A REVIEW OF THE ECONOMIC BENEFITS OF NATURAL GAS UTILIZATION IN NIGERIA

(CASE STUDY OF CADBURY NIGERIA PLC. LAGOS)

BY

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98/6958EH

FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA

NOVEMBER, 2004.

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG) DEGREE IN CHEMICAL ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

NOVEMBER, 2004.

DECLARATION

I, Eludinni Omowunmi Ibironke, hereby declare that the work presented here "Review of economic benefits of natural gas utilization in Nigeria", has never been presented else where to my knowledge for the Award of Bachelor Degree in Chemical Engineering (B. Eng.). All literatures consulted have been duly acknowledged.

....	22/11/2004 ....
STUDENT.	DATE

CERTIFICATION

This is to certify that this research project titled "The economic benefits of natural gas utilization in Nigeria" is an original work undertaken by Eludinni Omowunmi Ibironke and has been prepared in accordance with the regulations governing project presentation in the department of Chemical Engineering, Federal University of Technology Minna.

______________________	17/11/2004
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______________________	______________________
External Examiner	**Date**

DEDICATION

This project is dedicated to my ailing Father, Mr. Moses Oyebisi Eludinni who despite his ill health has continued to provide for me. May God Almighty spare your life.

ACKNOWLEDGMENT

I am most grateful to Almighty God for seeing me through the University successfully.

My profound gratitude goes to my highly esteemed project supervisor Engr. S. A. Abdulkareem for this constructive criticisms and scholarly advice during the course of this project work.

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The following people contributed in no small measure to the success of this project work, Engr. Bola Osunlana of Cadbury Nig. Plc, Nathan Unugbua of Gaslink, Mr. John, Dcns Christy Gana.

I specially thank my true and dear friend, Iseoluwapo Ademosu for his invaluable support and encouragement, you kept me moving. To two priceless gems, Charles Onyedibe and Fadekemi Oduyela for tested friendship.

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Above all, to my parents Mr. & Mrs. Oyebisi Eludinni who provided me with abundant love and care, you are both simply the best.

ABSTRACT

The reduction of operational expenditure and maximisation of profit with out reducing standards has been a great challenge to engineers in the manufacturing sector. This project work analyses how natural gas can be substituted for conventional fuel types such as diesel, petrol etc in monetary terms using mathematical principles in calculation, and how friendly its utilization is to the environment. The results obtained shows that up to 60% on diesel and 30% on low pour fuel oil (LPFO) could be saved translating to about ₦ 723 million and ₦ 146, million respectively over a period of five years for Cadbury's utilisation of natural gas.

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1.0 INTRODUCTION

Natural gas occurs naturally and abundantly in the south – south region of Nigeria. Its main constituent is methane (CH_4) but also present are ethane (C_2H_6), propane (C_3H_8), butanes (C_4H_{10}) and pentanes (C_5H_{12}) at typically 5 – 10% by volume. The gas generally contains impurities such as carbondioxide, hydrogen sulphide and nitrogen and is processed to make the gas clean for use (Dunlop,1995). Natural gas is colourless, odourless and environmental friendly if carefully handled.

Natural gas is commonly found in close association with crude oil and so close that it is considered to be the gaseous phase. However, natural gas can be differentiated into 'associated' and 'non-associated'. (Odoziaku,1999). The hydrocarbons, which occur in natural gas primarily, are listed in Table 1.0 below (Ekpo, 1999):

Table 1.1 Constituents of Natural gas

COMPONENT	BOILING POINT AT ATMPRESS	
Methane CH_4	$-161.5^{O}C$	
Ethane C_2H_6	$-88.5^{O}C$	
Propane C_3H_8	$-42.2^{O}C$	Gaseous at NTP
Iso butane C_4H_{10}	$-12.1^{O}C$	
n- butane C_4H_{10}	$-0.5^{O}C$	
Iso pentane C_5H_{12}	$-27.9^{O}C$	
n – pentane C_5H_{12}	$-36.1^{O}C$	Liquid at NTP
n – heaxane C_6H_{14}	$-69.0^{O}C$	
n – heptane C_1H_{16}	$-98.4^{O}C$	

Nitrogen is an impurity which lowers the heat of combustion of the gas and its removal by expensive cryogenic process is essential is order to enhance the commercial value of the gas.

In Nigeria, the gas is produced by exploration and production (E&P) companies namely Shell, Chevron, Mobil etc where Nigeria National Petroleum Corporation (NNPC) has participatory stake holding. Nigeria Gas Company (NGC) purchases the gas for onward sales to gas distribution companies where it is made available to end-users

Natural gas has been in use for over twenty five years in Nigeria. Over the years, power generation; cement and steel sector have enjoyed the benefits of utilizing natural gas as fuel. (Garba, 2003). Presently, about thirty industries utilize natural gas to power their boilers, oven, chillers, furnace, turbines, cookers and various engineers in Lagos. (Wunmi, 2004). Natural gas has inherent utilization qualities by being operationally flexible and efficient and economically beneficial. Some of its advantages include convenience, controllability, efficiency, price differential, cleanliness and dependability of supply. (Osezua, 2003) in comparison to conventional fuels such as coal and fuel oils.

The use of natural gas rather than fuels such as Automotive Gas Oil (AGO), and Low Pour Fuel Oil (LPFO) in most processes became one significant way of achieving this end, thus the sensitisation and awareness of the potentials and economic benefits of natural gas. (Wunmi, 2004). A keen look at Cadbury's operation and the contribution of energy to its operational expenditure (OPEX) shows that gas utilization in its process has tremendously reduced its cost of doing business.

1.1 COMPRESSIBILITY OF NATURAL GAS

All gases deviate from the perfect gas law at some combinations of temperature and pressure, the extent depending on the gas. This behaviour is described by a dimensionless compressibility factor Z that corrects the perject gas law for real gas behaviour, $PV = ZRT$. Z is unity for an ideal gas but for a real gas, Z has values ranging from less than 1 to greater than 1 depending on temperature and pressure. Because the value of Z for natural gas is significantly less than unit at ambient temperature and at pressures greater than 1Mpa (145 Psia), the compressibility must be taken into account in gas measurement, gas purchased at high line pressure will give a greater volume when the pressure is reduced than it would if the gas were ideal.

Natural gas pipeline operators use a super compressibility factor, also called Z, but defined as $Z = (RT/PV)^{1/2}$ which is convenient for use with differential pressure flow meters. (Perry, 1995).

1.2 EARLIEST ATTEMPTS TO COMMERCIALISE NATURAL GAS

The earliest attempt to commercialise natural gas in Nigeria was undertaken by SHELL – BP in the 1960's to supply some industries in Aba and the then Electricity Corporation in Nigeria (ECN) power plant at Afam.

In 1978, NNPC commissioned the Sapele Gas supply system (to the NEPA power station at Sapele) and the Gas department, under the then commercial division, which was charged with the responsibility of operating the system.

The Gas department later metamorphosised into the Gas Division of the NNPC oil and Gas sector, and is now the Nigeria Gas Company (NGC). The NGC is responsible for gathering, heating and transmitting gas to industries in Nigeria and ECOWAS sub-region.

NGC, as a non – oil drilling company, get its national gas from flow stations usually owned by oil operating companies such as shell, Gulf etc. the gas is either in associated or non-associated form. Associated gas is the natural gas components that comes in conjunction with crude oil. It is the higher, more volatile components obtained after the heavier, less volatile components have been extracted. In contrast, non-associated gas comes directly from the gas wells. The gas to oil ratio is very high compared with that of associated gas.

Nigeria has however moved unto improving her economy by utilisation of natural gas.The tables below show the existing natural gas transmission and distribution lines in Nigeria.

Table 1.2 EXISTINC :AS TRANSMISSION LINE

GAS SUPPLY SYSTEM	CUSTOMER BEING SUPPLIED WITH GAS	DESIGN CAPACITY (MMSCFD)	LINE DIAMETER (INCHES)	PIPELINE LENGTH (KM)
Aladja Gas pipeline system	Delta Steel Plant Aladja	70	6,8,14 & 16	130
Oben – Ajaokuta Gas Pipeline System	Ajaokuta Steel Plant	200	24	198
Sapele Gas Pipeline System	Nepa Power Station Sepele Plant	200	10 & 184	44
Obigbo North/Afam Gas Pipeline system	Nepa Power Station Afam Plant.	90	14	19
Imo River Aba Gas Pipeline system	IGIL, PZ, ABATEX, NE, LB, and IINTEL EUITABLE	34	12	28
Alscon Gas Pipeline System	Alscon Akot-Abasi plant	180	14,16 & 24	117
Alakiri-onne Gas Pipeline system	NAFCON, ONNE plant	138	14	17
Escraves-Lagos Gas Pipeline system	NEPA EGBIN and Delta IV Ughel li, Warri Refinery, WAPCO Shagamu, Warri Refinery, KEW Metal Works, Ikorodu.	1100	30 & 36	514
Ibafo-Ikeja City Gas Gas Pipeline System	Greater Lagos and Its environs	50	24	48.4
TOTAL PIPELINE LENGTH				**1,115.4**

Table 1.3 EXISTING GAS DISTRIBUTION LINE

Gaslink's Ikeka phase 1A Gas Distribution project.	Cadbury, Dunlop, Guiness, CMB, WAMCO, WEMPCO, Reliance, UNICO, PMP, ROBICON, Cocoa Ind, NWECO, WAHUM, PRESTIDGE. Domgas, SID, 7up, Cook' N' Lite, Epesok Paper etc.	20	3,4,6,8,10,	11.2
Gaslink's Ikeja phase 1B Gas Distribution Project.	7UP & Green Eagles and Cork	5	3,6	4.2
Gaslink's GLIA 2	Under construction	60	3,4,6,8, & 10	84
SNG Agbara/Otta Gas Project	Hong Kong Synthetics, Sona Breweries, Nestle Foods, Beta Glass, Aluminium Rolling Mills etc.	42	3,4,8,10	70
TOTAL PIPELINE LENGTH				**169.4**

1.3 AIMS AND OBJECTIVES

The aim of this project is to carry out a cost Benefit Analysis on natural gas utilization in comparison to other conventional fuels with a case study of Cadbury Nigeria Limited. This can be achieved through the realization of the following objectives.

1. Evaluation of the economic effects of gas flaring and utilization in Nigeria.
2. Review of the impact of natural gas utilization on the environment, industries and general public.
3. Suggestions of how maximum utilization can be achieved in present day Nigeria.

1.4 SCOPE OF WORK

The scope of this study covers

a. Comparison of cost analysis of various fuels.

b. Environmental Impact of natural gas leak to the environment.

c. The effects of natural gas utilization by industries.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 GAS FLARING

In the 1960's and 1970's there were few markets for gas in Nigeria and at the same time, little awareness of the consequences of gas flaring, not much done to find or develop gas reserves and no facilities were built to collect the associated gas (Ageh, 2000). Crude oil production results in the release of dissolved natural gas when oil is brought to the surface. When this gas cannot be economically conserved, it is usually flared at the location where it is produced. Associated gases are routinely flared in the course of producing and processing oil. In certain circumstances, such as emergency shutdowns, non planned maintenance, or disruptions to the processing systems, flaring serves a vital safety purpose (Global gas, 2002). With elevated flares, combustion is carried out through the top of a pipe or stack where the burner and igniters are located.

