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Natural Gas and It's Prospect for Effective Utilization in Nigeria.

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ABSTRACT
This research is focused on natural gas and its prospects for effective utilization in Nigeria. Both primary and secondary sources were surveyed in collecting relevant and up to date data for the study. From the study, it was found out that Nigeria has presently 140 trillion cubic feet of natural gas, the largest proven reserve in the world and the largest in African. The country's current gas production of around 3.5 billion cubic feet per day exceeds the foreseeable needs of domestic and international markets, and about 74% of Nigerian gas is flared while the balance goes into field uses (e.g., re-injection) and other industrial, domestic, and commercial consumers. Contemporary economic reality makes continuation of gas flaring in Nigeria most undesirable. The present study deals extensively on gas reserves, gas utilization options, investment opportunities in gas, projects and policies geared toward increased gas utilization, factors affecting gas utilization, the Nigerian Gas Industry, and its projected natural gas demand. The benefits of this study if exploited are optimal development of gas resources, increased gas utilization, reduced gas flaring and, it also provides recipe for the bottleneck in utilizing Nigerian natural gas effectively. Such benefits are prerequisites to enhancing the contribution of gas to the national economy in its use as fuel and feedstock and in the generation of foreign exchange from export earnings and consequent investment in gas have traditionally taken a secondary importance to oil. This accounts for Nigeria having one of the highest flaring rates in the world. About ninety-five percent of the associated gas obtained per day is flared (a figure estimated to be about a quarter of world gas flares).

I. INTRODUCTION

1.1 DEFINITION, COMPOSITION AND CLASSIFICATION OF NATURAL GAS

Natural gas is a gaseous mixture of hydrocarbon and non-hydrocarbon gases occurring naturally from reserves thousands of feet below the earth's surface.

Natural gas is formed from sediments rich in organic matter which in the past have been treated to very high temperatures and pressures. It is a mixture of flamed hydrocarbon vapors and gases found naturally beneath the surface of the earth; it consists mainly of methane with few percentage of ethane, propane, butane, pentane and other heavier hydrocarbons. It also contains some impurities such as water vapor, hydrogen, and in nature either dissolved in crude oil as associated gas) or free of oil in gas reserves (as non-associated gas).

The pentane and heavier hydrocarbon cuts which are liquid at atmospheric temperature and pressure are commonly known as Condensate or Natural Gasoline, while ethane, propane and butanes when untreated are collectively known as Natural Gas Liquids (NGL). On the other hand, Liquefied Natural Gas (LNG) is natural gas mainly methane which has been liquefied by cooling to −161.5℃ at atmospheric pressure, while liquefied Petroleum Gas (LPG) is any mixture in either the liquid or gaseous state of propane and butane.

1.2 ORIGIN OF NATURAL GAS

Freshly deposited sediments at the bottom of seas and lakes are the site of intense bacterial activity that is capable of producing methane, carbon dioxide, nitrogen and nitrogen-oxide from the organic matter sediments. With burial of the sediments beneath succeeding s deposits, bacterial activity uses and the organic matter is transformed into kerogen, and insoluble product with a complex macromolecular structure.

Most petroleum and natural gas are produced by the degradation of kerogen within the Earth by naturally occurring heat. The sediment containing the organic matter that produces gas is expelled and migrates to reserve levels which are made up primarily of sands and sandstone porous space for example, between sand grains. Normally, the pores a`re filled by water, but gas, because of its much lower specific gravity, tends to occupy the upper parts of the reserve level whereas water remains in the lower parts. For gas to accumulate the gas must be trapped, that is the reservoir must be sealed at the top by an impermeable stratum or cap rock, such as clay or salt, the entire reservoir-cover structure shaped in such a way as to prevent gas from leaking to the surface.

1.3OCCURRENCE OF NATURAL GAS

Natural gas occurs in vast quantities associated with producing oil wells (AG) or as gas deposits not associated with oil (NAG).
Non-Associated Gas (NAG) is gotten from the combining Crude Oil + Associated + Condensate Gas
(AG): solution gas and /or gas cap gas
A post war development in Belgium and Great Britain to recover most of the fire damp by "drainage" through a series of boreholes sited from 150ft behind the coal face. Boreholes can be used to recover methane from thin worked seams. Total quantity produced in Great Britain was 8000ft3, it is estimated that ten times this quantity can be produced per annum.
The gas is mainly methane varying from 93 to 99% with ethane up to 3% carbon dioxide up to 4% and nitrogen plus inert less than 6%.

SEWAGE GAS
The decomposition products of many forms of organic matter by bacteria include methane as a major item. In sewage works, this gas may be recovered as a profitable by product. In some works, the gas is burned in gas engines to produce electrical power.

The usual composition of sewage gas is: -

Methane	75%
Carbon dioxide	25%
Calorific Value	750Btu/a3 at STP

1.4NATURAL GAS –IT'S USES AND BENEFITS
Natural gas could be put into various uses. These include among others that:-
1. Natural gas can be utilized in power generation
2. It serves as the most efficient industrial fuel
3.It can be used as a feedstock to produce intermediate and finished chemicals such as acetylene, ammonia, carbon black and others which have widespread applications.
4. Natural gas can be used by steel makers to reduce iron ore and as such constitute a metallurgical use
Provides the missing link for subsea gas processing. Subsea dehydration with twister would allow gas to be transported safely and cost effectively over long distances and in some areas would even allow a direct tie-in to nearby sales – gas pipeline system. The cost and environmental benefits of this technology could significantly extend the boundaries of economic viability for development of natural gas reserves.

1.5 ASPECTS OF GAS UTILIZATION
Natural gas has various ways in which it is utilized. It can be processed for the liquid hydrocarbon that it contains. Natural gas is used primarily as a fuel. There are premium uses of natural gas in industry; these include its use in total energy systems, incineration, filling of carmine products and direct drying processes. Hence, natural gas has also been identified as a good feedstock for a limited amount of chemical processes.
Natural gas can be utilized by oxidation to carbon black and plants are having been built for burning the gas to carbon dioxide and hydrogen. This gas can be synthesized mainly into gasoline and other numerous products such as methyl, ethyl, propyl, butyl and amyl alcohol, acetic acid, acetone etc.
Other uses of natural gas are highlighted below:-
(i)Natural gas is of high calorific vale, uniform in composition and free from undesirable impurities. These properties make it a valuable fuel gas for all applications when burned in suitable appliances.
(ii)Natural gas is an excellent fuel for internal combustion engines. Its high anti-knock qualities make high compression ratios possible with consequent improved efficiency.
(iii)Methane and Natural gas are also good fuels for gas turbines.

USE AS A CHEMICAL RAW MATERIAL
(i)When burned in a limited amount of air in the presence of cooled metal surfaces, carbon black is produced. This is a valuable pigment and reinforcing agent for rubber.
(ii)By the reaction with steam, methane may be converted into water gas or synthesis gas for the production of methyl alcohol or gasoline. It may also be converted into water gas for the synthesis of ammonia.
(iii)By pyrolysis, natural gas may be partially converted into hydrogen, methane, benzene and other aromatics.

(iv)By controlled oxidation of methane, methyl alcohol and formaldehyde are formed.
(v)By the process of chlorination of natural gas methyl chloride is obtained. Figure 1.1 is a flowchart for the production and uses of natural gas.

