THE POTENTIALS OF NATURAL GAS AS A VERITABLE ALTERNATIVE ENERGY SOURCE

By

Jonah, S.A., Baba-Kutigi, A.N., *Onuevho, C.I., Crown, I.E., Kolo, M.T., *Onoduku, U.S., and Egbobi, H.I.

Physics Department, Federal University of Technology, Minna, Niger State

*Department of Geology, Federal University of Technology, Minna

Abstract

This paper highlights the benefits derivable from the use of natural gas as a present and future alternative to our energy sources. The discussion is centred on a multi-dimensional and multi-disciplinary approach to the exploitation of our natural gas resource. This paper is expected to be of a vital interest to anyone interested in the natural gas exploration, gathering, treatment, transmission and utilization.

Introduction

Energy, as defined in physics, is "the ability to do work". Various sources of energy are abundant in nature. These include energy from the sun (solar), water (hydro), wave (tidal), and hydrocarbon (oil and natural gas) (Nelkon, 1994). Natural gas is a vital component of the energy supply chain and it is one of the cleanest, safest, cheapest sources of energy. There have been misconceptions about the "gas" that is used to power some motor vehicles as being natural gas. Of course, this is erroneous because the word "diesel fuel" is used synonymously with gas. Natural gas is one of the natural resources with a wide geographical distribution since it can be found in the territorial realms of many countries in the world. It is estimated that Nigeria has at least twice as much gas as oil, with an estimated 124 trillion cubit feet (tcf) of proven gas reserve and another 45 trillion cubit feet (tcf) which remains undiscovered despite large quantities being flared daily. Natural gas is found either in associated form mixed with crude oil in a reservoir or in non-associated form where it is found above or on top of the crude oil in a well reservoir (Okeke and Sobotie, 2002). Natural gas is a naturally-occurring gaseous mixture of hydrocarbon gases found in underground reservoirs. In its pure form, it is colourless, odourless, and it gives off a great deal of energy when it is burnt. When it is burnt, it releases very low level of harmful by-products into the air. The composition of combustible hydrocarbon gases is given in Table 1.

Table 1: Composition of Combustible Hydrocarbon Gases

HYDROCARBON GAS/ OTHER GASES	% COMPOSITION
Methane	70-95
Ethane	
Propane	
Butane	0-20
Heavier hydrocarbon	
Carbon dioxide	0-8
Oxygen	0-0.2
Nitrogen	0-5
Hydrogen sulphide	0-5
Water vapour	0-5
Rare gases	Traces

In its purest form, natural gas is almost dry methane (CH_4). Other hydrocarbon components are collectively called "natural gas liquids (NGLs)".

Exploration, Gathering, Treatment, and Transmission of Natural Gas

Exploration: This is the first step in the search for gas by the use of seismic exploratory techniques. Seismic exploration is the use of seismic energy to probe beneath the surface of the earth, usually as an aid in searching for economic deposits of oil, gas or minerals, but also for engineering, archaeological and scientific studies. In exploration seismology, the method is applied at or near the earth's surface to measure the elastic properties. Variation and discontinuities in subsurface elastic properties are usually indicative of changes in lithology or rarely, pore fluids. Exploration seismology has been applied for subsurface investigation of depths as great as 150km. However, it is particularly useful for depths up to 10km and its spatially resolving power is significantly finer than the resolving ability of other remote geophysical methods for this depth regime. Because this region of the earth's subsurface includes nearly all of its oil and gas reserves, exploration seismology plays a prominent role in the energy industry.

Gathering: Once a potential natural gas deposit has been located by a team of explorationists, it is the duty of a team of drilling experts to actually dig down to where the natural gas is thought to exist and at the same time getting the drilled natural gas to a common collection point for further processing. The decision whether or not to drill a well depends on a variety of factors, not the least of which are the economic characteristics of the potential gas reservoir. The exact placement of the drill site depends on a variety of factors, including the nature of the potential formation to be drilled, the characteristics of the subsurface geology, and the depth and size of the target deposit.