Available statistics indicate that volumes of more than 100 billion standard cubic metres (3,530 billion standard cubic feet) are currently being flared annually world wide, equivalent to 200 million tonnes of carbondioxide emissions. However, global statistics are incomplete and highly uncertain (NNGS, 2002). The energy available from Nigeria's flared gas is prodigious. equivalent to one quarter of energy requirement by France. Many of the oil producing and gas flaring companies in Nigeria are now working on flaring reduction strategies and possible elimination through conservation, reinjection, gathering and harnessing of associated gas (Ageh, 2000).

The fig 2.1 below shows the amount of gas that was flared between 1990-2001.

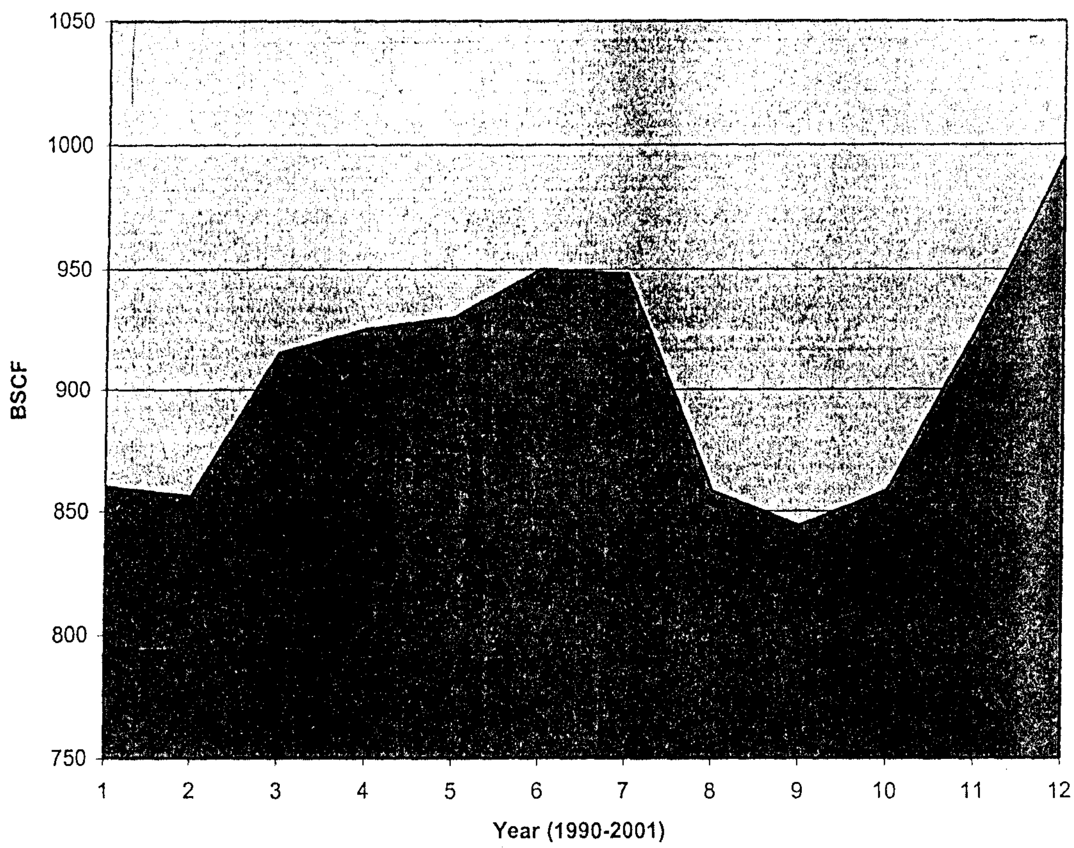


Fig 2.1 Gas flared in Nigeria between 1990-2001.

2.1.1 GAS FLARING AS A PROBLEM

Despite commitments by governments and companies, global gas flaring levels have remained virtually constant since 1983 (Global gas, 2002). However, when access to a cheap, reliable and clean fuel is improved, the global community will benefit from the provision of public good such as lower green house gases emissions, poverty reduction and diversity of energy supplies.

Flaring of gas is a problem because

1. It wastes resources: The estimated 108 billion cubic metres (bcm) of natural gas flared globally per year is a significant waste of energy resources that could be used productively. The amount being flared at the same level as the combined gas consumption of Germany and France. Flaring in Africa (37bcm in 2000) could be used for power generation in efficient power plants to produce 200 Tonne Watt hr(TWH), an approximate 50% of the current power consumption of the African continent (Global gas, 2002).

2. It harms the environment: Carbondioxide emissions from flaring and methane emissions from venting have high global warming potentials and contribute to climate change. Flaring may in some places have harmful effects on human health and ecosystem near flaring sites (Global gas, 2002).

2.1.2 GAS FLARING REDUCTIONS

The Federal government of Nigeria hopes to put an end to flaring by the end of year 2008(NNGS,2002). Gas flaring reduction will depend critically on three broad alternatives, which are:

a. International markets

b. Domestic markets and

c. Reinjection.

2.1.3 INTERNATIONAL MARKETS

2.1.3.1 Regional Pipelines

Regional pipeline systems that could carry associated gas to other neighbouring countries will aid the use of otherwise flared has. The West Africa, Gas pipeline project (WAGP) in which Chevron and its palrtners plan to build a 620 – mile off shore line capable of shipping approximately 1.9bcm of gas per year is a viable export project. This gas will be transported to power plants and other major gas were in Benin, Ghana and Togo.

2.1.3.2 Gas to Liquids (GTL)

Gas to liquid technology, based on Fischer–Tropsch synthesis, can produce a number of liquid products that could be exported. Some, such as synthetic diesel might also be marketed locally, using existing product distribution infrastructure. The major disadvantage of GTL technology is that it is relatively new to the world market and construction and operating costs remain high.

2.1.3.3 Liquefied natural gas (LNG)

LNG is basically natural gas in liquid for fort the purpose of transporting it over long distances to areas where the markets exists and cannot be economically piped. ($1m^3$ of natural gas occupies $^1/_{600}$ of its gaseous volume as liquid). This unique characteristic enables transportation of large volumes of gas in liquid form. The natural gas is cooled in a main cryogenic box to – 161^0C and then transferred to storage tanks.

The Nigeria LNG, an export based project located at Bonny, River state, consists of a gas transmission system, a two train liquefaction plant, LNG storage tanks, a loading jetty and carriers for the evacuation of LNG.

2.1.4 DOMESTIC MARKETS

This can be achieved by giving franchise to private investors to operate gas sales in the country. Although there exists two major companies namely Gadink Nigeria Ltd and shell Nigeria Gas, participation is not to the fullest and full exploitation is not in place. Domestic market will create room for the general public to utilize natural gas hence reduce need for flaring.

2.1.5 REINJECTION

In West Africa, flaring ratios are expected to decline significantly over the next two decades, mostly due to improvements in Nigeria and Angola. Nigeria has large projects in development to reinject associated gas or bring it to market though the projects have to contend with policy and market barriers.

2.2 POLLUTION

Ignition of large flammable mixture of air and natural gas will give rise to flames and large fires. Domestic incidents have caused confined explosions with corresponding blast, structural damage and personnel injury or even carbondioxide, sulphur dioxide and other types of contaminates pouring from industrial smokestacks arising from natural gas combustion contribute to the world's atmospheric pollution.

The atmosphere is a self – cleaning entity and pollutant concentrates are reduced by atmospheric mixing which depends on weather conditions such as temperature, windspeed, the movement of high and low pressure systems and their interaction with the local topography e.g. mountains and valleys. When the rate of generation of these contaminants exceeds the rate of removal, accumulation occurs producing a temperature of thermal inversion. Inversions can be sustained under a stationary high-pressure system coupled with low windspeed and results in poor atmospheric mixing which is hazardous (Ekpo, 1999).

2.3 GLOBAL WARMING

Like glass panes in a green house, gases in the earth is atmosphere permit the sun's radiation to heat the earth but do not allow the infrared energy radiated by the earth to escape into space these gases primarily carbondioxide, methane, oxides of nitrogen and water vapour are responsible for maintaining a global temperature acceptable to life and this process is called the Greenhouse Effect. Without this effect, the earth's average temperature would be much colder and the planet covered with ice (Gaslink EIA, 1999).

Gas flaring is a major contributor to the release of greenhouse gases, smog and acid rain. This phenomenon of global warming could lead to severe erosion of shorelines, submersion of low lying islands, increase in coastal flooding, saline intrusion, skin diseases etc.

2.3.1 NITROGEN OXIDE

Some nitrogen oxides are produced in natural gas flames but the quantity produced is lower than most other fossil fuels. Oxides of nitrogen at certain temperatures cause serious injury to vegetation and reduce visibility. In the presence of sunlight, these oxides can react with hydrocarbons to form photochemical oxidants harmful to human health. Principally, atomic oxygen reacts with molecular oxygen to produce ozone, which destroys rubber by cracking it. (Ekpo, 1999).

2.3.2 SULPHUR OXIDE

Where natural gas contains virtually no sulphur, the quality of sulphur oxides from combustion is negligible. The major source being fuel combustions chemical plants, metal processing and trash burning produced sufficient amount to combine with moisture and oxygen thus causing yellow leaves in plants, dissolution of marble and corrosion of iron and steel from acid rain.

2.3.3 CARBONDIOXIDE

This is the major greenhouse gas and contributes up to 82% of the total greenhouse emissions. (Ekpo, 1999) carbondioxide is an inevitable product of combustion of natural gas during flaring. CH_4 (g) + 20_2 (g) – CO_2 (g) + $2H_{20}$.

2.4 STATISTICS OF NATURAL GAS IN NIGERIA

Statistics show that Nigeria has a gas reserve of about 159 trillion cubic feet (15g TCF) which in energy terms is about twice the crude oil reserve. About 3 Billion cubic feet (3BCF) is produced per day in which 70% is flared and the remaining 30% is utilised as fuel or reinjected (Gaslink, 2001). It is currently estimated that about 2 Billion SCF of gas is being flared daily in Nigeria, the highest known estimate in the world. Consequently, Nigeria accounts for over 20% of the total amount of gas flared globally. This quantity released equates to a figure of around 730 billion SCF per year (Global gas, 2002). In monetary terms, the average price of natural gas (European) effective 31st July, 2002 was $ 3.152 ***MMBTU***. Thus, calculating.

2 Billion SCF of natural gas = 2000 Billion BTU

= 2 Million MMBTU

3.152 x 2,000;000 = US $ 6, 304, 000 per day

= US $ 2.3 billion on per year.

Although this figure has a wide margin, it is clear that gas can make a significant addition to our export revenues. There is need for Nigeria to harness her resources of natural gas to reduce expenses on forex in the refining of crude oil to supplement her energy demands. (Wunmi, 2004).

2.4.1 NATURAL GAS RESERVES

At the end of 2001, Nigeria proved gas reserves were estimated to be 124 tonnes cubic feet (TCF), Nigeria is ranked 9th in the world for proved reserves and estimated to have proved and probable reserve of 158 TCF. (Global gas)

Table 2.1 World Ranking of Proved Natural Gas Reserves

S/NO	COUNTRY	AT END 1981 TCF	AT END 1991 TCF	AT END 2000 TCF	TCF	A END 2001 SHARE OF TOTAL
1	Russian. Federation	n/a	n/a	1699.34	1680.0	30.7%
2	Iran	483.96	600.01	811.9	812.3	14.8%
3	Qatar	60.00	162.03	393.60	508.5	9.3%
4	Saudi Arabia	118.25	184.62	213.56	219.5	4.0%
5	United Arab Emirates	23.30	199.01	212.15	212.1	3.9%
6	USA	198.03	169.09	167.32	177.4	3.2%
7	Algeria	130.96	116.50	159.56	159.7	2.9%
8	Venzuela	46.95	109.78	146.85	147.6	2.7%
9	Nigeria	40.60	104.84	123.90	124.0	2.3%
10	Iraq	27.18	94.96	109.78	109.8	2.0%

n/a – not available

2.5 GAS UTILIZATION IN NIGERIA

Due to unsustainable exploitation practices coupled with the lack of gas utilization infrastructure, Nigeria flares a substantial proportion of the gas it produces. When compared with oil production in advanced countries, Nigeria Lags far behind in terms of associated gas conservation and utilization. The figures below show gas utilization and flaring in Nigeria (NNGS, 2002).