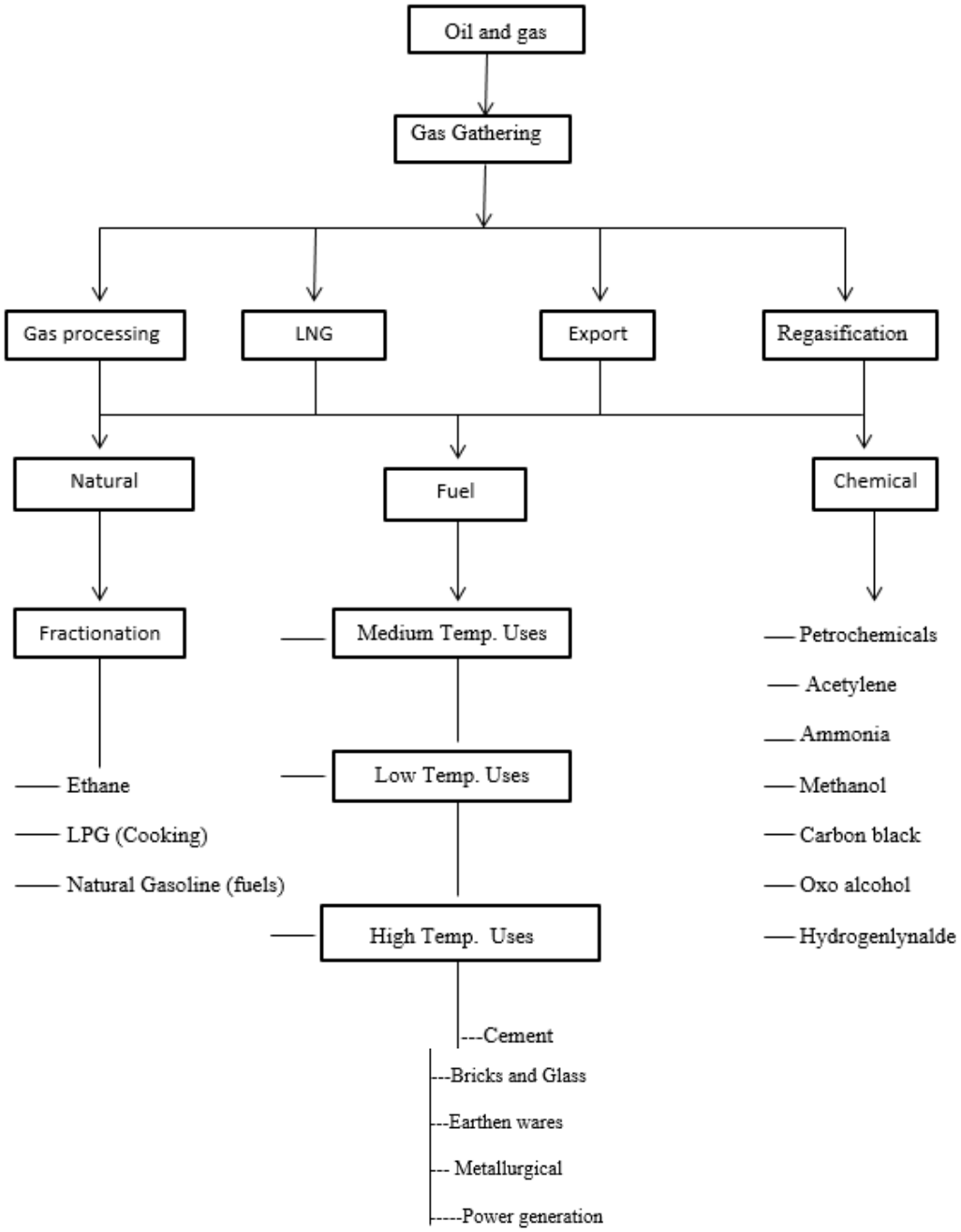

Figure 1.1: A flowchart for the production and uses of natural gas

II. MATERIAL AND METHODOLOGY

In the study both primary and secondary sources were surveyed in collecting relevant and up to date datafor the study.

MAJOR GAS PRODUCERS

None of the oil producing companies in Nigeria has prospected for produced natural gas in its own right. However, in the course of looking for oil, natural gas is described either as non associated or associated. The major outers in natural gas production and utilization include shell, Mobil, Chevron and Agip.

2.1SHELL

Shell has a long history of participating in the gas sector in Nigeria, starting from the early sixties. It initiated a project to supply gas to some industry in Aba and the then Electric Corporation of Nigeria for its Ughelli power station.

Shell with a total gas production of $503x10^6$mmscf in 1995 is the largest producer and foreign investor of natural gas in Nigeria, with subsidiary companies involved in all aspects of oil and gas development, including exploration, production, liquid natural gas (LNG) production and gas transmission, distribution and marketing. The company has a N10 billion sales and purchase agreement with the Nigerian Gas Company (NGC) to sell 250 mmscf/d gas to the latter for 20 years. The key gas projects that Shell is involved are shown in Table 2.0 below.

TABLE 2.0: GAS PROJECTS BY SHELL PETROLEUM DEVELOPMENT COMPANY

Nigeria LNG supply	600 million cubic feet of non-associated gas from Soku field of which 170 million standard cubic feet/day will subsequently be backed out by associated gas from Soku, Nembe Creek and Ekulam fields. Bonny NAG will be blended with associated gas to meet industry specifications.
Odidi Field Area Associated Gas Gathering	100 million standard cubic feet/day associated gas into the ELPS pipeline backing out Utorogu non-associated gas.
SPIL – Alakiri Gas supply	Standard Petrochemical Limited (SPIL) will be supplied by non-associated gas from Alakiri until Associated Gas project can be funded. Thereafter, 60 million standard cubic feet/day of associated gas will be the source of supply.
ALSCON/NAFCON	Aluminium Smelter Company of Nigeria (ALSCON) and National Fertilizer Company of Nigeria are supplied by non-associated gas from Bonny.
Associated Gas Injection Projects	Oil development projects at Belene, Gabaran, Akri/Oguta and Utapate South taking nearly 200 million standard cubic feet/day by 2004.

Sources: Shell Petroleum Development Company Ltd.

2.2MOBIL

Mobil is the second largest producer of natural gas in Nigeria. The company produced about $386x10^6$ million standard cubic feet/day of gas in 1995 out of which about 79.3% was flared. The company is currently promoting quite a number of gas projects implementation in the country. Mobil is involved in the implementation of Oso Natural Gas Liquids projects located at Bonny Island in Rivers State. This project is aimed at processing the Natural gas from the Oso condensate field and other sources to obtain Natural Gas Liquids. The project is expected to cost about $810 million. Mobil is also involved in the methanol project to be sited in Bonny, Rivers State. The project is aimed at producing 900,000 metric tons of chemical grade methanols for export. The project is executed using the ICI/John Brown Methanol Synthesis Process.

The company is also currently promoting the following gas projects:-

Ekpe Gas Compression Project at an estimated cost of $183 trillion and Edop gas Injection project with an estimated cost of $8.0 million.

2.3CHEVRON

In 1995, chevron produced a total of 229,971,935 million standard cubic feet/day of natural gas, out of which 7,149,451 million standard cubic feet/day were utilized and the remaining 97% was flared. Chevron has plan for comprehensive multi-phase gas utilization scheme, which will process the gas being flared in its operations. About 80% of this gas from its field namely: Mefa and Okan will be gathered and processed to liquefied petroleum gas and natural gasoline. The Ecravos Gas project to be executed in phases between 1993 and 2006 at an estimated cost of $1 billion the first phase of the project, Natural Gas Liquids Recovery plant came on stream in September 1997.

2.4 AGIP

Agip produced a total of 248,706,445 of natural gas in 1995 and about 36.8% was utilized as fuel gas and in gas lift/injection while the rest (63.2%) was flared. The company along with Elf and Shell would be supplying the total gas required for Nigeria Liquefied Natural Gas Project.

2.5 EFFECTIVE UTILIZATION OF NATURAL GAS IN NIGERIA

2.5.1 INTRODUCTION

Although the flaring of associated gas does not constitute part of the utilization of the gas, it deserves a special mention on account of the tremendous volume involved. Today, Nigeria ranks first in the world with respect to the volume of gas being flared, most of it being associated gas produced as a by-product of oil production. The country flares about 75% of the total gas produced. Apart from the phenomenal wastage that this represents, it is a vulnerable contributor to environmental pollution, including global warming. In any one year, more than 12 million tons of methane are released into the atmosphere in the Niger Delta Area. Thirty – five (35) million tons of carbon dioxide are released annually pollution, the flaring of gas constitutes a poor conservation philosophy which has to be seriously addressed, via sourcing avenues in which natural gas can be effectively utilized; followed by implementation of strategies/policies that will encourage more gas projects and further increase investment in the gas sector.