The best way to gain a full understanding of subsurface geology and the potential for natural gas deposits to exist in a given area is to drill an exploratory well. This consists of actually digging into the earth's crust to allow for study of the composition of the underground layers in detail. In addition to looking for natural gas, the need to examine the drill cuttings and fluids is important to gain a better understanding of the geologic features of the areas. Exploratory wells are only drilled in areas where other data has indicated a high probability of natural gas formation, and then logged. Logging refers to.

performing tests during or after the drilling process to allow well operators to monitor the progress of the well drilling and to gain a clearer picture of subsurface formation. Monitoring logs can ensure that the correct drilling equipment is used and that drilling is not continued if unfavourable conditions develop.

Treatment: Natural as we know it in its final state is much different from the natural gas that is brought from underground up to the wellhead. Although the processing of natural gas is in many respects less complicated than the processing and refining of crude oil, it is equally as necessary before it is piped to consumers. The natural gas used by consumers is composed almost entirely of methane. However, natural gas found at the wellhead, although still composed primarily of methane, is by no means as pure. Raw natural gas comes from three types of wells: oil wells, gas wells and condensate wells. Natural gas that comes from oil wells is typically termed "associated gas". This gas can exist separate from oil in the formation (free gas), or dissolved in the crude oil (dissolved gas). Natural gas from gas and condensate wells, in which there is little or no crude oil, is termed "non associated gas". Gas wells typically produce raw natural gas by itself, while condensate wells produce free natural gas, and once separated from crude oil (if present) it commonly exists in mixtures with other hydrocarbons principally ethane, propane, butane and pentane. Natural gas processing consists of separating all the various hydrocarbons and fluids from the produced natural gas to produce what is known as "pipeline quality" dry natural gas. The processing is done at the wellhead (point of extraction) and at centralised processing plants. The actual practice of processing natural gas to pipeline dry gas quality levels can be quite complex.

but usually involves main processes to remove the various impurities (NLNG, 2002; Matthews, 1996).

Transmission: The transmission process consist of a complex network of pipelines of varying diameters with natural gas flowing under varying conditions such as high or low temperature, high or low pressure, etc. Transmission involves transportation through pipelines at very high pressure, reducing the volume of the natural gas being transported (by up to 600 times) in accordance with Charles's law, and as well as providing propellant force to move the natural gas through the pipeline and distribution pipelines of smaller diameter at much lower pressure (Learmonth, 1985).

Potentials of Natural Gas Resource

Natural gas can be used in many different ways. There are lot of advantages in using natural gas over others forms of energy. Natural gas is very clean to use and this makes it environmental-friendly (i.e. it produces no soot or ash, or other pollutants when it undergoes combustion) when compared to other fossil fuels like coal and crude oil. It is also abundant in nature, less expensive to process, and relatively cheaper. Domestic and industrial uses for natural gas abound and this prospect can encourage investments in the long run.

Use as Automotive Fuel: The use of compressed natural gas (CNG) as an alternative automobile fuel is increasingly gaining recognition due to the rising cost of refined petroleum products, occasioned with increasing concern about atmospheric pollutions caused by petrol and diesel exhaust fumes and the uncertain state of crude oil in the international market. Crude oil supply uncertainties are influenced by factors like terrorism, war, instability etc. Countries like USA, Canada, Brazil, etc. have embraced this clean and alternative fuel. The use of CNG gives rise to lower operating and maintenance costs since it is cheaper to produce and it is pollution-free (NGC, 2002). It is vital to briefly point out here the safety aspects of CNG compared to petrol:

1. **Density Relative to Air**: Compressed natural gas at normal temperature is considerably less dense (0.555 g/cm^3) than air and when released from its tank it will rise, diffuse, and disperse into the atmosphere (Ababio, 1990). Petrol vapour is heavier than air at 3.4 g/cm^3 and therefore takes longer to diffuse and disperse into the atmosphere, which makes petrol more dangerous than CNG. Note that the density of air is 1.00 g/cm^3.
2. **Flammability Limit (Volume % in Air):** The flammability limit of CNG is 5% while that of petrol is 1%. This means that more natural gas must mix with air before the mixture can become combustible than is the case with petrol.
3. **Detonability Limit (Volume % in Air)**- The detonability limit of CNG and petrol are 6.3% and 1.1% respectively. More natural gas is required in air than petrol vapour in order to detonate it in the presence of any naked flame or spark.
4. **Minimum Ignition Energy in Air:** This is the amount of energy required to set equal amount of CNG: air mixture and gasoline: air mixture aflame, i.e. to ignite each mixture. This energy level is lower for CNG than it is for petrol. Thus, more energy is needed to set CNG on fire than required quantity of petrol.
5. **Auto-Ignition Temperature:** The temperature at which the compressed natural gas become auto ignited is much higher than that of petrol. This temperature for CNG and for petrol is 540^{0}C (1004^{0}F) and from 228^{0}C-471^{0}C (440-880^{0}F) respectively.
6. **Diffusion Coefficient in Air:** The rate at which CNG will diffuse into the air is faster than that of petrol. This diffusion rate is called *air diffusion coefficient* and it is 0.16cm/s (0.0016m/s) for CNG and 0.05cm/s (0.0005m/s) for petrol. The significance of this is that it is more difficult for CNG to remain in the atmosphere than petrol. Thus fire hazard persists longer with petrol.
7. **Heat Release Rate:** The rate at which heat is released in case of fire is lower for CNG than for petrol. In view of this, it becomes obvious that CNG is safer than petrol as a fuel.

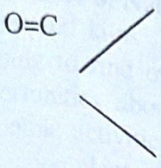
Use in Chemical Industries: Natural gas, which is 99% methane (CH_4) in its pure state, is a very good source of raw materials {i.e. chemicals used in various industries for production of various products like acetylene, ammonia, methanol, carbon black, hydrogen-cyanide, polypropylene, polyethylene, polyvinyl chloride (PVC)}. All of these products are vital in industries like fertilizers, pharmaceuticals, tyres, rubbers, plastics, lubrication, welding, and nylon manufacture. This is done by separating the main elements that make up natural gas. In obtaining the hydrogen, the Bosch process where steam is mixed with methane (obtained as natural gas) and passed over a nickel catalyst at about 800^0C is used. A mixture of carbon monoxide and hydrogen is produced and this is known as synthesis gas. The reaction is shown below:

$$\underbrace{CH_{4(G)}}_{METHANE} + \underbrace{H_2O}_{STEAM} \rightarrow \underbrace{CO_{(g)} + 3H_{2(g)}}_{SYNTHESIS\ GAS}$$

The hydrogen is mixed with carbon, nitrogen, etc to produce some of the products named above. Some of these reactions are

$$N_{2(g)} + 3H_{s(g)} \Leftrightarrow 2NH_{3(g)}$$

Nitrogen *Hydrogen* *Ammonia*

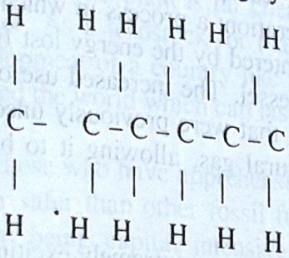


Urea for fertilizer

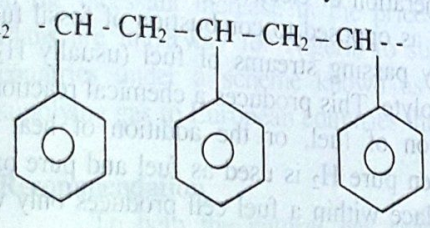
$$CH_3NH_{2(AQ)} + H_2O \rightarrow CH_3NH_3 + OH$$

Methylamine

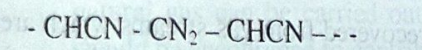
Methylamine is used for making nylon.



