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Gas Flaring in Nigeria: Some Aspects for Accelerated Development of SasolChevron GTL Plant at Escravos

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The drive for reduction of gas flaring in Nigeria, utilization of Nigeria's vast gas resources, and conversion of gas molecules into money for Nigeria, motivated the study of the development of Escravos gas-to-liquids (EGTL) project. SasolChevron is the product of the coalition of energy technologies for the exploitation of the EGTL project.

This article discusses some aspects of the SasolChevron gas-to-liquids (GTL) technology that uses the Fischer-Tropsch (F-T) technology as its background. To this end, the chemistry and process of the F-T technology for the manufacture of liquid hydrocarbon fuels from coal feedstock through natural-gas feedstock are reviewed and reported, as this article will show. Also, the annual magnitudes and trends of Nigeria's natural-gas production, consumption, and disposal by flaring are reviewed from 1970 to 2001, and presented, as will be shown in this article. The annual levels and profiles of pollutants emitted by gas flaring and venting, respectively, are discussed and reported.

The fiscal incentives are examined and reported. The trends of the annual work stoppages, trade disputes and man-days lost to trade disputes for 1980–1998 periods are reviewed and presented. The likely causes of trade disputes and work stoppages particularly in the Niger-Delta area are discussed.

Keywords gas-flare reduction, gas-utilization scheme, gas-to-liquid (GTL) technology, Fischer-Tropsch (F-T) process, slurry-phase-distillate technology, isocracking technology

Reflection

"Recognizing and reacting to innovations and new ideas are the marks of thinkers and doers. Creating those innovations and idea, and shaping their course are the marks of leaders and movers," so says Harold S. Kemp, the 1986 President of the American Institute of Chemical Engineers (AIChE).

Readers are implored to reflect on:

1. The pioneering role of Fischer-Tropsch (F-T) as the leader and mover in hydrocarbon-fuel manufacture from coal.

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2. The innovative role of Sasol as the thinker and doer in hydrocarbon-fuel manufacture from natural gas using the slurry phase distillate (SPD) in the gas-to-liquids (GTL) conversion technology.
3. The coalition role of SasolChevron as the thinker and doer in GTL manufacture by exploitation of energy technology synergy.

Introduction

Nigeria is endowed with abundant qualities of oil and gas resources. Erinne (1999) categorizes the Nigerian reserves of oil and natural gas as shown in Table 1. With about 202 and 30 years of proven reserves of natural gas and oil, respectively, Nigeria may be indeed considered a gas region with a little oil (Erinne, 1999).

However, statistics show that on the average, Nigeria flares about 86% of her natural gas production (Oguejiofor, 2003a). The year 2008 has been set as the target year for the phase out of gas flaring practices in Nigeria.

To make this target date realizable, Nigeria should seriously consider accelerating the paces of natural gas utilization projects. One such project is the SasolChevron joint venture that involves gas-to-liquids (GTL) conversion using Sasol's slurry phase distillate (SPD) technology. The Escravos GTL (EGTL) joint venture agreement was signed by Chevron Nigeria Limited and Sasol Limited, South Africa, before the merger of Chevron with Texaco. The agreement covers the development, implementation, management, and marketing of the EGTL venture based on the Sasol's SPD process.

According to Escravos gas-to-liquids project (SasolChevron EGTL, 2004), Chevron Nigeria Limited, together with Nigerian National Petroleum Corporation (NNPC), intends to build a 34,000 barrel-per-day GTL products plant in Escravos Nigeria (EGTL). The EGTL product will convert over 300 million cubic feet of natural gas per day to GTL diesel and GTL naphtha (SasolChevron GTL, 2004).

Accordingly, the EGTL project is predicated on:

1. The utilization of Nigeria's huge natural gas reserves.
2. The reduction of routine gas flaring practices by upstream oil producing companies.
3. The production of environmentally friendly fuel (ecofuels).

The EGTL project site preparations commenced in early 2002. The contract bidding is in progress at the time of this report. The project will be executed under a lump sum engineering, procurement, and construction contracting strategy, and first production is expected late 2006 to early 2007 (SasolChevron EGTL, 2004).