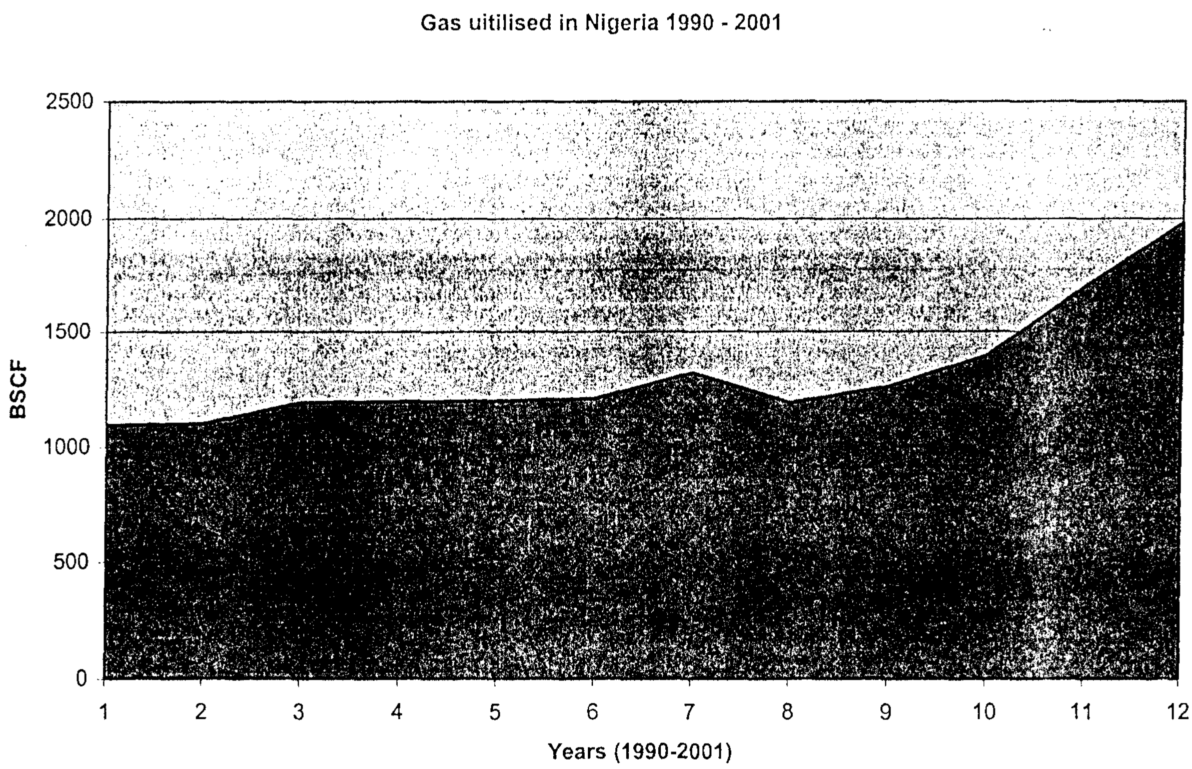


Fig 2.2 Gas utilisation in Nigeria (1990-2001)

2.5.1 COMPANIES UTILIZING NATURAL GAS IN NIGERIA

NEPA, Sapele Power station

Ajaokuta steel company

NAFCON

NBC Benin,

Iwopin Paper Mill,

West Africa Portland cement, Ewekoro

Cadbury Nig. Plc

Dunlop Plc.

Guiress Nig. Plc

7 – up company

Rehance Textiles Mills

Robicon Aluminium

Cook 'n' lite foods

Dangote Industries etc.

2.5.2 APPLICATION OF NATURAL GAS

The above listed companies ranging from the food industries to textile mills and to power generation use natural gas to run a number of engines such as boilers, ovens, chillers, furnaces, turbines, cookers, etc.

The potential investment areas where natural gas can be applied include.

LPG Plant

Compressed natural gas for vehicles

Fertiliser production

Petrochemical products

Power generation

Methanol/MTBE plants etc.

2.5.3 BENEFITS OF NATURAL GAS UTILIZATION

The damaging results of flaring such as acid rain, global warming, heat effects, noise pollution, and economic wastage can be abated by the utilization of this gas. The benefits of put to use are wide, it serves to protect the environment from desert encroachment and deforestation among others which include.

- A veritable source of domestic fuel in homes
- An efficient and economic source of process heat for industries.
- Use on low cost, high efficient machines such as combine- cycle gas turbines.
- Storage facilities not required and problems associated with liquid fuels such as accidents, traffic congestion etc are avoided.
- Since there is an established price, it is not influenced by rate or demand as there is constant supply.
- Eliminates cost associated with plant idleness due to angularity of supply of fuel oil leading to stability in operation.
- Reduce the production of greenhouse gases.

The use of natural gas for domestic, commercial and industrial application is ***intrinsically safe*** and poses little environmental concern. Natural gas apart from being the cheapest of the petroleum fuels is also the cleanest (Ekpo, 1999).

2.6 STRUCTURE OF THE NIGERIA GAS INDUSTRY

Below is the schematic diagram of the gas value chain in Nigeria. The gas is produced by the exploration and production (E&P) companies namely shell, chevron, mobil etc where NNPC has participatory stake holding. The gas is purchased by NGC from the E&P companies for onward sales to gas distribution companies who is turn market the gas to the endures (Garba, 2003).

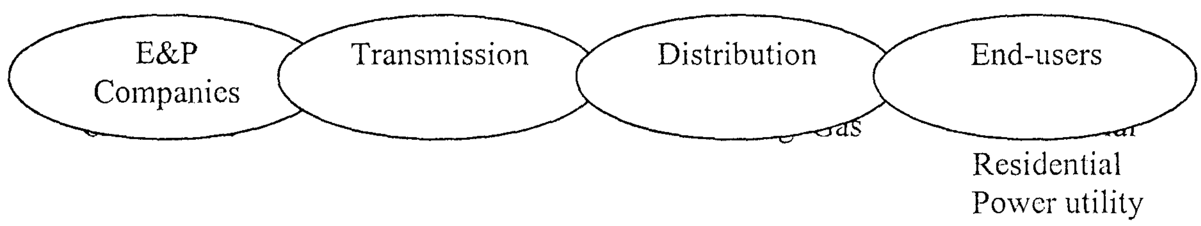


Fig 2.3 Structure of Nigerian Gas Company

The Federal government has devised a comprehensive policy to sustain and ensure supply of natural gas to end consumes in the domestic energy market.

2.7 NIGERIA FISCAL POLICY ON NATURAL GAS

Part of federal government effort to liberalize and encourage private sector participation in the development of Natural Gas infrastructure in Nigeria was the introduction of some economic incentives to give the operators some leverage and relief on some industrial policies (NGC, 2003)

These incentives are:

Based on the provision of Decree 18 of 1998 and Petroleum Profit Tax Act, all downstream investor shall enjoy the following tax incentives:

a. Initial Tax Holidays of 5 years, renewable for additional two years subject to satisfactory performance of the business.

b. Accelerated Capital Allowances after tax holidays period as follows:

- Tax Allowances of 20% for investment in plant and machinery for 4 years and 19% for 4th year with 1% left in the books.
- Petroleum Investment Allowance of 15%, which shall not reduce the value of the asset.

c. All dividends distributed during the tax holidays shall be tax free where the investments for the business was in foreign currency or the introduction of plant and machinery during the period was not less than 30% of the equity share of the Company.

d. 0% Import Duty and 0% VAT on pant, machinery and equipment imported by industrial establishment using gas in the manufacturing process.

e. Gas is to be transferred at 0% PPT and 0% Royalty.

f. Gas development projects including power generation, gas to liquid plants, fertilizer plants, gas transmission and distribution pipelines, are to be taxed under the provisions of Companies Income Tax Act. Where there is integrated oil and gas project, all expenditure pertaining to the integrated oil and gas project would be chargeable under the PPT.

g. Interest on loan for gas project obtained with prior approval of the Ministry of Finance, shall be tax deductible.

The objectives of these incentives and the national gas policy is to:

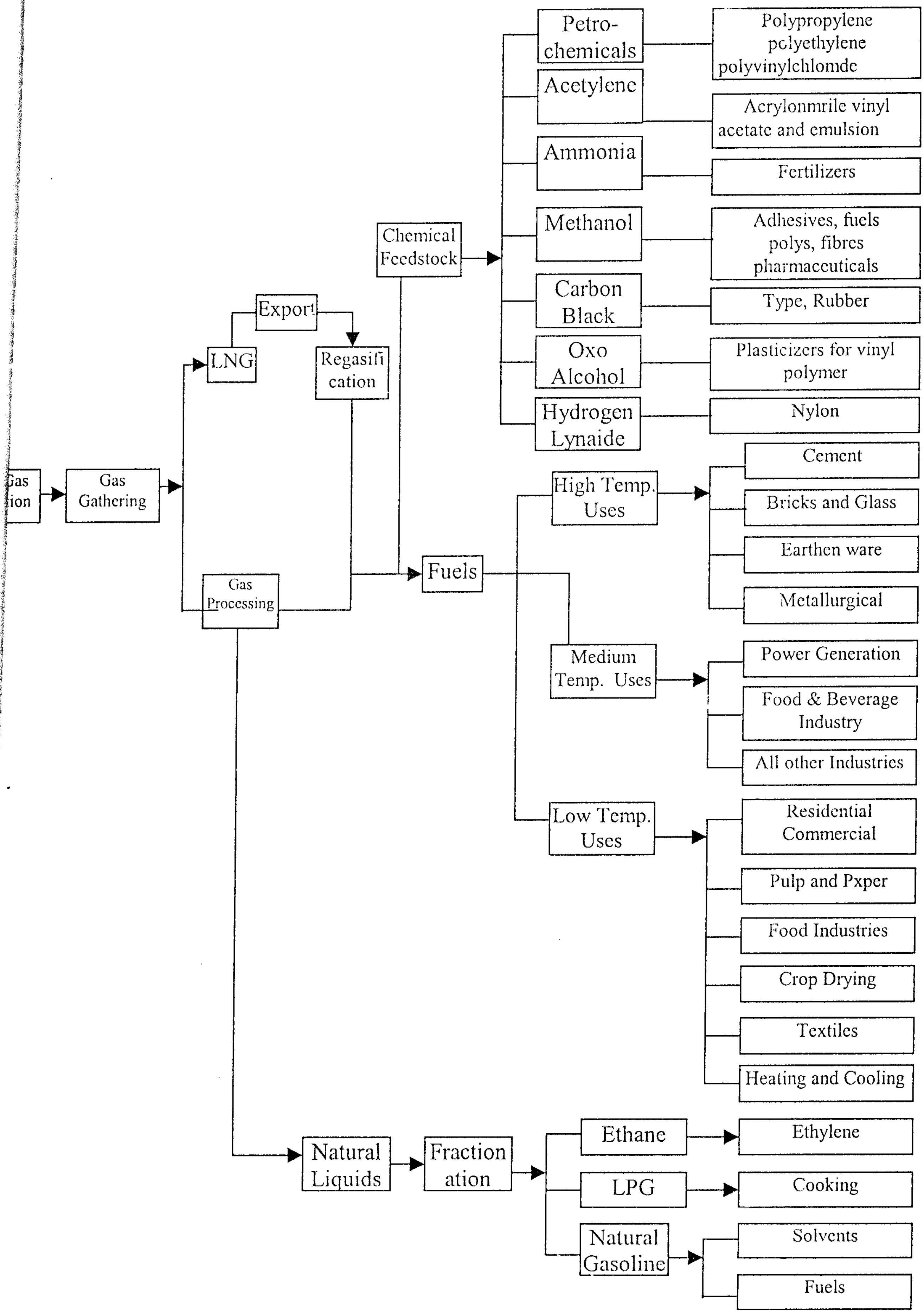
1. Define properly the roles and responsibility of operators in the gas sector.
2. Encourage increased local and foreign participation in the industry; especially in the export – oriented gas projects and other downstream gas based ventures such as the production of fertilizers and petrochemicals.
3. Give priority to the utilization of associated gas within the framework of the national energy mix and in the process eliminating gas flaring in the interest of the environment.
4. Encourage substitution of natural gas for oil resources like fuel oil, gasoline etc.