Polythene is used for plastic and nylon



Polystyrene is used for making see-through containers and lighting fixtures



Polypropenonitrite is used for textile production

Polychlorobuta 1, 3-diene (i.e. synthetic rubber) is used in the manufacture of foot wears and tyres

Use in Metallurgical Processes: Natural gas is of great importance in iron-ore reduction, especially in the steel industry. The synthesis gas obtained from mixing CH_4 with steam is used in reducing iron-ore to iron.

This makes iron-ore reduction less capital intensive as CH_4 is cheap to obtain.

Use in Agricultural Food Processing: Natural gas is also used for food processing (i.e. for drying of crops through gas refrigeration and air conditioning).

Domestic Uses of Natural Gas: Natural gas is used for cooling i.e. in refrigerators, freezers and air conditioners and also used for heating in temperate regions at wintertime. Natural gas is used widely for domestic cooking.

$$\underbrace{Fe_2O_{3(s)}}_{IRON\ ORE} + \underbrace{CO_{(g)} + 2H_{2(g)}}_{SYNTHESIS\ GAS} \rightarrow 2Fe_{(s)} + CO_{2(g)} + 2H_2O_{(g)}$$

↓

from

Use as Liquefied Natural Gas (LNG): When natural gas is cooled to about -260^0F (-525.6^0 C) at normal pressure it results in the condensation of the gas into liquid form, known as Liquefied Natural Gas (LNG). This is useful particularly for the transportation of natural gas, since LNG takes up about one-six hundredth (1/600) of the volume of gaseous natural gas. Because it is easy to transport, LNG can serve to make economical those stranded natural gas deposits for which the construction of pipelines is uneconomical. LNG is typically transported by specialized tankers with insulated walls, and is kept in liquid form by auto refrigeration: a process in which the LNG is kept at its boiling point, so that any heat additions are countered by the energy lost from LNG vapour that is vented out of storage and used to power the vessel. The increased use of LNG is vital for the production and marketing of natural gas deposits that were previously uneconomical to recover. LNG takes up much less space than gaseous natural gas, allowing it to be shipped more efficiently.

Use of Natural Gas Fuel Cells: Fuel cells powered by natural gas are extremely exciting and are promising new technology for clean and efficient generation of electricity. They have the ability to generate electricity using electrochemical reactions as opposed to combustion of fossil fuels to generate electricity. Essentially, a fuel cell works by passing streams of fuel (usually H_2) and oxidants over electrode that are separated by an electrolyte. This produces a chemical reaction that generates electricity without requiring the combustion of fuel, or the addition of heat as is common in the tradition generation of electricity. When pure H_2 is used as fuel and pure oxygen (O_2) is used as the oxidant, the reaction that takes place within a fuel cell produces only water, heat, and electricity.

Use as Natural Gas Liquids (NGLs): NGLs can be recovered from gas streams which are richer in heavier hydrocarbons. These liquids have high market values and find applications either in their raw form as solvents, feedstock (for production of various chemicals) and liquid fuels or

fractionated into their components, e.g. liquefied petroleum gas (LPG), cooking gas, natural gasoline, and various special boiling point (SBP) solvents. These NGLs include ethane propane, butane, pentane etc.

Use for Natural Gas Turbine: Power plant use natural gas to create steam which runs a huge and very carefully designed multi-stage turbine to spin an output shaft that drives the plant's generator. In a gas turbine, the pressurised gas spins the turbine. The engine produces its own pressurised gas and it does this by burning natural gas. The heat that comes from burning the fuel (natural gas) expands air, and the high-speed rush of this hot air spins the turbine. The advantages of this kind of turbine is that it has a great power to weight ratio compared to reciprocating engines i.e. the amount of power you get out of the engine compared to the weight of the engine itself is very good. Also, they are smaller than their reciprocating counterparts of the same power.