2.5.2OPPORTUNITIES FOR NATURAL GAS UTILIZATION

Natural gas is a versatile product which may be used as a fuel (energy use) or as a feedstock (non-energy use) for conversion to higher-priced products. As natural gas has a relatively low energy content per unit volume, it is expensive to transport. Therefore, the actual use of gas will be dependent upon the location and size of gas source and the surrounding market environment. Figure 2.1 gives natural gas utilization options:

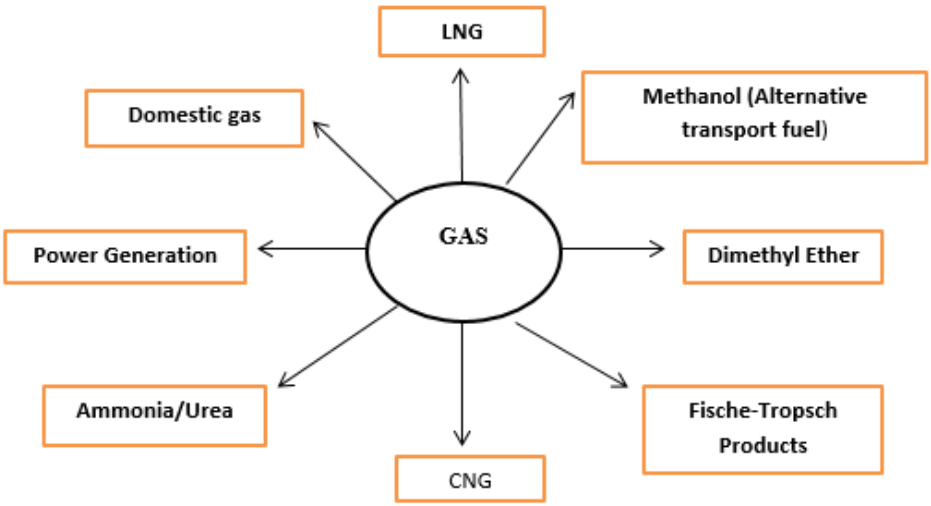

FIG. 2.1: NATURAL GAS UTILIZATION OPTION

2.5.3 ENERGY SECTOR

(i) **Power Generation:**

Electric power generation is one of the traditional channels of utilizing natural gas effectively. It provides a large volume off-take and, through the use of combined-cycle Gas Turbine (CCGT) technology, is a low cost-effective and efficient method of generating electricity. In a developing economy like Nigeria, with very cheap natural gas source, power plants operating with should be expanded. With the recent trend in demonopolizing power generation and sales such expansion is promoted.

(ii) **Domestic Gas**

According to Ette and others (1999), the recognition of the advantages of natural gas over other fuel forms suggests that natural gas should be used for heating at homes. This will follow in the form of water and electricity distribution network with appropriate metering of consumption for the purpose of tariff collection. With the removal of unintentional bottlenecks to the domestic (LPG) and industrial uses of natural gas, combined domestic and industrial gas demand would be expected to grow as much as 5% per annum. The concentration of rights and authority in oil and gas matters in the hands of the Federal Government through the NNPC and multinational firms has slowed the pace of domestic, industrial and commercial utilization of gas. Although some relaxation in government's grip has been seen in the upstream sector, a lot of grounds (not just products marketing) must be conceded particularly in Refining, Natural gas Processing and Natural Gas Distribution. It is probably counterproductive to expect Nigeria Gas Company (NGC) to fulfill the expectation of most Nigerians concerning the piping of methane to industries and homes at least in the planned/low density areas of existing towns and emerging towns. A possible scenario in actualizing this objective could be joint venture arrangement between NGC, Gas Producers and prospective Gas distribution companies holding gas distribution rights within state boundaries.

(iii) **Compressed Natural Gas (CNG)**

If a domestic gas grid is developed there may be an opportunity for the use of CNG to be used as a transport fuel. At present CNG is commonly utilized in major cities by buses and taxis. However, in some countries it is becoming increasingly popular for private vehicles. In Nigeria at the moment, weighty storage high-pressure vessels associated with CNG, refilling logistics and engine conversion costs make CNG less competitive as motor fuel.

(iv) **Liquefied Natural Gas (LNG)**

The LNG option as a means of reaching the gas market from remote sources is a painstaking one. It is hover a welcome development when the market (usually of but not necessarily a long term contractual agreement) is secured. It is just an alternative to pipeline gas export. In the absence of the LNG and pipeline export options; the political and economic solution to flaring is simply re-injection.

(v) **Cooling and Refrigeration**

Development of natural Gas based cooling and refrigeration systems will boost gas utilization in Nigeria; the amazing thing about these developments was the accomplishment of mechanical refrigeration without the use of electricity, or any moving parts to the mechanism.

(vi) **Flame Cutting and Welding**

Presently in Nigeria, the source of acetylene for cutting and welding in construction firms is by reaction of calcium carbide with water: -

With provision of storage and distributive facilities for acetylene from natural gas, this will increase gas utilization as a source of acetylene for welding and cutting.

(vii) **Fuel Cell**

The natural gas fuel cell (NGFC) energy system is a simple, reliable way to improve natural gas utilization and efficiency. This technology converts natural gas into electricity to provide a quiet, clean, and highly efficient on-site electric generating system and thermal source that can reduce facility energy service costs by 20% to 40% over conventional energy service. The NGFC utilizes an alternative cogeneration technology for improving fuel to electricity through an electrochemical process rather than a combustion process, the emissions from the NGFC are much cleaner and are primarily carbon dioxide and water. NGFC can serve effectively as an on-site energy supply to meet needs for base-load electricity, heat and hot water, while local electric and natural gas utilities provide for energy demand beyond the NGFC capacity.

2.5.4 NON-ENERGY/FEEDSTOCK SECTOR

One of the major feedstock opportunities for natural gas utilization is the synthesis gas process, which produces a mixture of carbon dioxide and hydrogen. This is the indirect route and the only route applied industrially at the present time. The direct route involves an attempt to convert methane directly to liquid hydrocarbons (oxidative coupling or thermal coupling) without transiting through a mixture of carbon monoxide and hydrogen. Methane chemical conversion has not been applied to a large extent due to the difficulty of activating methane chemically, which makes such operations relatively complex and expensive.

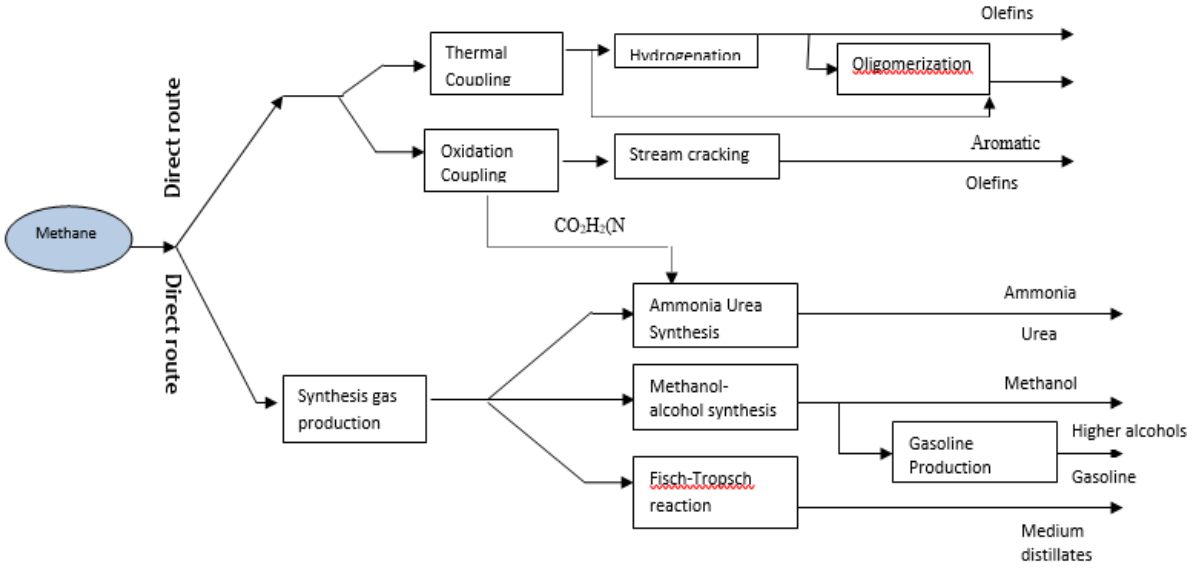

FIGURE 2.2: ROUTE FOR THE CHEMICAL CONVERSION OF METHANE
(SOURCE: ROJEY et al, 1997)

III. RESULTS AND DISCUSION

The vast amount of gas flared annually is an economic and environmental nightmare. It is estimated that about 75% of associated gas produced per annum is flared. 25% of the associated gas is however used as fuel gas in the field sold to industries, used for gas lift operation or re-injected to enhance oil recovery operation.

Nigeria is currently embarking on an ambitious plan to use gas through various gas based projects. These projects include among others the liquefied natural gas (LNG), the fertilizer plant, a petrochemical plant and the Aluminium smelting project as well as the proposed West African Gas Pipeline to import gas to Ghana, Togo and Benin Republic.

Table 3.1: below give history of and utilization of natural gas in Nigeria respectively.