Therefore the policy of the government is to encourage the utilization of gas in the domestic Energy market in order to stem the flaring of gas. Part of this policy is fixing the end-consumer price of natural gas as a maximum of 80% of LPFO; this keeps the price of gas always below the prevailing price of LPFO,. In energy terms. LPFO is the competing fuel to Natural gas in the Industrial market segment, replacing LPFO with natural gas offers an annual savings of 40% in the Energy bill of the end-users. Other premium features of natural gas include low maintenance cost, reliability of supply (available for 24 hours in a day for 365 days).

2.8 USES OF NATURAL GAS

Due to variety of natural gas, it finds wide application either as an energy source or as feedstock to the chemical/petrochemical industries fig. 2.2 chart of natural gas production and uses.

FIG 2.4 CHART OF NATURAL GAS PRODUCTION AND USES



2.9 PRICE SETTING

Basically, price retting is discretionary and opaque but in theory, the basis of gas pricing could be negotiated regulated or determined by competition.Currently, end user prices have effectively been negotiated between the state and the upstream producers. If there is going to be wider private sector participation in the sector, this might come at various points in the delivery and utilisation chain. Therefore prices are broken down into their component parts.

- Production and gathering
- Transportation
- Distribution and supply
- Storage and reserve capacity

2.9.1 GAS PRICING

Unreliable energy sources have forced most manufacturing industries to depend on diesel powered generators. This is more costly to operate in terms of money, time and maintenance.

In Nigeria, the price of natural gas is indexed to the price of the fuel it is substituting (LPFO), beginning from 60% and increased to 80% over a period of 5 yrs at an interval of 5% (rof) (Gaslink, 2003).

Gas price in the 1st contract year -------------------- 60% of prevailing official pump price of LPFO.

Gas price in the 2nd contract year -------------------- 65% of prevailing official pump price of LPFO.

Gas price in the 3rd contract year -------------------- 70% of prevailing official pump price of LPFO.

Gas price in the 4th contract year -------------------- 75% of prevailing official pump price of LPFO.

Gas price in the 5th–20th contract year ---------------- 80% of prevailing official pump price of LPFO.

Table 2.2 comparison of consumer prices of alternative energy product with natural gas as at January, 2003.

		Gross Calorific Value CV		Specific Gravity (SG)	Quantify in litres required to produce 1 MMBTU	Consumer price Naira/Lt	Equivalent Energy Price Naira/MMBTU
S/No	Product	Btu/lb	Btu/lt				
1	Fuel oil	19,224	38,330	0.9044	26.09	12.40	323.50
2	Automotive Gas Oil (AGO)	19,548	37.032	0.8592	27.00	26.00	702.00
3	Gasline (PMS)	20,196	33,410	0.7504	29.93	26.00	778.18
4	Kerosine (HHK)	19,782	35,831	0.8216	27.91	24.00	669.84
5	Liquefied Petroleum Gas (LPG)	22,282	Btu/kg 49,124	0.5689	Kg 20.36	₦1,050 per 12.5kg	1710.24
6	Natural Gas	Btu/Scf 1000		0.55-.65	SCF 1000		60-80% of fuel oil (negotiable)

CHAPTER THREE

3.0 RESEARCH METHOD AND PROCEDURES

In view of cost Benefit Analysis of natural gas, a survey was carried out in Cadbury Nigeria Plc., a confectionary conglomerate which has converted most of its machines to utilise natural gas. The conversion from conventional fuel type such as Automotive Gas Oil (AGO – Diesel) and low Pour fuel oil (LPFO-fuel oil) to natural gas involves proper engineering evaluation of equipments. A typical action program that is used to measure performance on natural gas utilisation is illustrated below.

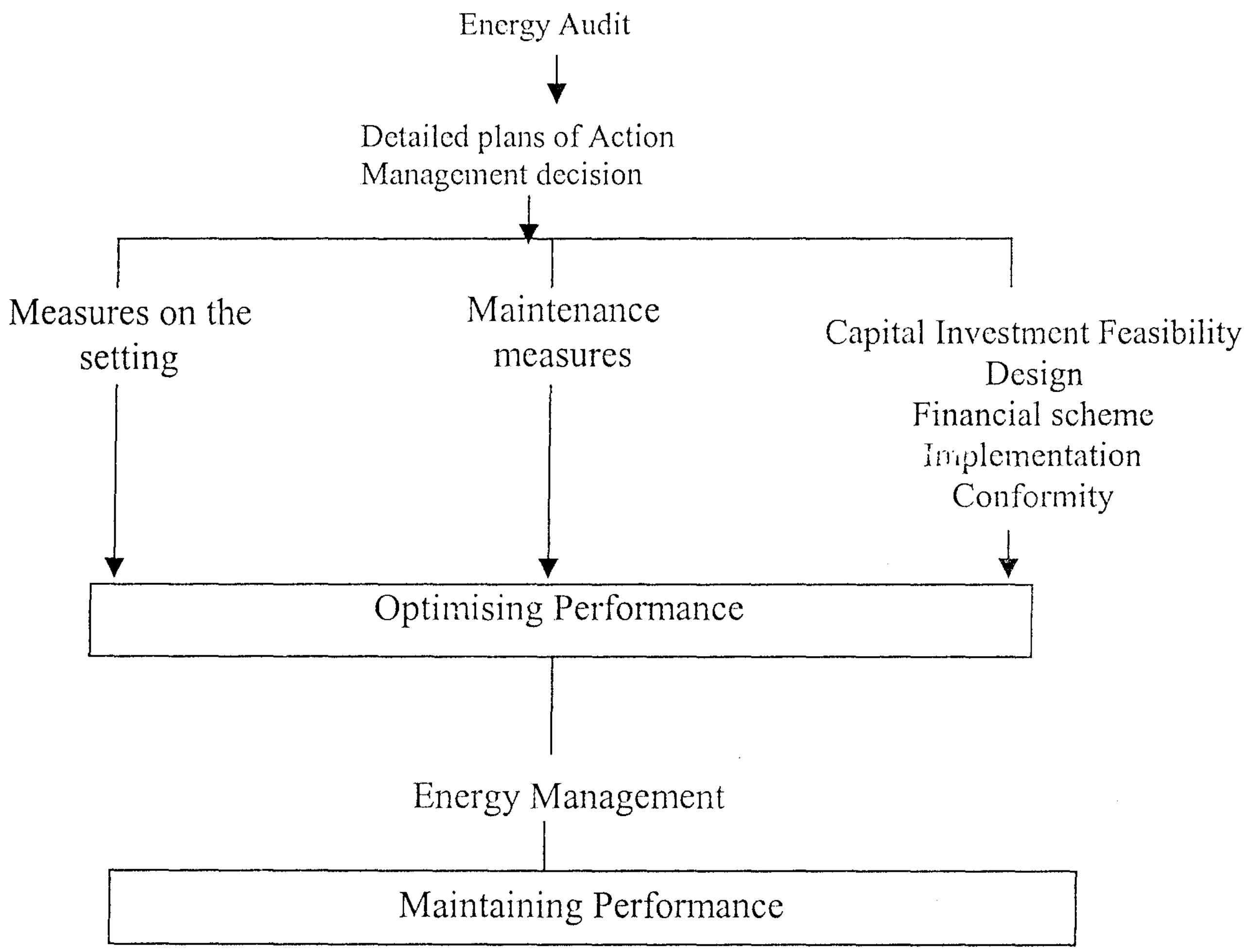


Fig 3.1: A typical Action Program Procedure for natural gas utilisation

The plant engineer of Cadbury Plc provided the figures of natural gas utilised within a period of six months from January 2004 to zJune, 2004. This is presented in the table below.

TABLE 3.1 Natural gas utilized by Cadbury between january- june, 2004

MONTH	NATURAL GAS
January	1,091,345 SCM
February	912,154 SCM
March	1,030,590 SCM
April	808, 986 SCM
May	1,106,970 SCM
June	900,225 SCM

This natural gas has replaced the average monthly utilization of 0.3 million litres of LPFO and 0.45 million litres of diesel (AGO).

The comparison of natural gas price to other fuel prices was done using mathematical principles of calculation.

3.1 NATURAL GAS SALES PRICE

Natural gas is indexed to the price of the fuel it is substituting, beginning from 60% and exalted over five years to a price equivalent of 80%, i.e an interval of 5% for each year and remains stable at the and of fifth year (Gaslink, 2003)

$$Pn = \sum_{i=0}^{k} (60\% + i)(\psi\ Pxi)$$

Where Pn – unit price of gas per 1000 scf in with year (n = 1,2,3-------------)

i= % exalation (0%, 5%, 10%, 15% and 20% for the 1st, 2nd, 3rd, 4th and 5th to the end of contract year respectively up to K)

k = limit of percent escalation (k = 20%)

ψ Pni = 26.09 Pa = ₦26.96

Q = appropriate gas equivalent volume to produce 1 MMBTU

Pa = Unit price of LPFO (₦ / litre)

ψ is calculated thus;

1 ltr of LPFO = 38.33 SCF of gas

1000 SCF gas = 1 MMBTU

Thus 33.833 SCF = $\frac{1000}{38.33}$ = 26.09 litr of LPFO

$$Pn = \sum^{k} (60\% + i)(\psi\, Pxi)$$

1[st] year $P_1 = (60\% + 0\%) \times 26.09 \times$ ₦ 26.96

= ₦422.03/MSCF (₦14.89/SCM)

2[nd] year $P_2 = (60\% + 5\%) \times 26.09 \times$ ₦26.96

= 0.65 x 26.09 x ₦26.96

= ₦457.20/MSCF (₦16.17/SCM)

3[rd] year $P_3 = (60\% + 10\%) \times 26.09 \times$ ₦26.96

= 0.7 x 26.09 x ₦26.96

= ₦492.37/MSLF (₦17.38/SCM)

4[th] year $P_4 = (60\% + 15\%) \times 26.09 \times$ ₦26.96

= 0.75 x 26.09 x ₦26.96

= ₦527.54/MSCF (₦18.62/SCM)

5[th] year $P_5 = (60\% + 20\%) \times 26.09 \times$ ₦26.96

= 0.80 x 26.09 x ₦26.96

= ₦562.71/MSCF (₦19.86/SCM)

Where 1 MSCF = 1000 SCF

1 SCM = 35.29 SCF

3.2 COST CONVERSION OF LPFO INTO NATURAL GAS

Cadbury PLC uses 0.3million litres of LPFO per month to generate power in its boiler engines for steam production. Converting this amount in energy terms will yield.