Use as Industrial Fuel: Natural gas is one of the most effective industrial fuels and it comes as a cheap substitute, and thus can help lower the cost of production of most finished goods in the long run. In Nigeria, industries like Nigeria Breweries, West African Cement Company, Kew Metals, and the Nigerian Aluminium Smelting Company all use natural gas as industrial fuel.

Other Uses of Natural Gas: Natural gas is used to run industrial boilers, industrial ovens, dryers and kilns. In the olden days, it is used mainly to light street lamps. Researches are still ongoing to find other areas where natural gas use can provide the utmost benefits. Investment opportunities abound in the natural gas sector and these opportunities can spur on increased economic activities in exploration, drilling, gathering, transmission, distribution, NGLs and LPG extraction plant, pipe manufacturing, gas to liquids production etc.

Conclusion

Natural gas is the cleanest of available fossil fuels like crude oil and coal and thus it is environmentally friendly and not dangerous to animals or other living organisms. When compared to other fossils fuels and even other sources of energy like energy from nuclear fusion or fission, it is seen that it is one of the cheapest source of energy around. Even the cost of construction of the natural gas plant is far cheaper than building a coal plant, crude oil refinery or even a nuclear reactor. As a feedstock for many industries, it can play a very important role for rapid economic development of a country like Nigeria. It is believed that there is abundant reserve of natural gas around the world which can last much longer than the present crude reserve.

For those who have apprehensions about the use of natural gas, it has been shown that natural gas is far safer than other fossil fuels. Reservations that are held about investment in the natural gas sector being capital intensive and requiring appropriate technology is outweighed in terms of long-term profitability. The widespread use of natural gas will help cushion the pinch that is felt in the incessant increase in the prices of petroleum products like kerosene, diesel, and petrol. Plans are underway for Nigeria to supply natural gas through pipelines to other West African countries under a scheme known as West African Gas Project (WAGP). Nigeria is already supplying gas to European countries through the Nigeria Liquefied Natural Gas (LNG) project.

Recommendation

To help the natural gas sector to develop the following recommendations are hereby suggested to boost this sector:

- Establishment of a National Energy Institute where researches on the other myriad uses of natural gas can be carried out. Government, the private sector, multi-national companies should be encouraged to contribute to this endeavour.

- Growing and well-planned urban centres like Minna can be used as a model town on the use of natural gas for both domestic and industrial purposes. This pilot project will involve the laying of a comprehensive pipeline network to households in the different districts of the town and measuring the positive impact that gas consumption can then have on efforts to protect the natural environment from wanton deforestation.
- Equipment and facilities for the development of this sector should be excluded from taxation and exercise.
- Government should endeavour to enforce the policy of zero-tolerance level for gas flaring by 2008. This will lead to proper utilization of natural gas and at the same time bring about the much needed investments that will help check youth restiveness, unemployment, etc.
- Government should adopt programmes that will bring about less dependency on crude oil and it derivatives and at the same time bring about orientation on the use of natural gas and it benefits.

References

Ababio, O.Y. 1990: "New School Chemistry"; Africana Fep Publishers Ltd, Onitsha.

Learmonth, J. 1985: "Petroleum Open Learning: Gas Flow Measurement"; Petroleum Open Learning, Aberdeen, Pp 1-49.

Matthews, P. 1996: "Advanced Chemistry"; Cambridge University Press, Cambridge, Pp 193 and 194.

Nelkon, M. 1994: "Principles of Physics"; Hart-Davis Educational Publishers, London, Pp 7, 153, and 200.

NGC 2002: "Natural Gas Utilization in Nigeria"; Nigerian Gas Company Ltd., Warri, Pp 4-9.

NLNG 2002: "Unit 1100 Operating Manual: Acid Gas Removal"; Nigerian Liquefied Natural Gas Company, Lagos, Pp1-17.

Okeke, F.C. and B.M. Sobotie 2002: "NNPC School Enlightenment Lectures"; Nigerian National Petroleum Corporation, Lagos, Pp 1 and 27.