Table 1
Nigerian reserves of oil and natural gas

	Oil	Natural gas
Ultimate reserves	31,400 million barrels	8,500 billion cubic meters
Proven reserves	20,000 million barrels	4,250 billion cubic meters
Annual production	663 million barrels	21 billion cubic meters
Depletion	30 years	202 years

This study will discuss some of the salient aspects of the EGTL project with a view to ensure a fast-track development. To this end, this article is broken up into the following objects:

Science and technology aspect
Economic aspect
Environmental aspect
Fiscal incentive and social aspects
Discussion
Conclusion

Science and Technology Aspects

Several GTL process technologies have been developed in recent times. Examples are the Shell's Middle Distillate Synthesis (SMDS) and the advances made by South Africa's Sasol in the F-T process, termed slurry phase distillate (SPD) technology.

Origin and Development of the F-T Process

The conversion of coal into liquid fuels and chemicals originated from the work of two German Chemists, Dr. Franz Fischer and Hans Tropsch. In the early 1920s, they developed the F-T process that produced synthetic fuel from coal (Sasol, 2000). Their discovery was patented in 1925 and commercialized in the mid-1930s for the production of synthetic petroleum and diesel in Germany. Later the technology right was sold to Sasol for the gasification of coal and conversion of syngas into hydrocarbon products (Sasol, 2000). This technology suited South Africa given her vase coal reserves.

Chemistry and Process of F-T in a Nutshell

Anubi (1999) presents the chemistry of F-T reactions as follows:

$$C_{(s)} + H_2O_{(g)} \rightarrow CO_{(g)} + H_{2(g)} \tag{1}$$

$$nCO_{(g)} + 2nH_{2(g)} \rightarrow C_nH_{2n(l)} + nH_2O_{(g)} \tag{2}$$

$$nCO_{(g)} + (2n+1)H_{2(g)} \rightarrow C_nH_{2n(l)} + (2+n)H_2O_{(g)} \tag{3}$$

Coal is gasified in the presence of steam under pressure and high temperature to produce raw gas. The raw gas is purified to produce synthesis gas consisting roughly of a mixture of hydrogen and carbon monoxide in a two to one ratio. According to Sasol (2000), the synthesis gas (syngas) is then passed over fixed bed tubular (ARGE) reactors, circulated with circulating fluidized bed (CFB) reactors or percolated through Sasol advanced synthol (SAS) reactor, and Sasol slurry phase distillate (SSPD) reactor, iron or cobalt-based catalyst between 350°C and 230°C.

The F-T technology is a very complicated process that requires a well-defined choice of reactors (namely SAS and SSPD), catalysts and operating conditions to synthesize the desired products.

Natural-Gas Beneficiation by F-T Process: The GTL Conversion

The F-T process remains the basis of Sasol's slurry phase distillate (SSPD) technology, and South Africa has the leading edge in the advancement of the F-T process for GTL conversion. Instead of coal, this South African innovation in the F-T process utilizes natural gas as the feedstock. This new F-T frontier is called the GTL process.

The Sasol developed GTL conversion entails a proven three-step process that would unlock Nigeria's latent wealth in natural gas reserves. The three-step process, according to Sasol (2002), are:

1. Haldor Topsoe's autothermal reforming technology.
2. Fisher-Tropsch's SPD technology.
3. Chevron Texaco's isocracking technology.

The scheme of the promising SasolChevron GTL technology for Nigeria's vast natural gas reserves is shown in Figure 1.

Haldor Topsoe's Autothermal Reforming Technology. The technologies available for natural gas reforming are: the stream reforming process, the Haldor Topsoe's autothermal reforming (ATR) process, and a combination of the above-mentioned technologies.

In the Haldor Topsoe's autothermal reforming (ATR) process, natural gas is reacted with oxygen and steam over a catalyst to produce syngas, a mixture of carbon monoxide and hydrogen. The chemistry of the reactions, according to Dybkaer (2003), are:

$$CH_{4(g)} + 1.5O_{2(g)} \rightarrow CO_{(g)} + 2H_2O_{(g)} \tag{4}$$

$$CH_{4(g)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + 3H_{2(g)} \tag{5}$$

$$CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)} \tag{6}$$

ATR chemical process is a combination of partial combustion and steam-reforming reactions, as Eqs. (4) to (6) show.