Consumption of LPFO per month = 0.3 million litres

0.3 million litre = 300,000 ltrs/month

Consumption per year = 300,000 x 12

= 3,600, 000 ltrs/year

Cost of LPFO per litre = ₦26.96

Energy bill for LPFO per year = 3,600,000 x ₦26.96

= ₦97, 056,000

Gas equivalent of 3,600, 000 ltrs of LPFO is:

1 ltr of LPFO = 38.33 SCF of gas

3,600,000 ltrs = 3,600, 000x38.33 SCF

= 137,988,000 SCF of gas

1 MMSCF = 1000 MSCF

= 137,988 MMSCF (3.91 MMSCM)

Table 3.2 Cost analysis of LPFO

Year	Cost of LPFO in ₦	Cost of gas Equivalent in ₦	Savings in ₦	% Savings
1	97,056,000	58,219,900	38,836,100	40.01
2	97,056,000	63,068,000	33,988,000	35.02
3	97,056,000	67,956,000	29,100,000	29.98
4	97,056,000	72,800,000	24, 256,000	24.99
5	97,056,000	77,650,000	19,406,00	19.99
Total	**485,280,000**	**339,693,900**	**145,586,100**	**30.00**

- The price of LPFO is assumed to be constant for the first five years
- The cost of gas equivalent is calculated using the price basis for each year.

  Yr 1: 3.91 MMSCM x 14.98 = ₦ 219,900

  Yr 2: 3.91 MMSCM x 16.13 = ₦ 63,068,000

  Yr 3: 3.91 MMSCM x 17.38 = ₦ 67,956,000

  Yr 4: 3.91 MMSCM x 18.62 = ₦ 72,800,000

  Yr 5: 3.91 MMSCM x 19.86 = ₦ 77,650,000

- Savings in ₦ = cost of – cost of gas LPFO equivalent
- % Savings = $\frac{\text{savings in ₦}}{\text{Cost of LPFO in ₦}}$ x 100

3.3 COST CONVERSION OF AGO (DIESEL) FUEL INTO NATURAL GAS

Cadbury PLC consumes an average amount of 0.45 million litres of AGO per month. This is converted in energy and monetary terms below.

Consumption of AGO per month	= 0.45 million litres
0.45 million litres	= 450, 000 ltrs
Consumption of AGO per year	= 450, 000 x 12
	= 5,400, 000 ltrs/yr
Cost of AGO per litre	= ₦ 45.00
Energy bill for AGO per year	= 5,400, 000 x 45
	= N243, 000, 000

Gas equivalent of 5,400, 000 ltrs of AGO

1 ltr of AGO	= 37.04 SCF of gas
5,400,000 ltrs	= 37.04 x 5,400,000
	= 200,016,000 SCF of gas
	= 200.016 MMSCF (5.668 MMSCM)

Cost of gas equivalent for each year

Yr 1: 5.668 MMSCM x ₦14.98 = ₦84,396,520

Yr 2: 5.668 MMSCM x ₦16.13 = ₦91,424,840

Yr 3: 5.668 MMSCM x ₦17.38 = ₦98,509,840

Yr 4: 5.668 MMSCM x ₦18.62 = ₦105,566,480

Yr 5: 5.668 MMSCM x ₦19.80 = ₦112,566,480

Table 3.3 Cost Analysis of AGO

YEAR	COST AGO IN ₦	COST OF GAS EQUIVALENT ₦	SAVINGS ₦	% SAVINGS
1	243,000,000	84,396,520	158,603,480	65.27
2	243,000,000	91,424,840	151,575,160	62.38
3	243,000,000	98,509,840	144,490,160	59.46
4	243,000,000	105,538,160	137,461,840	56.57
5	243,000,000	112,566,480	130,433,520	53.68
Total	**1,215,000,000**	**492,435,840**	**722,564,160**	**59.47%**

3.4 CONVERSION OF OTHER CONVENTIONAL FUEL TYPES

In the measurement of the extent of natural gas utilization in Nigeria, it is expedient to analyse the cost of other fuel types such as liquefied petroleum Gas (LPG), electricity, kerosene, coal and pure motor spirit (petrol). Arbitrary values are chosen reasonably at random for workability of a combustion process. Fuel costs vary widely from one area to another because of the cost of the fuel itself and the cost of transportation .

3.5 LIQUIFIED PETROLEUM GAS (LPG)

The chief constituents of LPG are propane, propylene, butane, butylenes and iso-butane. LPG is produced in the separation of heavier hydrocarbons from natural gas is mainly of the parafinic (saturated) series while those derived from oil refinery gas may contain varying low amounts of olefinic (unsaturated) hydrocarbon LPG, otherwise known as cooking gas is widely used for domestic services, supplied either in tanks or by pipeline. It is also used to augment natural gas deliveries on peak days and by some industries as a stand-by fuel.

LPG can be extracted from natural gas through the following methods:

i. Mechanical refrigeration
ii. Absorption method and
iii. Turbo – expander technology.

3.5.1 COST CONVERSION OF LPG

Consumption of LPG per year = 45,000x12

= 540,000kg

Cost of LPG per Kg = ₦105

Energy bill for LPG per year = 540,000x105

= ₦ 56,700,000

Gas equivalent of LPG

1 Kg of LPG = 49.12 SCF of gas

540,000 Kg = 49.12 x 540,000

= 26,524,800 SCF of gas

= 26.525 MMSCF (0.752 MMSCM)

Table 3.4 Cost Analysis of LPG

YEAR	COST AGO IN ₦	COST OF GAS EQUIVALENT ₦	SAVINGS ₦	% SAVINGS
1	56,700,000	11,197,280	45,502,720	80.25
2	56,700,000	12,129,760	44,570,240	78.61
3	56,700,000	13,069,760	43,630,240	76.95
4	56,700,000	14,002,240	42,697,760	75.31
5	56,700,000	14,934,720	41,765,280	73.66
Total	**283,500,000**	**65,333,760**	**218,166,240**	**76.95**

Cost of gas equivalent

Yr 1: 0.752 MMSCM x ₦14.89 = ₦11, 197,280

Yr 2: 0.752 MMSCM x ₦16.13 = ₦12, 129,760

Yr 3: 0.752 MMSCM x ₦17.38 = ₦13, 069,760

Yr 4: 0.752 MMSCM x ₦18.62 = ₦14, 002,240

Yr 5: 0.752 MMSCM x ₦19.86 = ₦14,934,720

3.6 ELECTRICITY GENERATION IN NIGERIA

National Electric Power Authority (NEPA) is in charge of power generation and supply in the country. The prolonged neglect of Nigeria's power sector in terms of capital investment and maintenance of existing facilities led to two total system collapse. No new power stations have been built since 1990 and no new transmission lines since the mid – 1980s.

The availability of natural gas to substitute electricity for both industrial and domestic uses will enhance maximum output and productivity.

NEPA is characterised by some negative features including; over loaded transmission and distribution infrastructure, inadequate metering, unreliable billing and inefficient revenue collection system, over centralised administration etc

3.6.1 COST CONVERSION OF ELECTRICITY

Consumption per year = 10,00,000 KWH

Cost per KWH = ₦9.00 (industrial use)

Annual Energy bill for electricity = 1,000,000x9.00

= ₦ 9,000,000

Gas equivalent of 1,00,000 KWH

1 KWH of electricity = 11 SCF

1,000,000 KWH = 1,000,000 x S11

= 11,000,000 SCF

= 11MMSCF

= 0.312 MMSCM

Table 3.5 Cost analysis of electricity

YEAR	COST ELECTRICITY (₦)	COST OF GAS EQUIVALENT ₦	SAVINGS ₦	% SAVINGS
1	9,000,000	4,645,680	4,354,320	48.38
2	9,000,000	5,032,560	3,967,440	44.08
3	9,000,000	5,422,560	3,577,440	39.75
4	9,000,000	5,809,440	3,190,560	35.45
5	9,000,000	6,196,320	2,803,680	31.15
Total	**45,000,000**	**27,106,560**	**17,893,440**	**39.76%**

Cost of gas equivalent

Yr 1: 0.312 MMSCM x ₦14.89 = ₦ 4, 645,680

Yr 2: 0.312 MMSCM x ₦16.13 = ₦ 5, 032,560

Yr 3: 0.312 MMSCM x ₦14.89 = ₦ 5, 422,560

Yr 4: 0.312 MMSCM x ₦14.89 = ₦ 5, 809,440

Yr 5: 0.312 MMSCM x ₦14.89 = ₦ 6, 196,320

3.7 KEROSENE

This fuel is widely used as illuminating oil for domestic needs. It has low viscosity and a good degree of refinement to be fairly stable, it is light in colour with a specific gravity of about 0.82, net calorific value of 18, 400Btu/lb, boiling point ranges between 150 – 250^{O}C and a flash point above 42^{O}C .

In Nigeria, almost every home is conversant with the use of kerosene since it is the primary fuel used in cooking stoves.

3.7.1. COST CONVERSION OF KEROSENE

Arbitrary consumption of 50,000 ltrs/month of kerosene for a hotel kitchen

Consumption per year	= 50,000x12 = 600,000 ltrs/yr.
Cost of kerosene per litre	= ₦60.00 (as at August,2004)
Energy bill for kerosene per year	= 600,000 x 60
	= ₦36, 000,000

Natural has equivalent of 600,0000 ltrs of kerosene:

1 ltr of kerosene	= 35.83 Scf of gas
600,000 litrs	= 35.83 x 600,000 lths
	= 21,498, 000 Scf of gas
	= 21. 498 MM Scf
	= 0.609 MMSCM

Table 3.6 Cost analysis of kerosene

Year	Cost of Kerosene ₦	Cost of natural gas equivalent ₦	Saving ₦	% Savings
1	36,000,000	9,068,010	26,931,990	74.81
2	36,000,000	9,823,170	26,176,830	72.71
3	36,000,000	10,584,420	25,415,580	70.60
4	36,000,000	11,339,580	24,660,420	68.50
5	36,000,000	12,094, 740	23,905,260	66.40
Total	**180, 000, 000**	**52,909,920**	**127,090,080**	**70.60%**

Cost of gas equivalent

Yr 1: 0.609 MMSCM x ₦ 14.89 = ₦ 9,068, 010

2: 0.609 MMSCM x ₦ 16.13 = ₦ 9,823, 170

3: 0.609 MMSCM x ₦ 17.38 = ₦ 10,584, 420

4: 0.609 MMSCM x ₦ 18.62 = ₦ 11,339, 580

5: 0.609 MMSCM x ₦ 19.86 = ₦ 12,094, 740

3.8 COAL

Coal is an abundant fossil fuel in Nigeria however because liquids and gases are more desirable fuel forms of fuel, technologies to convert coal into synthetic liquid and gaseous fuels have been developed. Current research, development and demonstration efforts are aimed towards technical and economic improvements in some of the old or first generation technologies with an end of clean coal conversion process. But, as long as the price of petroleum remains near current levels, then coal gasification and liquefaction will remain uneconomic while its substitution by natural gas becomes beneficial.

3.8.1 COST CONVENTION OF COAL TO NATURAL GAS

Arbitrary consumption of 40,000kg of coal per month

Consumption per year = 40,000 x 12

= 480,000kg/year.