TABLE 3.1: GAS AVAILABILITY AND UTILIZATION IN NIGERIA

YEAR	TOTAL GAS PRODUCED (MMSCF)	GAS UTILIZED (MMSCF)	RE-INJECTED (MMSCF)	FLARED (MMSCF)	% UTILIZED
1989	903	155	68	680	25
1990	939	149	90	701	26
1991	1056	169	103	784	26
1992	1193	175	108	910	24
1993	1186	170	120	895	25
1994	1359	161	290	907	33
1995	1339	173	306	941	30
1996	1367	175	310	860	31
1997	1389	180	327	800	35
1998	1346	176	310	890	34
1999	1390	186	350	854	32
2000	1434	184	400	900	40
2001	1456	190	410	905	38
2002	1489	196	405	910	42
2003	1560	190	415	920	45
2004	1489	198	400	930	45
2005	1670	220	420	932	47
2006	1689	200	412	908	42
2007	1665	178	400	914	41.5

2008	1700	240	425	920	43
2009	1780	190	440	932	45
2010	1889	200	452	940	46
2011	1870	198	456	950	46.7
2012	1922	243	450	930	44
2013	1950	250	452	940	45
2014	1970	311	460	944	46
2015	2040	350	457	960	47
2016	2080	327	470	977	47.5
2017	2150	390	478	950	50
2018	2177	400	480	966	51
2019	2230	570	480	967	51.7
2020	2500	550	350	800	48

***SOURCE**: NAPETCOR 4TH QUARTER 1996*

3.1 MAJOR USES OF NATURAL GAS IN NIGERIA

3.1.1 POWER GENERATION

The demand for natural gas from the Nigeria Gas Company for power generation stood at 196.52 million standard cubic feet per day. The natural gas demand for power generation is mainly by the National Electric Power Authority (NEPA) and Oil Minerals Producing Areas Development Commission (OMPADEC).

Gas demand for power generation is expected to reach 437.96 million standard cubic feet per day by 2084. It is indisputably clear that NEPA is the major consumer of natural gas in Nigeria. This position will be maintained in the foreseeable future. Table 3.1 gives the demand growth of natural gas for power generation and the graphical analysis respectively.The present peak production of 4.5 GW of electricity is about 2.8% of what Nigeria needs to become an industrialized nation. The Federal Government has a target of about 40 GW of electricity by the year 2020. This represents about 25% of the expected 1.0 MW per 1000 population for the country. Thus, the country projection for 2020 is 75% below what is actually needed to fulfil industrial revolution dream. South Africa with a population of about 53 million has a generating capacity of about 43 GW of electricity, which is approximately 0.8 GW per a thousand populations (Igbokoyi and Iledare, 2015).Figure 3.1 shows Nigeria's natural gas production and consumption data. LNG export started in September 1999, and as at 2012 consumes about 79% of the total gas production (Igbokoyi and Iledare, 2015). A lot of works have been done on strategies to be adopted for Nigeria's Gas to Power (Salahudeen and Amadi, 2014) (Igbokoyi and Iledare, 2015) (Nnamdi et al. 2016).

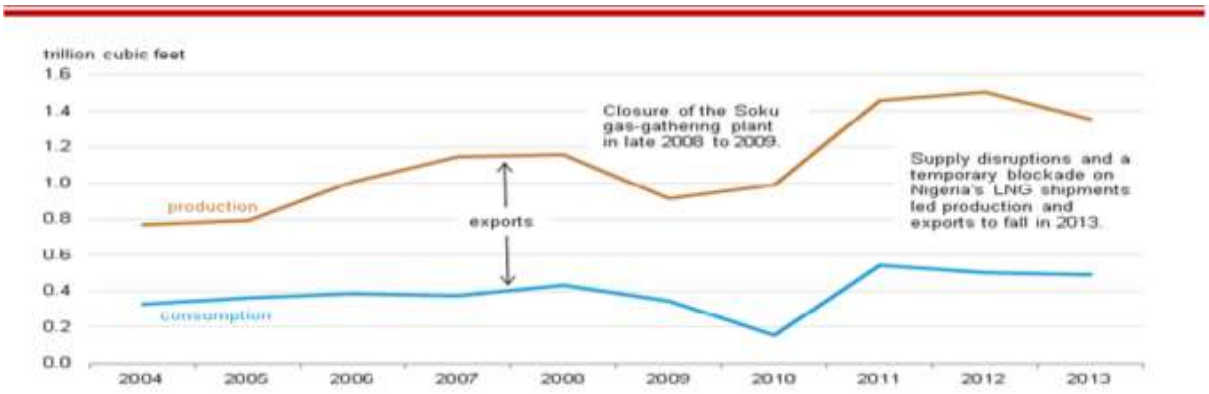

Figure 3.1 – Nigeria's natural gasproduction and consumption data (source: http://www.marcon.com/print_index.cfm?SectionListsID=30&PageID=2269)

3.1.2 INDUSTRIAL USES

Industrial uses of natural gas constitute the second major consumers avenue. Gas demand for industrial uses stood at 77.57 million standard cubic feet per day in 1995. Natural gas can be used for quite a number of industrial purposes apart from its commercial and domestic applications. These include petrochemical and fertilizer industries, and steel plant and other energy intensive industries such as glass, cement, textiles and paper factories as well as refineries. Table 10 below gives the approximate natural gas consumption by various industrial processes. There's no way a county can be industrialized more than her power generating capability and sustainability. However

Igbokoyiand Iledare suggested the current reserves of the country will only suffice in short to median time, even if LNG export is halted. However, natural gas can be supplemented with solar, hydro and wind energies which Nigeria has in abundance and even nuclear energy. Also, Nigeria has abundant sources of unconventional natural gas which are yet to be explored.

3.1.3 GAS TO LIQUID (GTL)

Gas to liquids (GTL) is a refinery process to convert natural gas or other gaseous hydrocarbons into longer-chain hydrocarbons such as gasoline or diesel fuel (Wikipedia, 2016). GTL technology generally refers to the chemical conversion of natural gas into readily transportable liquids such as methanol or conventional petroleum refinery type distillate fuels (Chinenye et al, 2007). Methane-rich gases are converted into liquid synthetic fuels either via direct conversion or via syngas as an intermediate, for example using the Fischer-Tropschor Mobil processes. It is an emerging technology which involve chemical transformation of natural gas, either into synthetic fuels (syncrude, diesel, kerosene, etc) or chemicals (methanol, DME, etc) (Balogun and Onyekonwu, 2009).

Presently, Nigeria is suffering from huge shortages in the production of petroleum products, especially the light and middle distillates. These shortages are due to the low production capacity of the old fashioned petroleum refineries. Nigeria needs at least 695,000bbl/d of light and middle distillates to balance present local consumption of liquid fuels, while all the local refineries produce less than 380,000bbl/d. The differences in local consumption could be covered in several ways like importing, building at least two new big oil refiners, or investing in natural gas by building GTL project. Unlike liquefied natural gas (LNG), GTL products are sold on the spot market. It does not require long term sales and purchase agreements. Currently, GTL has a very small market share in Nigeria, but the market potential for GTL products can essentially be considered unlimited. Given the superior quality and marketability, it is perhaps only a matter of time before GTL production becomes a formidable industry (Stanley, 2009). It can be achieved without the cost of modifying vehicle or installing much new infrastructures (Lukman, 2014). GTL technology with the principal interest in the production of diesel would be economically feasible when applied to a typical offshore Niger Delta large resource at oil prices of above US $35/bbl and feedstock gas price in the range US $0.25/mmBTU (Balogun and Onyekonwu, 2009).

3.1.4 Enhanced Oil Recovery (EOR)

EOR is the third stage of hydrocarbon production proceeding primary and secondary recovery, during which sophisticated techniques that alter the original properties of the oil are used. Enhanced oil recovery can begin after a secondary recovery process or at any time during the productive life of an oil reservoir. Its purpose is not only to restore formation pressure, but also to improve oil displacement or fluid flow in the reservoir (Schlumberger, 2016). Some EOR processes utilize natural gas for enhanced recovery of oil, e.g. miscible gas injection. Miscible gas injection is the most widely applied light oil enhanced oil recovery (EOR) process. A methodology, based on well-established physical principles, has been developed for estimating the conditions under which gas will be miscible with oil. The methodology enables rapid screening of a range of potential gas injectants (such as CO2, enriched hydrocarbon gas, N2, or H2S) through the use of readily available gas and oil properties. The methodology has been applied to numerous reservoirs worldwide (Teletzke et al., 2005).

