gas, estimated in excess of 160 trillion cubic feet (tcf). It is ranked amongst the 10th largest in terms of proven natural gas reserves in the world, and its natural gas reserves / production is estimated at 109 years. The expert geologists has forecast that there is a lot more gas still to be found, if companies deliberately explore for gas, as opposed to finding it by chance whilst in search of oil NLNG (2012). Unfortunately, Nigeria is one of the biggest gas flares in the world, in spite of the associated environmental hazards of gas flaring. The government is, however, working to achieve a target of zero flares in the near future. It is expected that all the NLNG trains, including the proposed Train 7, operating at full capacity will play a significant part to help put out these flares NLNG (2012).

The Nigeria LNG and the Progress So Far

The Nigeria LNG Ltd remains the largest consumer of the associated gas in the Nigeria gas project through the stakeholders companies (NNPC, SPDC Shell Gas B.V., Total LNG, and ENI International). A brief of the stakeholders are described as follows:

The Nigerian National Petroleum Corporation (NNPC) was established in 1977 under the constitution of the Federal Republic of Nigeria. It is the corporate entity through which the Nigerian government participates in the oil and gas industry. NNPC and its subsidiaries dominate all sectors of the industry - exploration, production, refining, pipelines, marketing, crude /product exports, and petrochemicals. NNPC owns 49% of the shares in Nigeria LNG Limited.

The Shell Gas B.V (SGBV) is a company incorporated under the laws of the Netherlands. Besides its interest in Nigeria LNG, Shell Gas and Power has interests in many of the world's major LNG production companies including those in Brunei, Malaysia, Australia and Oman and is one of the Royal Dutch Shell Group of Companies which operate throughout the world in all aspects of the petroleum industry. It sells over 80 billion cubic metres of gas yearly. SGBV owns 25.6% of the shares in Nigeria LNG Limited.

Total is a major integrated oil and gas company active in all aspects of the petroleum industry. Total explores in 25 countries, and has reported proven reserves of 3,639 million barrels of oil equivalent (492 million tons). Of these, crude oil accounts for 71% and natural gas for 29%. Total owns 15% of the shares in Nigeria LNG Limited.

Eni is a fully integrated oil and gas company engaged in all aspects of the petroleum business. Eni is involved in exploration, development and production of oil and natural gas. Eni owns 10.4% of the shares in Nigeria LNG Limited.

Currently, the Nigeria LNG Ltd is made up of 6-functional cryogenic plant in Bonny Island, Rivers State. Other proposed LNG projects include Olokola LNG and Brass LNG among others. The Nigerian Gas Company currently caters for Independent Power Producers, and local industries in Lagos and other parts of the country. The proposed West African Gas Pipeline Project (WAGPP) will make gas available to other West African countries for domestic and industrial uses.

MAJOR SUPPLY AND DEMAND ZONES OF LNG

New technologies in LNG and the upward gas price trends are creating the opportunities for re-gasification terminals to spring up in a variety of areas. These areas include the United States East and West Coasts, Northwest Mexico, Italy, Germany, England, Spain and even emerging markets such as China and India. Asian counterparties such as Japan, Korea and Taiwan, who have historically constituted approximately 70% of demand in the LNG market, are also building new terminals. The gas supply to meet expected growth in LNG demand is from stranded gas reserves associated with crude oil production that historically did not have much hope of coming to market. These reserves are typically owned and operated by many major worldwide energy companies. Longstanding production zones include Algeria, Libya, Nigeria, Qatar, Malaysia, Australia, Brunei, Indonesia and the United States (Alaska, Cook Inlet). Many proposed new areas of LNG liquefactions include Norway, Trinidad & Tobago, Venezuela, Bolivia and various countries of the Middle East.

The ideal economic scenario when evaluating the LNG terminal projects make sense with contingent upon studies related to where and how much gas demand is going to be, where the supply will come from, and how much gas to produce.

THE FUTURE OF GLOBAL LNG PRODUCTION AND CONSUMPTION

The LNG Production and Consumption

While natural gas consumption growth rates are expected to increase over the next twenty years by 50% as compared to a current level of 1.84 billion m^3/day, the solution to providing the supply to satiate such growth is not quite as transparent as just evaluating the face-value economics of alternative sources.