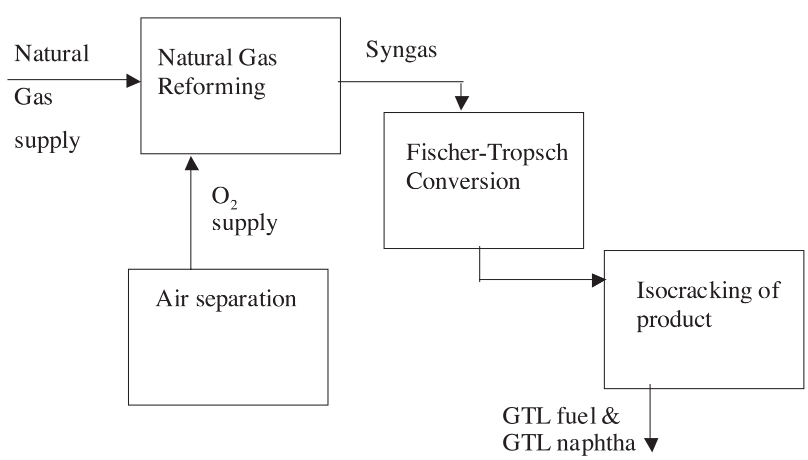

Figure 1. Scheme of the three-step SPD (SasolChevron GTL, 2004).

Dybkaer (2003) shows the chemistry of steam reforming process to consist of the following equations:

$$CH_4 + H_2O \rightleftarrows CO + 3H_2 \tag{7}$$

$$C_nH_m + nH_2O \rightleftarrows nCO + (n + m/2)H_2 \tag{8}$$

$$CO + H_2O \rightleftarrows CO_2 + H_2 \tag{9}$$

Fischer-Tropsch's SPD Technology. The synthesis gas (syngas) from the reformer is converted into longer-chain or waxy hydrocarbons in the low-temperature Sasol slurry phase (SSD) reactor. This is the Fischer-Tropsch gas-to-liquids (GTL) conversion. The simplified reaction, according to Sasol (2002), is:

$$CO_{(g)} + 2H_{2(g)} \rightarrow -CH-_{2^-(l)} + H_2O_{(g)} \tag{10}$$

Alternatively, the F-T synthesis can be represented as:

$$nCO_{(g)} + 2nH_{2(g)} \rightarrow (CH_2)n + nH_2O \tag{11}$$

Sasol (2002) states that syngas is fed to the bottom of Sasol slurry phase reactor, where it is distributed into the slurry consisting of liquid wax and particles of proprietary advanced cobalt catalyst especially developed for application in the Sasol low-temperature Fischer-Tropsch (LTFT) slurry phase reactor. As the gas bubbles upwards through the slurry, it diffuses into the catalyst and is converted into waxy syncrude, the synthetic equivalent of crude oil. The wax product is separated from the slurry containing the catalyst particles in a proprietary Sasol process. The lighter, more volatile fractions leave in a gas stream from the top of the reactor. The gas stream is cooled to recover the lighter cuts and water. The hydrocarbon streams are sent to the product ungrading unit.

Chevron Texaco's Isocracking Technology. Isocracking catalytically cracks the heavier hydrocarbon molecules and upgrades them to premium-grade diesel and naphtha that are virtually free of sulphur and aromatics. The isocracking technology right belongs to Chevron Texaco.

GTL Technology Synergy and Equity Fund

The Escravos GTL project is an amalgamation of GTL technologies and investment funds for the exploitation of the vast natural gas reserves in Nigeria with the GTL partners contributing as follows:

1. Sasol, the world leader in F-T technology, bringing her slurry phase distillate (SPD) technology.
2. Chevron Texaco contributing gas-harnessing facilities and the isocracking technology.
3. Nigerian Natural Petroleum Corporation's (NNPC) subsidiary, the Nigerian Gas Company (NGC), providing the natural-gas resource for GTL conversion.

Besides technologies, Sasol is also providing investment funds. Sasol (2002) states that Sasol is jointly investing US$2.1 billion to develop GTL plants in Nigeria and Qatar to convert natural gas into a high-quantity GTL diesel.

Economic Aspect

From an economic perspective, gas flaring in Nigeria wastes valuable resources. A report from Shell (1996) shows that in 1996, Nigeria flared a total of some two billion standard cubic feet per day (scf/d), which is estimated to be about a quarter of the gas the world flares and vents. Also, Shell (1996) reports that the energy available from Nigeria's flared gas is prodigious, equivalent to one-quarter of France's gas requirements.