Cost of coal per kg = ₦100

Energy Bill for coal per year = ₦100 x 480,000

= ₦48, 000, 000

Natural gas equivalent of coal:

1 kg of coal =23.82 Scf of natural gas

480,000kg = 23.82 x 480,000

= 11,433, 6000 Scf of gas

= 11.434 MMSCF

= 0.324 MMSCM

1MMSCF = 1000 M SCF

1Scf = 35.29 scm

Table 3.7 Cost analysis of coal

Year	Cost of Kerosene ₦	Cost of natural gas equivalent ₦	Saving ₦	% Savings
1	48,000,000	4,824,360	43,175,640	89.95
2	48,000,000	5,226,120	42,773,880	89.11
3	48,000,000	5,631,120	42,368,880	88.27
4	48,000,000	6,032,880	41,967,120	87.43
5	48,000,000	6,434,640	41,565,360	86.60
Total	**240, 000, 000**	**28,149,120**	**211,850,080**	**88.27%**

Cost of gas equivalent

Yr 1: 0.324 MMSCM x ₦ 14.89 = ₦ 4,824, 360

2: 0.324 MMSCM x ₦ 16.13 = ₦ 5,226, 120

3: 0.324 MMSCM x ₦ 17.38 = ₦ 5,631, 120

4: 0.324 MMSCM x ₦ 18.62 = ₦ 6,032, 880

5: 0.324 MMSCM x ₦ 19.86 = ₦ 6,434, 640

3.9 PETROL (PURE MOTOR SPIRIT (PMS)

Petrol is also referred to as gasoline and is used to run car engines. It has a boiling point of $37^{O}C$ to $180^{O}C$ and a heat of combustion of 44.5 M^2J/kg.

When gasoline is combusted, it gives the heat required to drive the pistons in internal combustion engines.

3.9.1 COST CONVERSION OF PMS

Consumption (Arbitrary) of PMS per day	= 1500 litres
Consumption per month	= 45, 000ltrs
Consumption per year	= 45,000 x 12
	= 540, 000lts/yrs
Cost of PMS per litre	= 42.00
Energy bill for PMS per year	= 540,000x42
	= ₦22,680,000

Natural gas equivalent of PMS

1 litre of PMS	= 33.41 Scf of gas
540,000ltrs	= 33.41 x 540, 000 ltrs
	= 18,041,400 Scf of gas
	= 18.0414 MMSCF
1Scm = 35.29 Scm	= 0.511 MMSCM

Table 3.8 Cost analysis of pure motor spirit (petrol)

Year	Cost of PMS ₦	Cost of gas equivalent ₦	Saving ₦	% Savings
1	22,680,000	7,608,790	15,071,210	66.45
2	22,680,000	8,242,430	14,437,570	63.66
3	22,680,000	8,881,180	13,798,820	60.84
4	22,680,000	9,514,820	13,165,180	58.05
5	22,680,000	10,148,480	12,531,540	55.25
Total	**113, 400, 000**	**44,395,680**	**69,004,320**	**60.85%**

Cost of PMS equivalent

Yr 1: 0.511x ₦ 14.89 = ₦ 7,608, 790

2: 0.511x ₦ 16.13 = ₦ 8,242, 430

3: 0.511x ₦ 17.38 = ₦ 8,881, 180

4: 0.511x ₦ 18.62 = ₦ 9,514, 820

5: 0.511x ₦ 19.86 = ₦ 10,148, 460

Table 3.9 summary of results of cost benefit analysis of conventional fuel as compared with natural gas within 5 years

	Conventional fuel	Current price of convention fuel (₦)	Cost of conventional fuel (₦)	Cost of natural gas (₦)	Savings (₦)	% savings
1	LPFO	26.96/lt	485,280,000	339,693,900	145,586,100	30.0
2	AGO	45.00/lt	1,215,000,000	492,435,480	722,564,160	60.0
3	LPG	105/kg	283,500,000	65,333,760	218,166,240	77.0
4	Electricity	11.00 (*)	45,000,000	27,106,560	17,893,440	40.0
5	Kerosene	60.00/lt	180,000,000	52,909,920	127,090,080	71.0
6	Coal	100/lt	240,000,000	28,149,120	211,850,880	88.0
7	PMS	42/lt	113,400,000	44,395,680	69,004,320	61.0

* NEPA charges 11.00 per kwh for industrial consumption of electricity.

It is assumed that the price of each conventional fuel remains relatively stable.

From the table 3.8 above, it is obvious that monetary savings ranging from 30% for LPFO to 88% for coal can be realised in a span of 5 years. Though the cost of conversion of equipments and machines to use natural gas may be very high in addition to the cost of laying internal pipes, it is compensated for in a year or two by the amount of money that is saved.

Other inherent savings

Apart from monetary savings, other inherent savings accrue to the use of natural gas. They include.

a. Reduced maintenance cost of plant

b. Continuous supply of gas (planned production)

c. Zero storage cost

d. No pilfering or wastage or fuel

e. No advanced payment for fuel

f. No decanting of liquid fuels and switch overs in the case of LPG

g. Less production of green house gas and other pollutants.

CHAPTER FOUR

4.0 CALCULATING ACCIDENTAL RELEASE FLOW RATES FROM PRESSURIZED GAS SYSTEM

Most plume dispersion models were developed for either a continuous gas flow from the source point or for an instantaneous puff release of very short duration but many short term releases are neither continuous nor instantaneous, for example, emergency venting from pressure relief valves in an industrial plant may last form one or two minutes up to 10 or 15 minutes before corrective actions can be taken to stop the emergency venting.

4.1 GENERALIZED GAUSSIAN DISPERSION EQUATION FOR A CONTINUOUS POINT SOURCE PLUME

$$C = \frac{Q}{U\sigma_z\sigma_y 2\pi} e^{-y^2}/2\sigma y^2 \left[e^{-(Zr - He)2}/2\sigma^2_z + e^{-(Zr + He)2/2\sigma z2}\right] \text{-------------------------} (1)$$

Where C = concentration of emissions, g/m^3, at any receptor located at x meters down wind, y metres crosswind from the centre line, Z_r metres above ground.

Q = source emission rate g/sec.

U = horizontal wind relocity, m/sec.

He = plume centreline height above ground, m

σ_z= vertical standard deviation of the emission distribution, m.

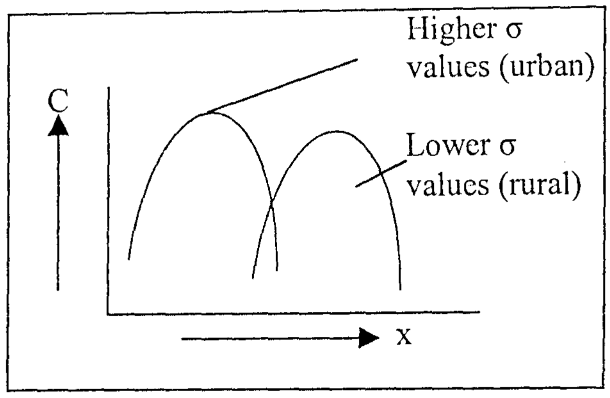
σ_y = horizontal standard deviation of the emission distribution, m.

equ (1) is only valid within a set of constraints. Therefore, since there are constraints, The plume dispersion equation for a point source depends upon the variety of a good many assumptions.

4.2 DISPERSION COEFFICIENT

Dispersing plumes encounter more turbulence in urban areas than in rural areas, due to the buildings as well as the some what warmer temperatures in urban areas. Higher turbulence also occurs in industrial plants densely populated with buildings or other structures which is enough to alter the localized atmospheric stability to a les stable class.

The higher coefficients cause an urban plume to spread more rapidly than in rural plume, and hence, the maximum ground level concentrations of an urban plume occurs closer to the emission source that it does for a rural plume.



C – ground level concentration

x – down wind distance

Fig 4.1 Effect of urban dispersion coefficient.

The effect of urban dispersion coefficient is that, at distances near to its emission source, an urban plume has higher ground level concentrations than a rural plume at the same distance form its source; where as at distances for form its source, an urban plume has lower ground level concentrations than a rural plume at the same distance from its source.

4.3 THE RASOULI AND WILLIAMS SOURCE MODEL

The Rasouli and Willaims source term model for choked gas flows, from a pressurized gas system was used to calculate the initial instantaneous flow rate for the pressure and temperature existing in the source system when a release first occurs.

Choked flow is also referred to as sonic flow and it occurs when the ratio of the source gas pressure is equal of greater than $[(k+1)/2]^{k/(k-1)}$ where k is the specific heat ratio. Cp/Cv. for many, gases, k ranges from about 1.1 to about 1.4 and so choked gas flow occur when the source gas pressure is about 25 to 28 psia. The Rasouli and Williams model is in c form specific for methane gas releases and contains an error correction generalised to obtain.

$$P_2^c - P_1^c = C_D\,({}^{A}/v)\,(gR/M)^{1/2}\,[(k-1)/2k]k^{3/2}\,[2/(k+1)]^a\,(T_o/P_o^b)^{1/2}\,(t_2 - t_1)\text{------------}(2)$$

Where C_D = coefficient of discharge

A = Area of the source leak, in ft^2

V = Source vessel volume in ft^3

g = gravitational acceleration of 32.17ft/s^2

R = universal gas constant of 1545 (lbs/ft^{-2}) (ft^2)/(lbmol) (^{o}R)

M = molecular weight of the gas

k = Cp/Cv of the gas

$a = (k+1)/(2k-2)$

T_o = initial gas temperature in the source vessel in ^{o}R

P_0 = initial gas pressure in the source vessel in lbs/ft^{-2} absolute

$b = (k - 1)/k$

to = the time of flow initiation through the leak, in sconds

t_1 = any time to or later in seconds

t_2 = any time later than t_1 in seconds

P_1 = the gas pressure in the source vessel at t_1 in lbs/ft^2 abs.

P_2 = the gas pressure in the source vessel at t_2, in lbs/ft^2 abs.

$c = -(k-1)/2k$

4.4 PROFILE OF TIME – DEPENDENT DECREASE OF METHANE

The Rasouli and Williams model was used to obtain a profile of the time dependent decrease in the pressure, the temperature and the weight of the gas in a vessel storing methane gas at 60^{o}F and 3,430 psia when a 0.5 inch diameter leak occurs.

Given; $C_D = 0.72$, $A = 0.001363$ ft^2

$V = 51.4$ft^3 $M = 16.04$

$k = 1.307$ To = 520^{o}R P_o = 493,920 lbs/ft^2 abs.

Calculation

$$P_2^c - P_1^c = C_D\,(^A/v)\,(gR/M)^{1/2}\,[(k-1)/2k]k^{3/2}\,[2/(k+1)]^a\,(T_o/P_o^b)^{1/2}\,(t_2 - t_1)$$

$$C_D\,(^A/v)\,(gR/_M)^{½} = 0.72 \times \frac{0.001363}{51.4} \times \left(\frac{32.17\text{x } 1545}{16.04}\right)^{½}$$

$$= 1.0628\text{x } 10^{-3}$$

$$[(k-1)/2k]\,k^{3/2} = \frac{(1.307-1)}{2(1.307)} \times 1.307^{\,1.5} = 0.1755$$

$(2/k+1)^a = (2/1.307+1)^a$ where a = 3.757329

$= (2/2.307)^{3.757329} = 0.58476$

$(T_o/P_o^b)^{1/2} \quad = \quad (520/493{,}920^{\,0.2349})^{1/2} = 4.8897$

$c = -(1.307-1)/2(1.307) = -0.1174$

$P_2^c - P_1^c = (5.3329 \times 10^{-4})(t_2 - t_1)$

$P_2 = [(5.3329 \times 10^{-4})(t_2 - t_1) + P_1^{-0.1174}]^{-8.5179}$ --(3)

Thus eqn (3 was used to obtain P_2 values for each value of $(t_2 - t_1)$. The corresponding T_2 temperature values were obtained from this expression from the isentropic expansion or compression of an ideal gas.