In any energy infrastructure project, due diligence on regulatory, permitting, and environmental factors is quite important. A hiccup in procuring the necessary political approvals, permits and rights-of-way can be devastating to the economics and viability of a project. Projects have been known to come to a dead halt, much to the chagrin and expense of the lead project developer and production consortium, over matters such as residential noise or particulate pollution, wildlife endangerment, political vacillation, or just plain general nuisance.

LNG re-gasification terminals are viewed as large, obstructive and generally displeasing to the eye for local residents and businesses. Although designs to bury such large facilities underground have been forthcoming, general apprehension related to the “don’t build in my backyard” philosophy still emphatically exists. One mitigant to that problem is sighting the terminal off-shore or aboard the LNG transport ship itself, far from residential or commercial areas. Although such new technologies regarding offshore and ship-board re-gasification is being studied and developed by a variety of industry players, the educating process required with political parties is an on-going and sometimes frustrating process.

The guidelines regarding the oversight, regulatory standards and environmental compliance of on-shore or off-shore terminals are still in debate. In the United States, three of the four import terminals are overseen by the federal energy regulatory commission, FERC. Regulatory oversight can be an issue to contend with as most merchant energy firms and pipeline companies vie for ownership, control, and equity interest. For such market participants, FERC jurisdiction impedes profitability and ease of management control of the owners and its merchant gas off-take counterparties. Many of the industry participants building and sighting these terminals contend to the FERC that if they have the burden of finding, constructing, funding, and permitting a terminal, they should not be subject to losing the economic potential to sell such re-gasified gas into open market by subjecting the capacity to a FERC-controlled 'open-season'. After all, if one firm does all of the work, why would that firm surrender the market opportunity to profit from the off-take gas sales to another firm who has not incurred the same 'finders' costs? For many of these project leaders, equity ownership of a FERC-jurisdiction terminal at a regulated rate of return is not enough. They want the most facile way to attain the real 'juice', that is, they prefer the sole ability to sell their upstream LNG into the interstate domestic markets as gaseous gas and take merchant positions in key locations.

The LNG non-Operational Risks

The two LNG-related non-operational risks that are worth mentioning at this time are terrorism and/or accident risk and sovereign government risk. Terrorism has been shown to be a more significant influence on energy endeavours than ever before. With the threat of oil tanker, nuclear reactor and LNG ship sabotage, political risk to sighting an on- or off-shore re-gasification unit is high. Man-made or accidental explosion of such a tanker can be catastrophic in the mind of the common person, and although studies have shown that LNG volatility is much lower in its liquid cooled form, the image of a giant vapour cloud can have devastating effects on the human psyche and at the very least create an apocalyptic image that few are willing to internalize. However, the Nigeria LNG Ltd has been having smooth operations of the production trains since the official commissioning in October 2000. This success is due to a trusted and fulfil memorandum of understanding, MOU with the hosting communities.

Secondly, since much of the gas that is being liquefied in the western countries (US and Europe) comes from foreign and third-world countries, sovereign risk can be quite disenchanting as compared to reliable, high-credit, highly-liquid United States gas. Changing governments, political coups, local customs, and draconian regimes can portend inconsistent supply. Due to this factor, price concessions are usually made in relation to United States-priced gas supply, however, the sovereign risk inherent in such supply must to be evaluated concomitantly with the discounted pricing.

CONCLUSIONS

The global world is in need of additional natural gas sources based on forward fundamental supply/demand and price expectations. More so LNG appears to be one of the viable and constantly improving choices of energy source. While the economic viability of LNG as a necessary gas supply-stack contributor as compared other hydrocarbon in many ways. However, the issues on politics, sovereignty and regulatory risk can impede the progress of such beneficial projects and turn what was once a supply saviour into a bureaucratic roundabout of the hosting communities. To the global world, the LNG and the reduced gas flaring has an approximate benefit to the tune of $5 billion US in a month. Nigeria alone, generate a sum of $200 - $300 million US monthly. This study is to serve as an eye-opener to investors in the oil and gas projects because of its viability and high economic advantages in various ways over the conventional hydrocarbon products (gasoline and diesel oil etc.).

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