The annual statistics of natural gas production and disposal by utilization and flaring is extracted from Nigeria National Petroleum Corporation (NNPC, 2001). Figure 2 represents the plots of the NNPC data on gas production, utilization, and flaring in Nigeria (1970–2001), all of which, on the average, reveal steady rising trends over the years. While Figure 3 is the profile of percentage utilization and flaring of gas in Nigeria (1970–2001). On the average, Figure 3 reveals a steady decline in flared gas percentage over the years, on one hand; and on the other hand, steady corresponding rise over the years in percentage utilization. However, in 1999 and 2001 (Figure 3), utilization and flaring percentages nearly tied at about 50%. Near 50% flaring is still high and requires redress in the form of additional flare-reduction schemes for Nigeria, such as the SasolChevron GTL project. The flared gas profiles in Figures 2 and 3 are indicative of 31 years of colossal economic wastes of Nigeria's gas resources. The decline in the volume of flaring from 1998 is due to the commencement of liquefied natural gas (LNG) manufacture which increased noticeable volume of utilized gas.

The crux of the waste of gas resources by flaring is rooted in the limited commercial outlets and investments that would take up the gas produced from crude oil production. The SasolChevron initiative in GTL conversion is another investment addition in the utilization of Nigeria's gas. This has the promise of considerably arresting the gas-flaring trends, shown in Figures 2 and 3, starting from A.D. 2007 when the plant comes onstream. The EGTL promise is rooted on the design capacity of the EGTL plant predicated to take up over 300 million cubic feet of natural gas per day as feedstock. Nigeria flares some 2 billion standard cubic feet per day (scf/d) of natural gas and the EGTL will take up 300 million scf/d from this, thereby resulting in flared-gas reduction to 1.7 billion scf/d. While the SasolChevron EGTL project is welcomed, the pace of the development needs

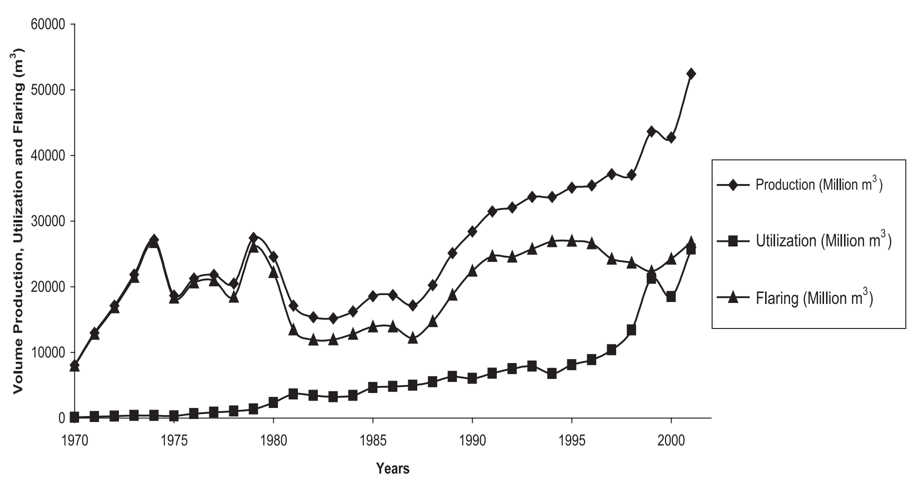

Figure 2. Graph showing the volumetric trends of gas production, utilization, and flaring in Nigeria from 1970–2001.

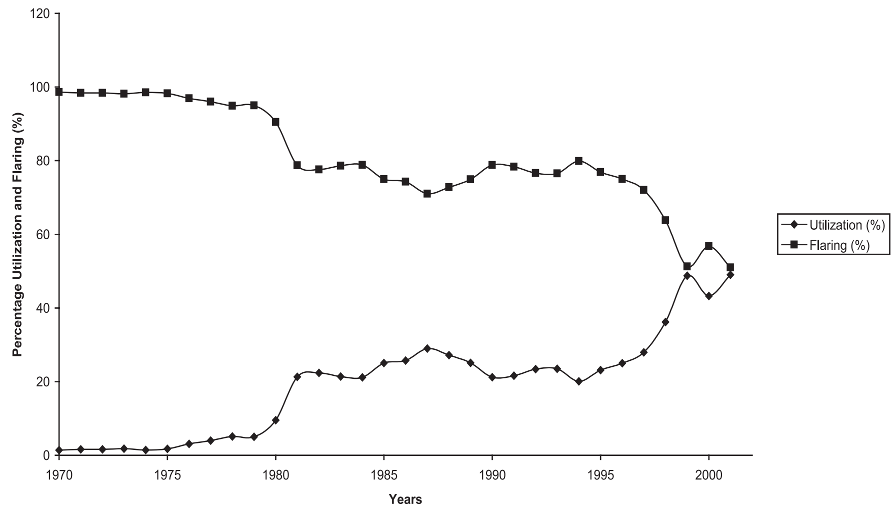

Figure 3. Plot showing the profiles of percentage utilization and flaring of Nigeria's gas, 1970–2001.

to be hastened so as to ensure quicker curtailment of the protracted waste experienced by several years of gas flaring starting from 1970 to date (see Figures 2 and 3).