3.1.5 Feedstock for Petrochemical Industries

The petrochemical market is the foundation of many chemicals industry, as it provides the building blocks for most chemical products. For instance, Olefins (Ethylene, propylene, butadiene) and aromatics (benzene, toluene and xylene) are used in end-user markets such as paints, plastics, explosives and fertilizers. Natural gas and natural gas liquids are used to manufacture a gamut of intermediate chemicals and finished products (fig. 3.2).

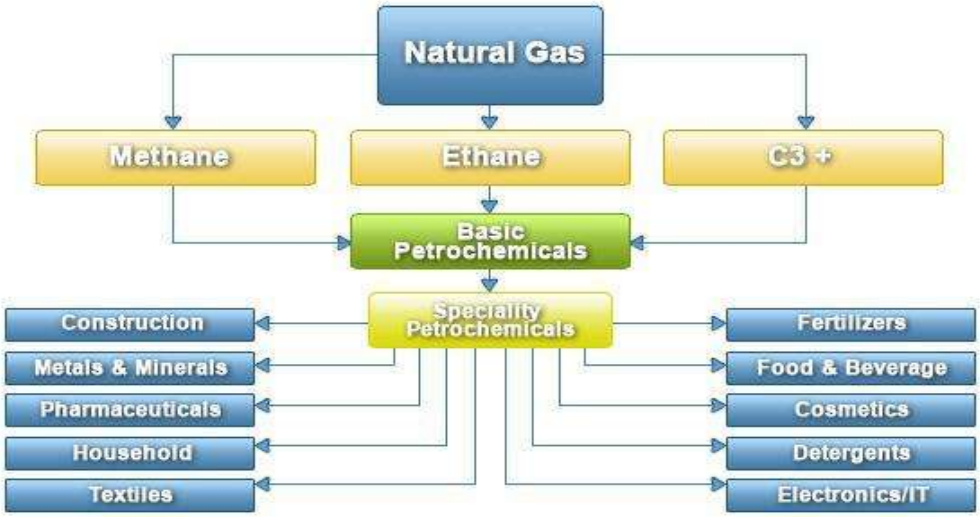

Figure 3.2- Petrochemical products from Natural gas.
(**Source:**http://www.gascities.com/products-process.html)

TABLE 3.2
NATURAL GAS CONSUMPTION RATES BY VARIOUS PROCESSES

APPLICATION	**APPROXIMATE NATURAL GAS CONSUMPTION RATES**
Methanol	35,000 cu.ft/metric ton of methanol
Ammonia	35,000 cu.ft/metric ton of ammonia
Power Generation	10-12 cu.ft/kwh
Cement	4,000 cut.ft/ton of cement
Bricks	7-10 cu.ft/1,000 bricks
Iron Ore Beneficiation (Mining, Grinding and Pelting)	1000-2000 cu.ft/ton of ore processed
Iron making	2000 – 4000 cu ft/ton of hot metal
Steel making	18000 -21000 cu.ft/ton of raw steel
Aluminium (conversion & Reduction)	200000 cu ft/ton of raw aluminium
Hydrogen	500 cu.ft/1000 cu.ft/Hydrogen (excludes fuel)
Coper, Lead & Zinc smelting	20000 – 40000 cu.ft/ton of metal

Source: International Gas Development Corporation Houston U.S.A

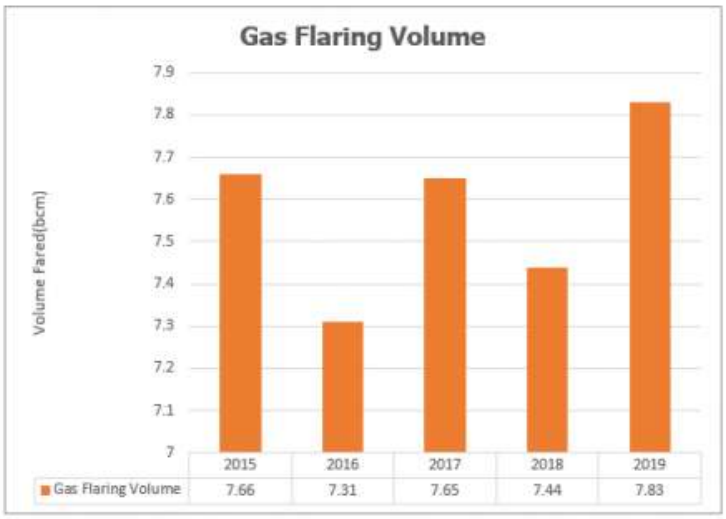

Figure 3.3: Gas Flaring Data from Production facilities all over Nigeria.

3.1.6 DOMESTIC AND COMMERCIAL USES

There is currently inadequate supply of natural gas for domestic and other commercial heating purposes in the county. However, there is a pilot project to supply natural gas for domestic use to shell staff housing estate in Warri. Others accomplished natural gas projects for commercial uses include its supply to Port Harcourt Trans. Amadi Industries, PHC Refinery, Aba Industries, Delta Steel Aladja, Ajaokuta steel and Aluminium smelting complex in Ikot Abasi. Natural gas through the butanisation process is however made available for cooking purposes. Figure 3.3 gives the flowchart of natural gas to domestic outlets.

3.1.7 UNDERGROUND STORAGE (UGS)

This is another utilization option when natural gas utility is to be deferred for future use by injecting into underground storages. This gas resource can be accessed for later use when it is convenient. This is a gas preservation method which is unused in Nigeria till date. Gas storage is principally used to meet seasonal load variations. Gas is injected into storage during periods of low demand and withdrawn from storage during periods of peak demand. Atoyebi in 2010 stated that it is also used for a variety of secondary purposes, including:

(i) Balancing the flow in pipeline systems: This is performed by mainline transmission pipeline companies to maintain operational integrity of the pipelines, by ensuring that the pipeline pressures are kept within design parameters**.**

(ii) Leveling production over periods of fluctuating demand: Producers use storage means to store any gas that is not immediately marketable, typically over the summer when demand is low and deliver it in the winter months when the demand is high.

(iii) Meeting regulatory obligations: Gas storage ensures to some extent the reliability of gas supply to the consumer at the lowest cost, as required by the regulatory body. This is why the regulatory body monitors storage inventory levels.

(iv) Reducing price volatility: Gas storage ensures commodity liquidity at the market centers. This helps contain natural gas price volatility and uncertainty.

IV. RECENT ONGOING NATURAL GAS PROJECTS IN NIGERIA

Nigeria is a powerhouse of Africa in many sectors, but oil and gas has been the hallmark of the country's economy for decades. For this reason, the Nigerian government is encouraging and facilitating special investment in gas so that the country may increase supply to power companies and move the economy from over-dependence in oil, which currently drives the majority of revenue in the country. Despite Nigeria's natural gas reserves, the export of crude petroleum accounts for over 90% of its export earnings. Luckily, Nigeria has no short supply of major projects that are helping to evolve and enhance the nation's oil and gas production. **Hon. Chief Timipre Marlin Sylva, State Minister of Petroleum Resources** has declared 2020 as the **"Year of Gas"**, stating that new initiatives will *"drive gas commercialisation to create open and competitive access to Nigeria's gas infrastructure"*. Under the guidance of the Gas Master Plan, Nigeria is racing toward a future that will generate more power, provide employment and stimulate the economy from within.

According to **Engr. Sarki Auwalu, the Director of DPR**, *"Many projects are only waiting for FDI, such as deep-water development and inland basin exploration. It is evident that the country is now looking more to be a global player rather than a simple revenue earner, which I give credit to the present administration."* One such project to revitalise the sector is **LNG Train 7**. The Nigeria Liquefied Natural Gas (NLNG) Train 7 project is an exciting new expansion of Nigeria LNG's existing plant, which currently has six operational trains at work. Located on Bonny Island in Rivers State, the plant is capable of producing 22 million tonnes per annum of LNG (liquefied natural gas). This proves to be an incredible benefit for Nigeria as the LNG demand **expected to increase by 72% between 2017 and 2030** worldwide.

LNG Train 7 is in accordance with the current administration's Gas Revolution. As gas is a cleaner form of energy, this project will spur Nigeria's gas sector for the industrialisation agenda, which is focused on domestic consumption rather than exportation. Not only that, another benefit of LNG Train 7 is that it will create over 40,000 direct and indirect jobs in Nigeria for local content, improving livelihoods on an even larger scale. This project is coming at the right time as Nigeria seeks to invest in new production as the nation readies for more foreign direct investment as it continues to excel among the top rankings of global LNG exporters.