$(T_2/T_1) = (P_2/P_1)^{(k-1)/k}$

And the weight of gas (W, in pounds) remaining in the source vessel at the end of each increment of time $(t_2 - t_1)$ was obtained from the universal gas law expression.

W = PVM/RT

Visual Basic Program was used to generate the values of the pressure, temperature and weight columns given below.

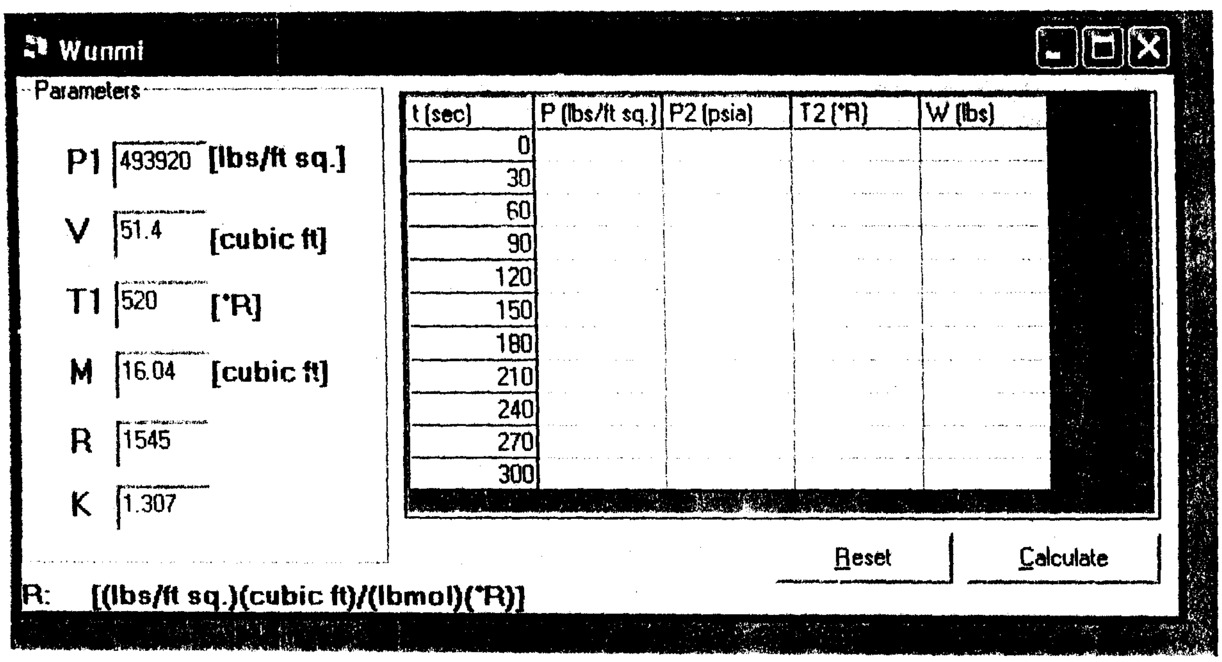
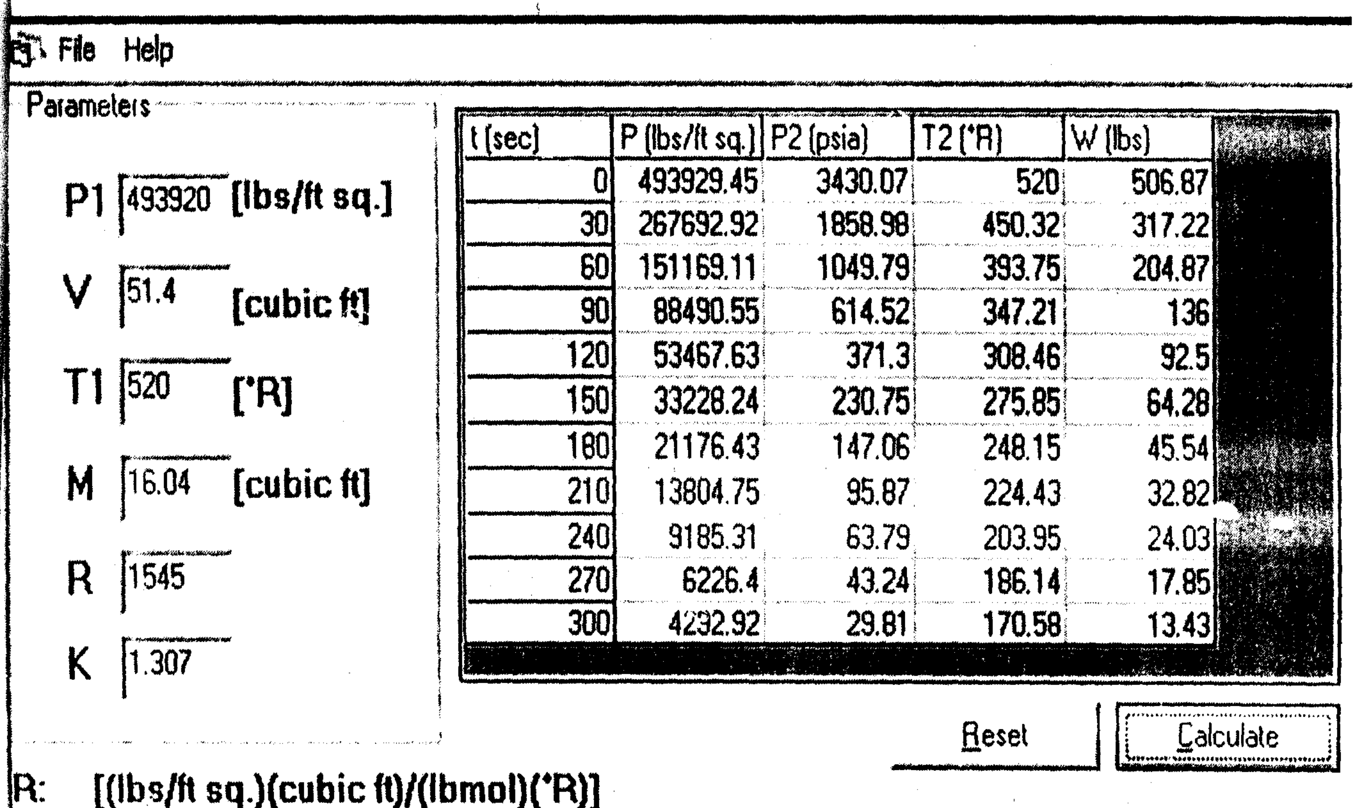


TABLE 4.1: PROFILE OF TIME DEPENDENT DECREASE OF STORED METHANE GAS



t (sec)	P (lbs/ft sq.)	P2 (psia)	T2 (°R)	W (lbs)
0	493929.45	3430.07	520	506.87
30	267692.92	1858.98	450.32	317.22
60	151169.11	1049.79	393.75	204.87
90	88490.55	614.52	347.21	136
120	53467.63	371.3	308.46	92.5
150	33228.24	230.75	275.85	64.28
180	21176.43	147.06	248.15	45.54
210	13804.75	95.87	224.43	32.82
240	9185.31	63.79	203.95	24.03
270	6226.4	43.24	186.14	17.85
300	4232.92	29.81	170.58	13.43

Table 4.2 Natural gas analysis from Ikeja metering station

S/NO	COMPOUND	FORMULA	MOLE%
1	Nitrogen	N_2	0.6695
2	Methane	CH_4	91.6672
3	Carbon-dioxide	CO_2	1.283
4	Ethane	C_2H_6	4.6533
5	Propane	C_3H_8	0.9937
6	I – Butane	C_4H_{10}	0.1332
7	n – butane	C_4H_{10}	0.1595
8	neo – pentane	C_5H_{12}	0.057
9	I – pentane	C_5H_{12}	0.1290
10	n – pentane	C_5H_{12}	0.0661
11	Hexanes +	C_6 +	0.1885
	TOTAL		**100.000**

Temperature of sampling: $25^{o}{}_{C}$

Sampling pressure: 6 bars

Cross calorific value of gas (GCV) 41.8527 MJ/M

Net calorific value of gas (NCV) 37.7928 MJ/M

Deq point of gas $51^{o}{}_{C}$

Parts per million water vapour by volume (VPM) 34 VPM

Water vapour pressure 0.025mmHg

Molecular weight of gas (MW) 17.7091

Specific gravity of gas 0.6161

Table 4.3 combustion data

Combustion Data	Fuel Gas	Fuel Oil	Coal
Higher heating value,	1,093Btu/scf	150,000Btu/gal	8,020 Btu/lb
Excess. Combustion air, %	12%	15%	20%
Amount of wet exhaust gas Scf/MMBtu of fuel	11,6000	11,930	13,985
$C0_2$ in wet exhaust gas, vol. %	8.8	12.4	13.5
0_2 in wet exhaust gas, vol. %	2.0	2.6	3.3
Molecular weight of exhaust gas	27.7	29.0	29.0
Amount of dry exhaust gas scf/MMBtu of fuel	9,510	10,600	12,130
$C0_2$ in dry exhaust gas, Vol%	10.8	14.0	15.5
0_2 in dry exhaust gas, vol%	2.5	2.9	3.8
Molecular weight of dry exhaust gas	29.9	30.4	30.8

4.5 COMBUSTION VALUES

Heating or combustion value of a fuel can be expressed as the quantity of heat released during the combustion process where oxygen reacts with hydrogen and carbon.

The table below shows the gross heating and net heating values of some common gases.

Table 4.4 heating values of common gases

	K cal/kg		K cal/Nm^3	
Fuel Gas	**Gross Heating values**	**Net Heating values**	**Gross Heating value**	**Net Heating values**
Hydrogen	33,889	28,555	3,050	2,570
Methane	13,284	11,946	9,530	8,570
Ethane	12,400	11,350	16,700	15,300
Ethylene	12,020	11,270	15,100	14,200
Natural gas	16,206	11,642	10,060	9,090
Propane	12,030	11,080	24,200	22,250
Propylene	11,700	10,940	22,400	20,900
n –butane	11,830	10,930	31,900	29,400
Iso –butane	11,810	10,900	31,700	29,200
butylenes –1	11,580	10,830	29,900	27,900
Iso pentane	11,600	10,730		
LPG (average)	11,920	10,997	28,000	25,775
Acetylene	11,932	11,514	13,980	13,490
Carbon monoxide	2,411	2,411	3,014	3,014

Table 4.5 Heat energy content of fuels

Fuel	Heat content MJ/kg	Heat content Btu/lb
Crude oils	42.6-45.4	18300-19,500
Gasoline	47.7	20,500
Kerosene	46.1	19,800
Benzole	42.1	18,100
Ethanol	27.0	11,600
Gas oils	44.1	19,200
Fuel oil	42.6	18,300
Coal	23.7-34.0	10,200-14,600
LNG	51.9	24,300

Table 4.6 fuel specific gravity ranges

Fuel	*Specific gravity*	*Barrels per tonne*
Crude oil	0.80-0.97	8.0-6.6
Aviation gasoline	0.70-0.78	9.1-8.2
Motor gasoline	0.71-0.79	9.0-8.1
Kerosene	0.78-0.84	8.2-7.6
Gas oil	0.82-0.90	7.8-7.1
Diesel oil	0.82-0.92	7.8-6.9
Lubricating oil	0.85-0.95	7.5-6.7
Fuel oil	0.92-0.99	6.9-6.5
Asphatic bitumen	1.00-1.10	6.4 – 5.8

Source of Tables 4.2 to 4.6- Gaslink Nigeria Limited, 2003

CHAPTER FIVE

5.0 DISCUSSION OF RESULT

The vast amount of natural gas flared annually is a huge economic waste and an environment unfriendly act. The estimate of about 2 billion cubic metres of natural gas flared daily which translates to about US $ 2.3 billion per year does not only imply a colossal loss of revenue but has placed Nigeria in the apex among the league of natural gas flaring nations. (NNGS,2002). Saudi Arabia has virtually stopped flaring natural gas, today less than 0.6 billion cubic metres of gas in flared per year. This is a dramatic reduction from the early 1980s when as much as 38 billion cubic metres was flared. In Nigeria, reduction in flaring will be achieved as a result of government policy and gas utilization which is expected to increase over the years due to awareness.