Environmental Aspect

Gas flaring and venting are environmentally damaging and everything in the environment, namely humans, animals, buildings, process plants, vehicles, and vegetation, to mention a few, are adversely affected by their pollution.

Gas-Flaring Pollution

Oguejiofor (2000) reports the annual tonnages and trends of flue gas pollutants emitted by gas flaring from 1970 to 1999. These pollutants are particulates SO_x, NO_x, CO, and they have disastrous environmental consequences. As oxides, they are acid anhydride and they mix with humid air around to acidify the environment and to produce contaminated rain termed acid rain.

Figure 4 is the profile of pollutants from gas flaring that spans from 1970 to 1999. On the average, the annual magnitude of the flue gas pollutants, namely particulate ashes SO_x, CO, and NO_x gases, produce rising trends over the 19-year span, 1970–1999.

The small magnitude of SO_x pollutants relative to the magnitudes of other flue gas pollutants, particularly NO_x pollutants (see Figure 4) probably causes the SO_x trend line to tie with the x-axis of the plot. By minimization of the y-axis scale, the plot for SO_x emission alone is shown in Figure 5. The exact nature of the SO_x magnitude and trend over the years is revealed by Figure 5.

When the SasolChevron EGTL plant takes off in 2007, the levels of gas-flaring pollution (see Figure 4) will likely show appreciable reduction in magnitudes and profiles. This is because the EGTL plant will reduce gas flaring by over 300 million scf/day and over 108 billion scf/year. The level of flare reduction compels one to call for accelerated development of the EGTL project so as to ensure an earlier than scheduled realization date.

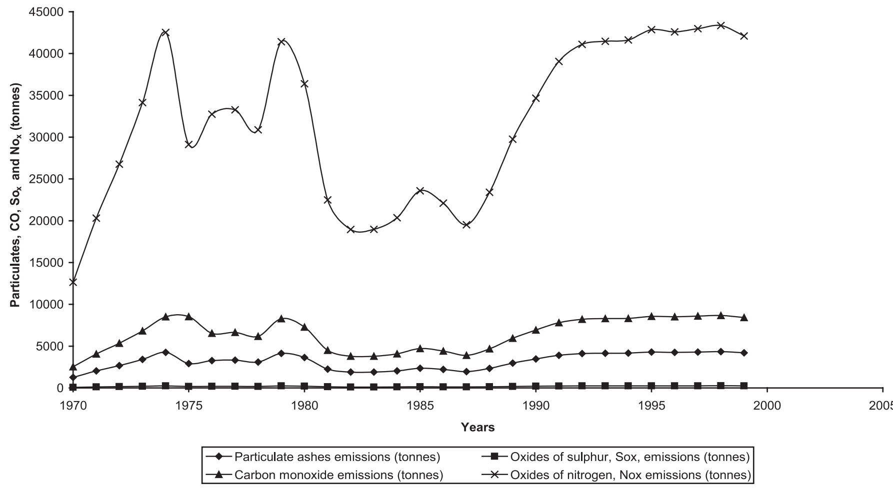

Figure 4. Graph of the trends of flue gas pollutants emitted from gas flaring, 1970–1999.