- **The Ajaokuta-Kaduna-Kano (AKK) pipeline** is a 614km-long natural gas pipeline currently being developed by the Nigerian National Petroleum Corporation (NNPC) and is a continuation of infrastructure build for the domestic gas market. The pipeline is slated to originate from Ajaokuta and pass through Abuja and Kaduna before ending at a terminal gas station in Kano. The AKK pipeline is envisaged as the first part of the Trans Nigeria Gas Pipeline Project (TNGP) development. *"The AKK pipeline is part of the gas masterplan,"* says **Emeka Okwuosa, CEO of Oilserv.** *"It is going to move 1.5 billion scf of gas a day and provide resources for power generation and other energy requirements. It is not only a development of the north; it is such for the entire country. So, this single project can transform the whole of Nigeria in terms of industrial capacity."*

- The TNGP, which is expected to be 1,300km in total length, forms a piece of the **Trans Sahara Gas Pipeline (TSGP) system**, which is envisaged to pump Nigerian gas through Algeria or Morocco to Europe. The pipeline project is being implemented via a build and transfer public-private partnership model, which harnesses the strength of both the private and public sectors. Not only will this increase gas availability, but the AKK natural gas pipeline will also reduce gas flare and environmental impact.

The Nigerian government plans to ensure that gas significantly contributes to the power sector, and the AKK natural gas pipeline is aligned with that agenda. The pipeline is intended to boost Nigeria's electricity generation capacity, as well as strengthen the industrial sector within the country's eastern and northern regions. The project is also expected to promote and increase the local usage of domestic gas, which will enable power-starved communities across the country to have greater access to electricity while providing stranded commercial and industrial customers with a cleaner and more efficient source of energy. On this note, **Mele Kolo Kyari, Managing Director of NNPC**, said: *"We believe whatever can be achieved internationally, can be achieved locally. We are also counting on the support of our local and international partners, service providers as well as regulators across the industry value chain."* Additionally, the AKK pipeline is anticipated to increase the country's revenue generation through the export of natural gas. The on-going implementation of the Gas Master Plan will continue to play an increasingly important role to ensure that Nigeria progresses forward towards the next level.

- **The Deepwater Bonga North project**, which Shell Nigeria Exploration and Production Company (SNEPCo) and its partners manage, is an important milestone for Nigeria's deepwater industry and has generated numerous jobs and businesses. Bonga North West ties into the existing Bonga vessel, one of the largest floating production, storage and offloading vessels in the world. The project team safely drilled and connected new wells in a highly challenging environment more than a kilometre below the ocean's surface. **Through close collaboration with the NNPC and industry regulators**, the project has unlocked new energy resources to help meet the world's growing demand.

- In some of the highlights on Nigerian content development, 90% of the people who worked on the Bonga North West project during its four-year development were Nigerian. SNEPCo awarded the major engineering and construction contracts for the project to companies that were either indigenous, have local staff, or possess domesticated capabilities in the country.

Likewise, the Deepwater Bonga Southwest/Aparo (BSWA) project, spearheaded by Shell Nigeria Exploration & Production Company (SNEPCo) and its partners, will open further opportunities in the deepwater oil and gas sector in Nigeria, whilst creating significant benefits for the state. BSWA will be the first major deepwater project in Nigeria since Egina. BSWA has the potential to produce approximately 150,000 to 200,000 bpd, which will account for around 10% of Nigerian crude oil production.

- Yet another promising project currently underway in Nigeria is **the Ultra-deepwater Zabazaba-Etan project.** The Zabazaba and the Etan fields are located in offshore Nigeria in the **Niger Delta of the Gulf of Guinea,** in water depths ranging from 1,200-2,400 metres. The deepwater project is expected to support small and medium-sized businesses in Nigeria, with half of the Zabazaba FPSO topside currently slated to be fabricated and integrated into the country. The Zabazaba and Etan fields are estimated to hold a combined total of 560 million barrels of oil equivalent.
- Additionally, **the Assa North/Ohaji South (ANOH) project** is one of the seven gas production infrastructures in Nigeria in which the government of Nigeria has announced plans to reduce the reliance on oil in the country. As a joint gas project between Seplat Petroleum Development and NNPC, the plant will process wet gas which has a capacity of 300 standard cubic feet per day and will begin production works in the last quarter of 2020 with its major supply targeted to begin in 2021. When fully developed, the project will have the capacity to expand to 1.2 billion cubic feet per day. The ANOH project is a critical gas supply hub in Nigeria's burgeoning gas-infrastructure network designed to provide the linkage between the Eastern, Western and Northern gas pipeline system. According to **Austin Avuru, CEO of Seplat Petroleum**, ambitious projects such as these require a few critical elements: *"I would say, hard work, humility and integrity, (plus a good dose of God's grace) will always, ultimately produce results."*
- **The Owowo project** is a prime example of the gas revolution on the horizon. Nigeria has aspirations to boost oil production to closer to three million bpd over the coming years with the development of the Owowo field. The sandstone reservoir is estimated to hold 500 million to 1 billion barrels of recoverable oil, making it Nigeria's largest oil discovery since 2004. Once fully running and connected, these initiatives will help propel **Nigeria to the gas hub within West Africa.**

FIGURE 4.1:Seplat Gas Production Master Plan Mapping for Nigeria.

V. CONCLUSION AND RECOMMENDATIONS

In terms of proven reserves, natural gas is the most abundant resource that Nigerian Is endowed with. That is enough gas to meet Nigeria development needs and even those of others in the ECOWAS sub-region but its ultimate exploitation is limited only by the capital requirements.

Natural gas flaring is considered in economic term as an illegal exercise, the flaring of gas has never done any nation any good, the economic advantage where it exists is always one-sided that is only the operator of the oil sector gains from such activity, the government of that nation is always at the disadvantage economically.

The effective utilization of the associated gas therefore, in order to curb gas flaring is major challenge for the Nigerian government and its populace. The move to base industrialization on the u8se of natural gas demands our effort; continuous energy wastage involved in gas flaring is in fact a national embarrassment which of course requires special and urgent attention.

An associated gas utilization policy has so far not manifested itself enough in our industrial endeavor's, this of course is a matter of national concern. In the light of the present circumstances, the following points should be given consideration so as to curb gas flaring.

a. In view of large capital involved in both the re-injection process and the consumption of this commodity, the government should encourage the private sector by way of specific budget provisions such as development of gas based project, gas exploitation and utilizing tax allowances on all capital investments.

b. The domestic utilization of natural gas as little to write home about. While the absence of natural gas grid has made the gas usage in our homes impossible, the relative subsidy enjoyed by fuel oil has further compounded the situation. The domestic and industrial sectors of the economy are dominated by fuel oil, which is as a result of the subsidy.

c. In order to facilitate the realization of gas based industries, infrastructural and economic incentives have to be provided, if this is done, the level of gas utilization will increase thereby curbing the flaring activity.

d. The department of petroleum resources which is the arm of government that controls the activities of the oil sector operators should be adequately equipped so as to enable it discharge its legislative duties effectively by implementing polices and regulatory measures that would attract investments in the gas sector.

e. The implementation of all planned and on-going gas based projects by government and the joint venture partners will undoubtedly reduce gas flared to an insignificant level by year 2008.

f. The present structure of the NNPC creates a situation in which much attention is given to oil development as oil is the main foreign exchange earner, to the detriment of which can also be developed to compete favourably with oil

Greater growth and development will be achieved in the gas sector if a national gas corporation that is separated from the NNPPC is established. In conclusion its appropriate here, to emphasize on issues and challenges that must be addressed in order to effectively utilize Nigeria gas. Some of the significant issues include:-

- Development of Natural Gas Grid
- Policy, Regulatory and Legal issues
- Health, safety and environmental concerns
- Funding and technological issues.
- Human Resources.

It is therefore essential that we begin to focus on the issues and development appropriate strategies and solution for addressing them if we are to effectively utilize Nigerian natural gas.
In order, to achieve an efficient gas production and utilization development with long term benefit in Nigeria, the following strategies should be considered and implemented:

5.1.1. Sustainable Management Structure
For economic development to thrive from gas production and utilization in Nigeria there is need to have sustainable management structure of gas infrastructures and this can achieved by full divestment of the current gas pipeline operating companies (i.e NGPTC and NGMC). The private participation will bring in full competition in this sector and breakdown the monopoly of the federal government of Nigeria, The sustainable management shall consist of a select International Oil Companies as a joint venture to operates gas infrastructures; the model shall be similar to the Nigerian Liquefied Natural Gas company model, but shall exclude the NNPC from the joint venture or consortium.