The cost benefit Analysis carried out on natural gas as shown in Table 3.8 in comparison to other conventional fuels such as diesel, petrol etc relates that the price of natural gas is about 30% for fuel oil and over 80% for coal less than the price of other fuels, however economic analysis shows that generating power using natural gas can yield more than 40% savings compared to other fuels apart from law maintenance cost and availability (Garba, 2003). It is observed that the use of natural gas to substitute diesel and fuel oils have drastically reduced the cost expenditure on the purchase of fuels and the continued supply has enhanced production activities of Cadbury Nigeria Plc. (Gaslink, 2002).

Natural gas, an alternative to conventional fuel types is delivered to heating units with a lot of convenience, controllability, efficiency, price differential, cleanliness and dependability of supply. The advantages of substituting natural gas for other fuel types are immense, natural gas burns clearly resulting in less maintenance of burner tips, there is no soot – blowing, no ash handling, no clearing up of oil spills and there are less painting of soot covered buildings and structures. Natural gas is easily controlled and provides good environments because there is no smoking or ash from stack. Due to its mode of transmission, systems are well protected against damages and human interruptions or disturbances.

The potential hazard consequent on the escape of natural gas into the atmosphere depends on the size of the escape as well as on the phase of methane, the major constituent of natural gas.

From the results is table 4.1, the time dependent profile yielded by Resouli and Williams source model for stored methane gas indicates that methane release in the first 30 seconds was at a higher rate of 6.3 lbs/sec than in the last 30 seconds of 0.1 lbs/sec. After which only 2.65% of the initial 507 lbs of methane remains in the vessel, this shows that rate of accidental release of methane is reduced with time. Since natural gas is lighter than air, gas leaking into the atmosphere will produce gas clouds aided in their dispersion by a buoyancy factor. Natural gas tends to disperse rapidly before critical cloud sizes can be achieved (Ekundayo, 1999). Natural gas has a very narrow range of flammability and high ignition temperature which makes accidental ignition very unlikely. The potential hazard of escape leading to ignition is also reduced by the use different kinds of safety devices incorporated into the design of gas distribution pipeline system. For example, there are automatic emergency shut – off valves installed as safety back up, also a supervisor control and data acquisition (SCADA) for remote monitoring of pipeline and process variables exist.

5.1 CONCLUSION

Natural gas utilization and development generally requires significant upfront investments in pipelines and other infrastructure. This implies that both upstream (exploitation and development) and downstream (market policy) must be well coordinated for successful distribution and sale of natural gas to the consumes.

Based on the values generated in table 3.8, it can be deduced that a savings of N722,564,160 on diesel and N145,586,100 on fuel oil would be realised while high percentage savings are also recorded for electricity, coal kerosene, LPG etc. It can be concluded from this project work that the use of natural gas by Cadbur y Nigeria Plc. in place of diesel and fuel oils enhances productivity and higher profit margin by reduction in the cost of energy fuel for her engines.

Conclusively, the use of natural gas for domestic, commercial and industrial applications is relatively safe, generate more profit than other energy fuels and poses little environmental concern.

5.2 RECOMMENDATION

Fiscal incentives and the proper enabling environment are necessary ingredients to stimulate major stake holders in the oil industry to embark upon gas utilisation strategies and projects. Thus, a review of the various gas policies by the Federal Government of Nigerian should be implemented if it is to actualise its vision to eliminate flaring by the year 2008. With this, natural gas utilization as a source of energy will definitely bring about a cleaner and safer environment in Nigeria and the world over.

Attendant exploitation of gas oil will increase revenue generation, technology transfer and decline in community disturbances and related issues. In this respect, if states generate her own power using abundant natural gas, this would uplift the living conditions of her citizens, boost industrial activities and create employment opportunities.

APPENDIX

Conversion factors used in oil and gas industry.

1 gross ton (shipping) = 2.83168 cubic metres or 100 cubic ft. of permanently enclosed space.

Mass: 1 ounce = 28.3495g

1 pound = 0.453592 kg

= 0.00892857 hondred at.

1 kg = 2.20462 lbs

= 0.01 quintal

1 hundred wt. = 112 pounds

= 50.8023 kg

1 American ton = 2000 lbs

= 0.907185 tonnes

1 metric ton = 2204.62 lbs

= 1.10231 short ton

= 0.984207 long ton

1 imperial (long) ton = 2240 lbs

= 1.12 short ton

= 1.01605 tonnes

ENERGY AND POWER

1 international table (IT) caloric = 4.1868 J

1 15C calorie = 4.1855 J

1 thermochemical calorie = 4.184 Joules

1 kilo caloric (IT) = 1000 calories

= 3.96832 BTu

= 1.163 watt hrs

= 0.001 thermic

1 kilowatt hr = 3412.14 BTu

= 859.845 kilo caloric (IT)

= 3.6 mega joules (MJ)

= 1.34102 hp.

1 therm = 100, 000 BTu

= 105, 506 MJ

= 29.3071 KW hrs

= 25, 1996 thermies

1 metric horse power = 735. 499 Watts

= 542. 476 ft lbs f/s

= 0.986320 imperial hp

1 imperial horse power = 745.700 watts

= 550 ft lbf/s

= 0.01387 metric hp

1 kilowatt = 737.56 ft lbf/s

= 1.359b2 metric hp

= 1.34102 imperial hp

Converting gas amounts to other units

1 MMBTu = 10^6 BTu

1 MMKcal = 10^6 Kg calories

1 MW hr = 1 mega watt hr = 10^6 watt hrs

1 MM Btu = 0.252 MMK cal = 0.293 MW hr

1 MM K cal = 3.968 Btu = 1.163 MW – hr

! MW – hr = 3.413Btu = 0.860 MMK cal

1 Scf = standard cubic feet measured at 60^0f and atm. Press

1 WM^3 = normal cubic metres measured at $O^0{}_C$ and atm. press = 37.326scf

1 Scf/MMBtu = 0.1063 Nm^3/MMK cal = 0.0914 Nm^3/MW Mis hr

KEY WORDS

NOX – oxides of nitrogen

SOX – oxides of sulphur

SCM -- standard cubic factre

SCF -- standard cubic feet

MSCM -- 1000 SCM

MMSCM -- 1000,000 SCM

BSCF – 1,000,000,000 SCF

TSCF – 1,000,000,000,000 SCF

Program Code

```
Private P1, V, T1, M, R, K, deltaT As Double

Private Sub Command1_Click()
   getValues
End Sub

Private Sub Command2_Click()
   For i% = 1 To 11
      sheet.TextMatrix(i%, 1) = ""
      sheet.TextMatrix(i%, 2) = ""
      sheet.TextMatrix(i%, 3) = ""
      sheet.TextMatrix(i%, 4) = ""
   Next i%
End Sub

Private Sub Form_Load()
   Me.Width = 8790
   Me.Height = 4485
   Dim t As Integer
   sheet.TextArray(0) = "t (sec)"
   sheet.TextArray(1) = "P (lbs/ft sq.)"
   sheet.TextArray(2) = "P2 (psia)"
   sheet.TextArray(3) = "T2 (°R)"
   sheet.TextArray(4) = "W (lbs)"

   t = 0
   For i% = 1 To 11
      sheet.TextMatrix(i%, 0) = t
      t = t + 30
   Next i%
```

```
End Sub
Private Sub getValues()
   P1 = Val(valu(0))
   V = Val(valu(1))
   T1 = Val(valu(2))
   M = Val(valu(3))
   R = Val(valu(4))
   K = Val(valu(5))


   deltaT = 0
   For i% = 1 To 11
      sheet.TextMatrix(i%, 1) = Round(P2, 2)
      sheet.TextMatrix(i%, 2) = Round(P2psia, 2)
      sheet.TextMatrix(i%, 3) = Round(T2, 2)
      sheet.TextMatrix(i%, 4) = Round(W, 2)
      deltaT = deltaT + 30
   Next i%

End Sub

Private Function P2() As Double
   P2 = ((5.3329 * 10 ^ -4) * deltaT + P1 ^ -0.1174) ^ -8.5179
End Function
Private Function P2psia() As Double
   P2psia = P2() / 144
End Function
Private Function T2() As Double
   T2 = T1 * ((P2psia / (P1 / 144)) ^ ((K - 1) / K))
End Function
Private Function W() As Double
 · W = P2 * V * M / (R * T2)
End Function
```

REFERENCES

1. Global Gas flaring Reduction Initiative, Report on consultations with stakeholders, World Bank group in collaboration with the Government of Norway, April 2002, Pgs 27-30.

2. Nigeria Natural Gas Strategy under supervisor of the world Bank, IPA Energy Consulting and Co., November, 2002, Pgs 12-18 section I, 16-25 section II.

3. Milton R. Beychok (1995)., Fundamentals of stack Gas Dispersion, 1102 colony plaza, Newport Beach, CA 92660, 3rd edition, Pgs 19-30, 177-179.

4. Ngofa, Kate (2002), The effects of Gas flaring in Niger Delta Area by, Chemical Engineering Department F.U.T Minna. (Unpublished B.Eng. Project), Pgs 4-6.

5. B.K. Bhaskara Rao (1990), Modern petroleum refining process, Oxford & IBH publishing Co., PVT. Ltd, New Delhi. 2nd edition, Pgs 126-215.

6. Odoziakpu, Ekpo (1999), Natural gas and the Environment, 26, Tombia street, GRA II , Port Harcourt, Pgs 169-172.

7. Olukoga, E.A.(2002), Natural Gas as a vehicular fuel, Nigeria Gas Association International Gas Conference Exhibition Paper, Pg 6.

8. Dunlop, A.J (May, 1995), Costain Oil, Gas and Process, An Introduction to Petrocarbon Technology, Pgs 27-30.

9. Ekundayo B.O.(2000), Environmental & Safety Hazards in Natural Gas utilisation, Pgs 83-84.

10. Garba Huruna Argongu (2003), The North and Natural Gas (Unpublished), Pgs 4-20.

11. Perry's R.H. (1996), Chemical Engineering handbook, Mc-Graw Hill Inc, New York 6th edition, Pgs 27-9, 27-12, 27-13.

12. Osezua, Charles (2003), Nigeria and Natural gas article, Gaslink Magazine, vol 1, Ist edition, Lagos, Nigeria. Pg 2 .