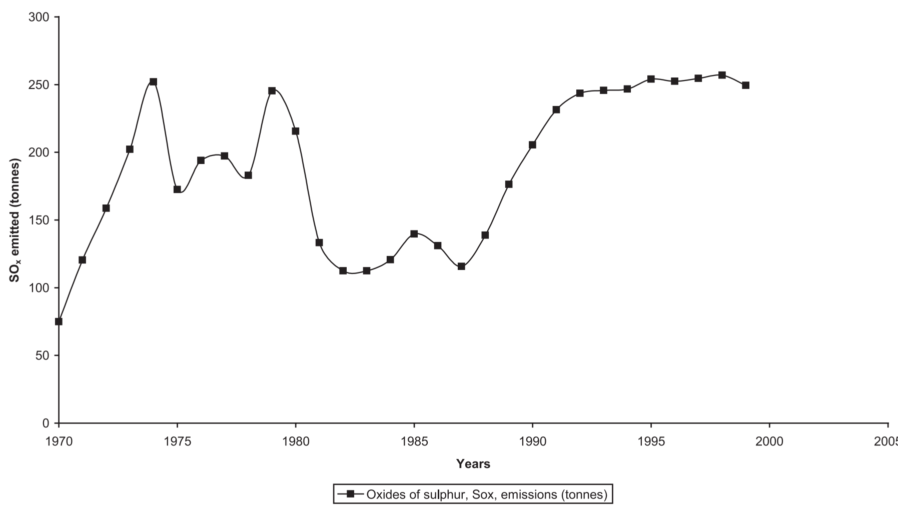

Figure 5. Graph of SO_X emitted from gas flaring from 1970–1999.

Gas Venting Pollution

Besides gas flaring, another method of disposal of natural gas in Nigeria's oil fields is by venting. This is another source of atmospheric pollution. Figure 6 shows the magnitude and trends of hydrocarbons emissions by Shell Petroleum Development Company (SPDC) of Nigeria and other oil/gas operators, respectively, from 1998 to 2002 (Oguejiofor, 2003b). The chief constituent of hydrocarbons emissions is methane.

Methane, the principal constituent of hydrocarbon emission, plays two pollution roles in the atmosphere. In the stratosphere, methane is a greenhouse gas, while in the troposphere (ground level), methane is one of the reactants in the photochemical reaction for the formation of ground level ozone and photochemical smog. According to

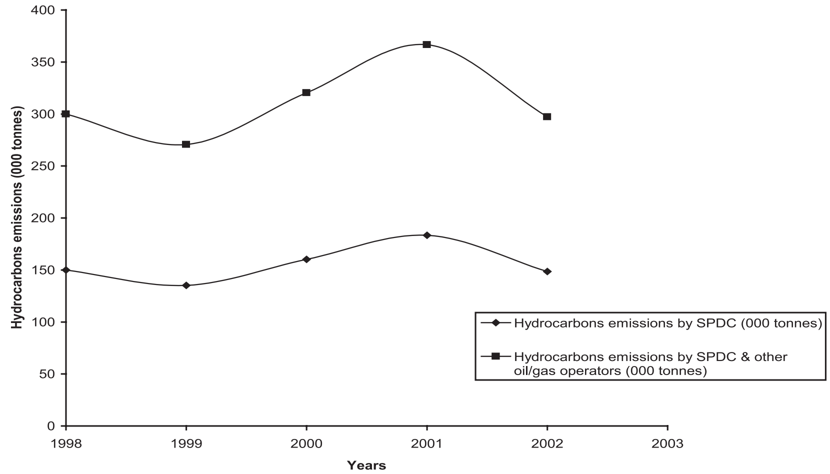

Figure 6. Graph of the profiles of yearly hydrocarbons emissions (000 tonnes).

Oguejiofor (2003b), the chemistry of photochemical smog formation is:

$$10NO_3 + 12O_2 + 2H_2O + CH_4 + C_3H_8 + C_6H_6 \rightarrow 2O_3 + 4CH_3CO_2NO_3 + 2CH_2O + 6HNO_3 \quad (12)$$

Interestingly, methane (CH_4) is part of the chemical equation [Eq. (12)] in smog formation. The products of the reaction are atmospheric pollutants, namely ozone, peroxyacyl nitrate, formaldehyde, and nitric acid [see Eq. (12)].

The SasolChevron EGTL project is a control on the pollutants emitted from both gas flaring and venting. The quickening of the realization date of the EGTL projects will no doubt save the atmosphere of considerable levels of gas flaring and gas venting pollutants.

Fiscal Incentives and Investment Climate

By virtue of the 1999 Constitution of the Federal Republic of Nigeria and the 1969 Petroleum Act, the federal government has exclusive ownership of petroleum and mineral resources, and is the sole authority that grants the right to exploit or participate in joint exploitation with any company.

Fiscal Incentives

To encourage investors, indigenous and foreign alike, the Federal Government of Nigeria (FGN) put in place various incentive packages for natural gas utilization. Gas utilization, as defined by National Petroleum Investment Management Services (NAPIMS, 2004) is the marketing and distribution of natural gas for commercial purposes and includes power plant, LNG and GTL plants, fertilizer plant, gas transmission, and distribution pipelines.