5.1.2. Sustainable Governance and Regulatory Structure
In order to achieve long term economic development from gas infrastructures, there is need to have a single regulatory agency with a gas act that would set the modalities for investors to participate in the sector.

5.1.3. Sustainable Financing Structure
There is need to have a sustainable financing structure for the gas pipeline development, because it requires huge investment and the strategy is set up Energy Bank in Nigeria, whose sole responsibility is to interface with international finance houses and firms on long term low interest loans for gas pipeline development in Nigeria.

APPENDIX

Appendix A: Table 1.0: Major gas project in Nigeria

S/N	Company	Project Title / Location	Expected Completion Date	Expected Production / Processing Capacity(MMscf/d)	Petrochemicals Product Output (Mtpa/Mtpd)
1	Chevron Nigeria Ltd	Abiteye NAG Development Compression Station project Abiteye in Delta State	2019	40	N/A
2	Chevron Nigeria Ltd	Okan and Meji Debottlenecking Projects	2019	340	N/A
3	Dangote Fertilizer Limited	DANGOTE Urea Fertilizer Plant Lekki Free Trade Zone, Lagos	2018	N/A	2.5 million TPA urea
4	Green Energy Int. Ltd	LPG Extraction Plant Otakikpo Marginal Field, Rivers State	2019	N/A	
5.	Greenville Oil & Gas Co. Ltd.	Mini LNG Plant Rumuji (Emohua LGA) Rivers State	2018	N/A	0.25 MTPA LNG
6.	Niger Delta Petr. Resources Ltd	Ogbele Gas Plant Expansion/Enhancement Works Ogbele, PH	2018	300	[illegible] • LPG • C5
7	Nigerian Petroleum Dev. Co. (NPDC)	UTOROGU NAG 2 PROJECT Utorogu, Warri, Delta State	2018	150	
8	Nigerian Petroleum Dev. Co. (NPDC)	Egbema West NAG Project		50	N/A
9	NLNG - Nig. LNG Ltd	Train 7 Project		N/A	7MTPA LNG
10	Pan Ocean	Gas Proc. Plant Ph. 2 (GPPP2) (Ovade-Ogharefe Gas Plant)	2019	200	N/A
11	Seplat Petroleum Development Co. Plc	Assa North/Ohaji South (ANOH) Midstream Project (NAPIMS) Assa/N./Ohaji S., Imo	2019	300	N/A
12	Seplat Petroleum Development Co. Plc	Oben Gas Plant Expansion project	2018	225	N/A
13	Shell Petroleum Dev. Co.	Southern Swamp Associated Gas Solutions Plus Project	2018	100	N/A
14	Shell Petroleum Dev. Co.	Assa North/Ohaji South (ANOH) Gas Plant Project, Ohaji North & Ohaji South fields, Imo State	2019	300	N/A
15	Shell Petroleum Dev. Co.	Forcados Yokri Integrated Project (FYIP), Forcados Yokri Area	2019	150	N/A
16	Shell Petroleum Dev. Co.	Sutu NAG Compression Project, Rivers State	2019	1 Tscf of gas recovery	N/A
17	Shell Petroleum Dev. Co.	Gbaran and AG Solution Project -- Agbada NAG Solution Project, Rivers State	2019	80	N/A

Source: Department of Petroleum Resource (2017).

Appendix B

Table 1.1: Gas reserves and resources in place and ownership type

2P GAS RESERVES / RESOURCES IN PLACE							
S/N	**Ownership Type of Gas**	**Gas Reserves (TCF)**					
		AG		**NAG**		**TOTAL**	
		Proved (2P)	**Resources in Place**	**Proved (2P)**	**Resources in Place**	**Proved (2P)**	**Resources in Place**
1	NPDC	0.33	1.13	1.64	2.60	1.98	3.73
2	NPDC JV	8.12	22.82	5.67	10.80	13.80	33.62
3	NNPC JV	74.44	187.87	60.43	100.41	134.87	288.29
4	PSC	13.01	43.71	17.03	14.60	30.04	58.32
5	Sole Risk/Independents	1.41	3.88	9.89	8.46	11.30	12.34
TOTAL		**97.31**	**259.41**	**94.66**	**136.87**	**191.99**	**396.3**

Source: National Gas Policy (2017)

Appendix C

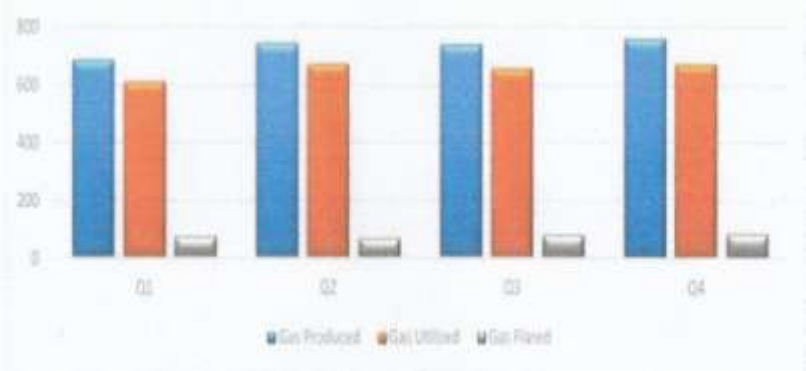

Figure 1.0: Gas Production and Utilization Profile in Nigeria

Source: Department of Petroleum Resource (2017)

Appendix D

Table 1.3: Nigerian associated and non-associated gas production

Year	**Associated Gas (AG) bscf**	**Non- Associated Gas (NAG)**	**Total Production, bscf**
2006	1,542	748	2,290
2007	1,599	1,008	2,607
2008	1,594	987	2,580
2009	1,582	646	2,228
2010	1,865	955	2,820
2011	1,839	1,127	2,967
2012	1,872	1,123	2,996
2013	1,787	1,025	2,812
2014	1,880	1,168	3,049
2015	1,740	1,262	3,003

Source: National Gas Policy (2017)

Appendix E

Table 1.4: Nigeria Gas Reserves

	Natural Gas Reserves (TCF)		
	Associated Gas, AG	Non Associated Gas, NAG	Total Gas
2010	92.945	89.872	182.817
2011	92.904	90.530	183.434
2012	89.729	92.529	182.258
2013	89.652	92.298	181.950
2014	90.094	97.904	187.998
2015	97.208	94.857	192.065
2016	97.253	101.485	198.738
2017	96.36	102.730	199.090

Source: Department of Petroleum Resource (2017)

Appendix F

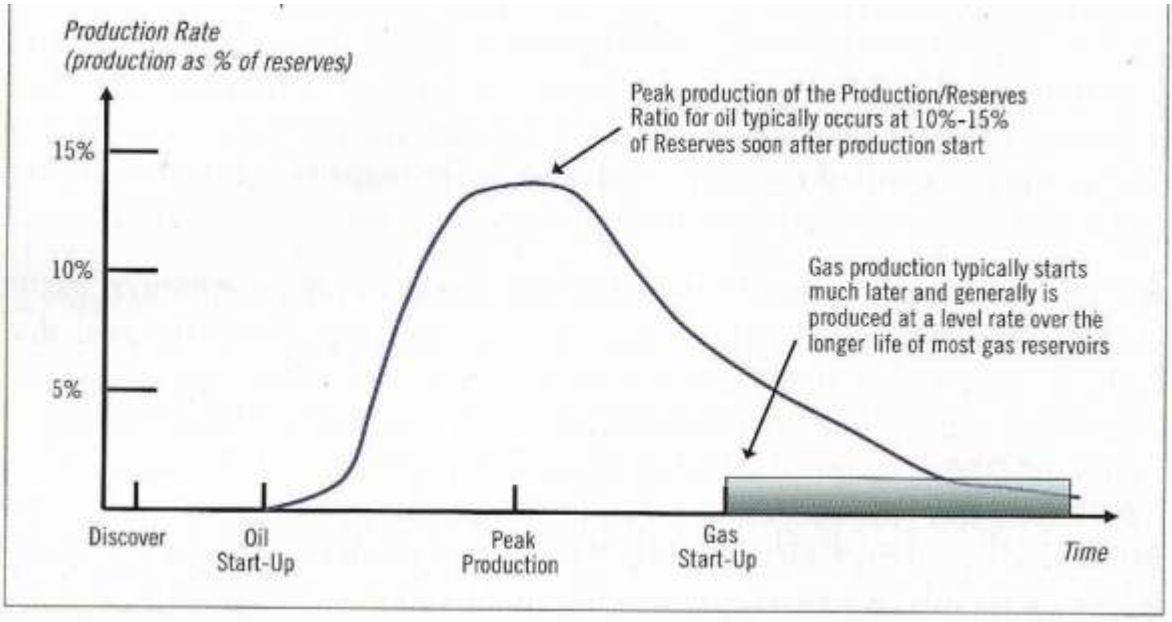

Figure 1.2: Typical Gas Production Profile Versus Oil Production Profile

Source: Inkpen and Moffett (2011)