Under the Finance (miscellaneous taxation provisions) Decree No. 18 of 1998 (Amendment to Petroleum Profit Tax Act), the fiscal incentives for investing in gas-utilization projects include (NAPIMS, 2000):

1. VAT and customs-duty exemptions on plant, machinery, and equipment purchased for gas utilization in downstream petroleum operations.
2. A 5-year tax holiday.
3. Accelerated capital allowance after the tax-free period in the form of 90%, with 10% retention in the books for investment in plant and machinery.
4. 15% investment capital allowance that shall not reduce the value of the asset.
5. Tax-free dividends during the tax-free period.

Also, Finance (miscellaneous taxation provisions) Decree No. 19 of 1998 (Amendment to Petroleum Profits Tax Acts) provides that interest on loans for any gas project is tax deductible if permission has been obtained from the Federal Ministry of Finance before taking the loan (NAPIMS, 2000).

Investment Climate

Nigeria is investor friendly especially for gas-sector development and utilization where the fiscal incentives discussed above are readily available. However, a review of the industrial relation indicators (see Figure 7) reveals some worrisome levels of work stoppages, trade disputes, and man-days lost to trade disputes and strikes. The major contributors to trade disputes are believed to be the crushing debt burden and the ailing national economy that manifested in about 1980 on the one hand, and on the other hand the IMF-induced structural adjustment program (SAP) introduced in 1986 to redress the problems associated with debt-burden and dwindling economy. These explain the levels and trend observed in Figures 7 and 8. The data for plotting Figures 7 and 8 are obtained from CBN (1999).

In the Niger-Delta area, work stoppages may be occasioned by restive youths. Unemployment, severe economic hardship, lack of infrastructure, political agitation for resource control, salary disparity between foreign and local staff/workers in oil/gas production and processing companies, could be responsible for Niger-Delta youths' restiveness. In recent

Figure 7. Graph showing the pattern of the numbers of trade disputes and work stoppages over the years specified.

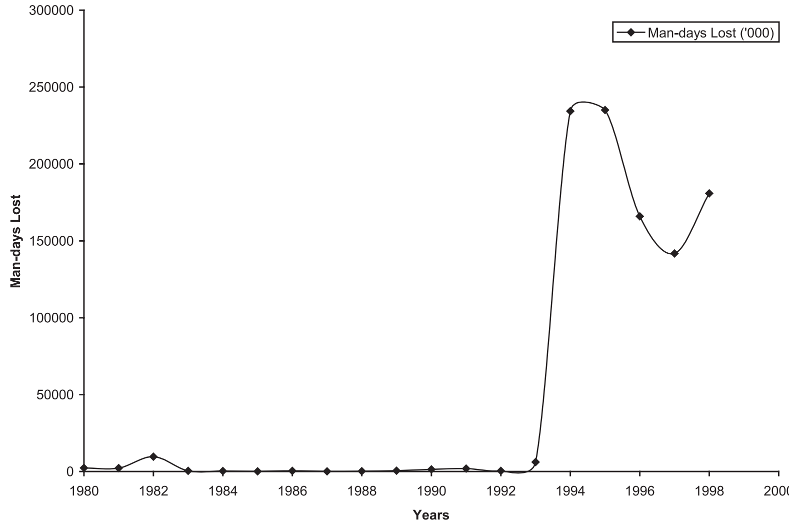

Figure 8. Graph of trend of annual man-days lost ('000).

times, however, the repeal of the onshore/offshore dichotomy in the sharing of oil revenue among oil-producing states, and the Niger Delta Development Commission (NDDC) law that apportions 15% derivation for the development of oil-producing areas, are the government's efforts in redressing the problems and enhancing the investor friendliness of the Niger-Delta area of Nigeria. These, no doubt, will be of considerable benefit in enhancing the pace of the execution of the SasolChevron EGTL project.

Conclusion

The GTL, no doubt, is one of the leading edge technologies in natural gas beneficiation, and SasolChevron is the GTL development driver in Nigeria's EGTL plant. To this end, the EGTL plant, when completed and commissioned in A.D. 2007, has a promise to accomplish the following:

1. Natural gas waste to wealth conversion, to the level of over 300 million scf/day and over 108 billion scf/year.
2. Gas resource exploitation and utilization.
3. Gas molecules to money converter.

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