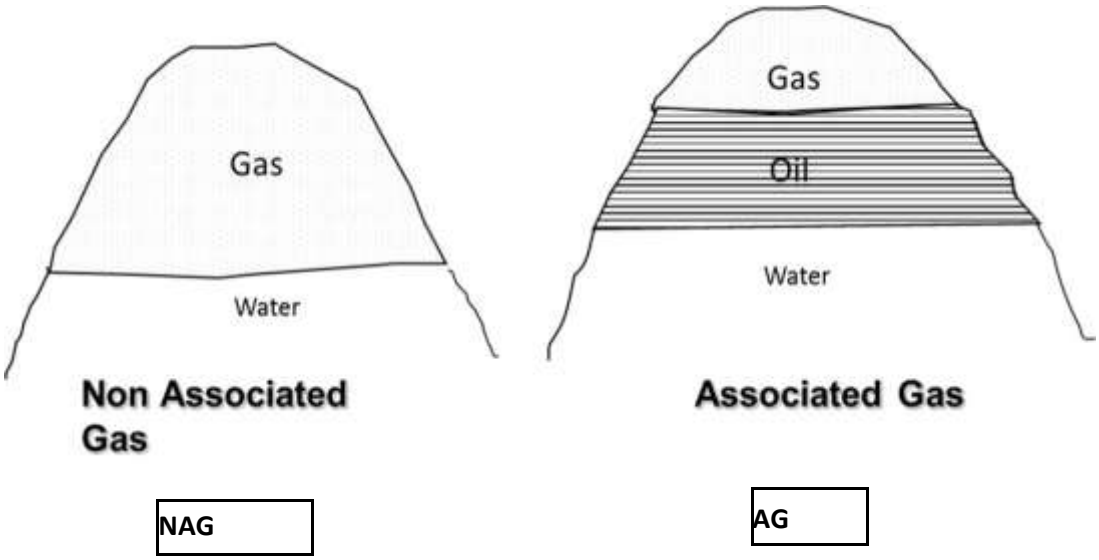

Figure 1.3: Associated gas and Non – Associated Gas Reservoir
Source: Onyekonwu (2016)

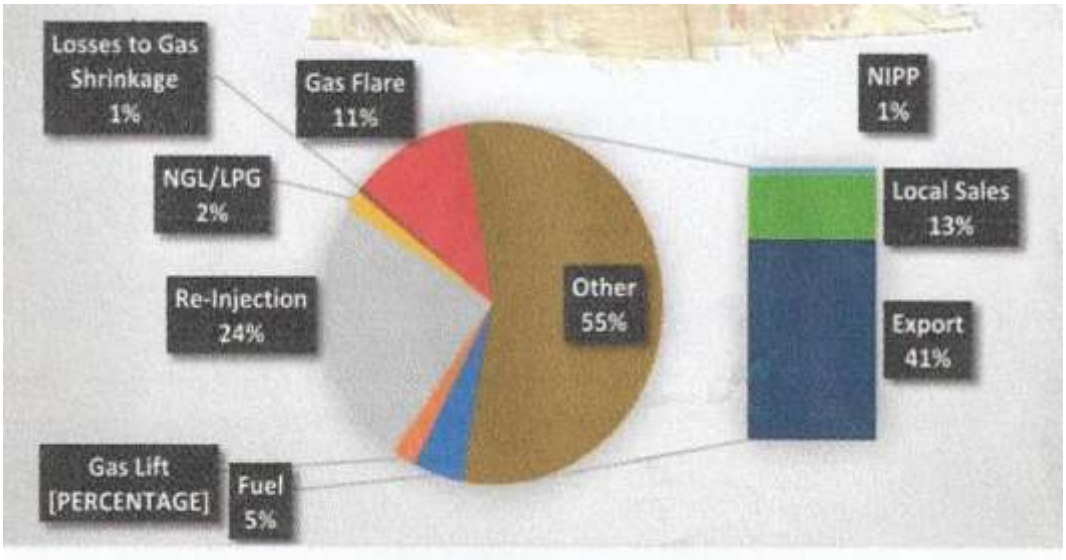

Figure 1.4: Nigerian Gas Utilization Breakdown**Source**: Department of Petroleum Resource (2017)

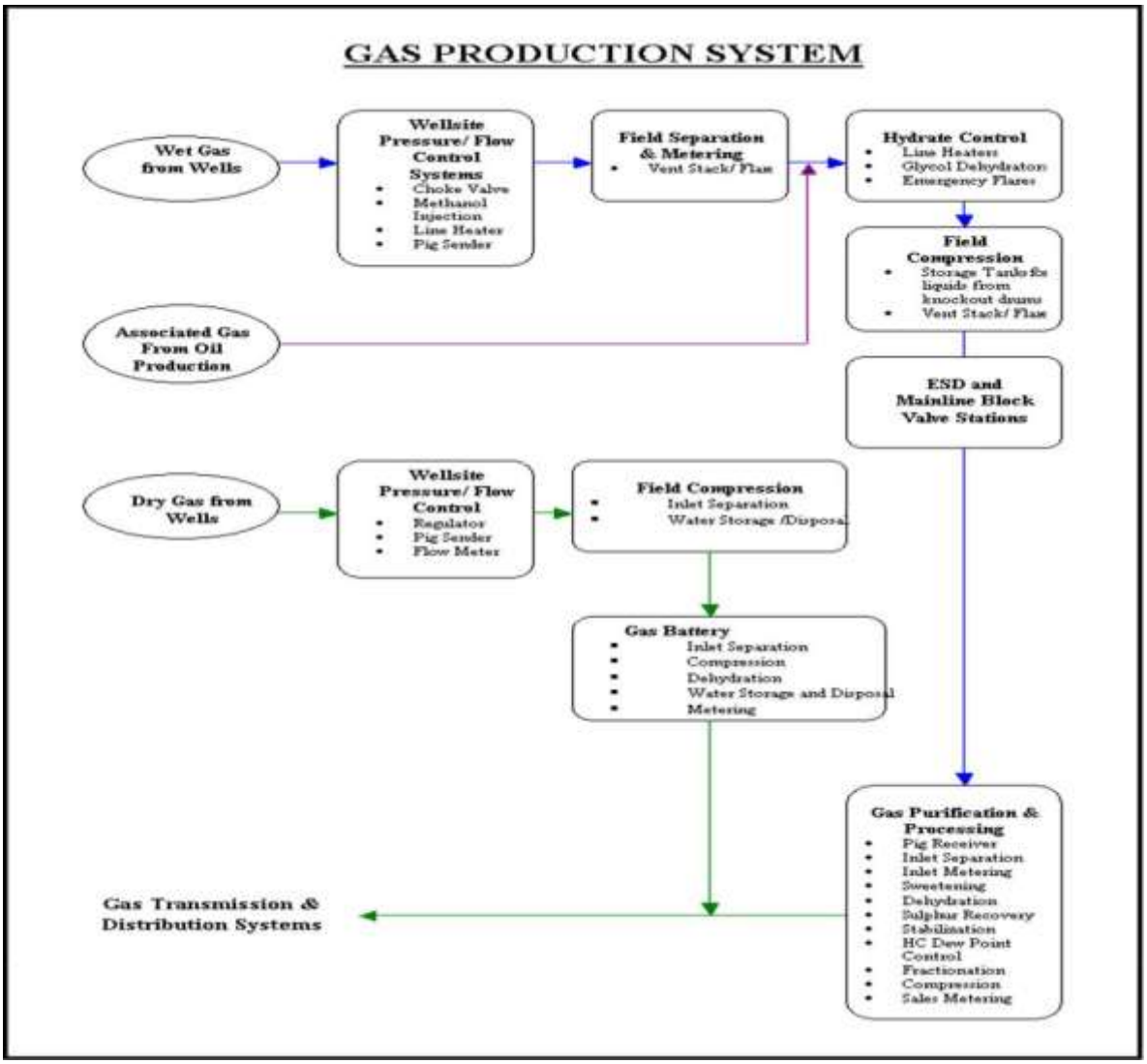

Figure 1.5: Gas Production System **Source**: Bismuke (2014)

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