

## THE POTENTIAL OF LIQUEFIED PETROLEUM GAS (LPG) AS A VIABLE ENERGY OPTION FOR THE INDUSTRIAL SECTOR IN GHANA

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### ABSTRACT

The purpose of this research was to assess the potential of Liquefied Petroleum Gas (LPG) as a viable energy option for the industrial sector in Ghana, as most of the LPG available in the Ghanaian market is utilized in the residential sector. Many households, industries and other consumers in Ghana continue to suffer from serious shortfall of electricity supply and highly volatile oil prices. Using data collected through face to face interviews, observations, and discussions from a sample of 60 industries located in Tema, Ghana, the research identified a potential for increased LPG use in industries if safety concerns, price volatility, product availability, technical issues associated with boilers and furnaces, and policies issues are addressed. The paper concludes that a policy shift and support to the private sector are needed to enhance LPG use in industry. It also concludes that a favorable investment climate, the development of technical infrastructure, as well as the regional cooperation and integration in the energy sector is essential for the sustainable development of the energy sector.

**Keywords:** Liquefied Petroleum Gas; Industries; Energy; Price Volatility; Policy

### BACKGROUND TO THE PROBLEM

Humanity faces a unique and far-reaching challenge. Our energy needs are growing as a result of continued population increases, economic growth, and individual energy consumption. At the same time, emissions from fuel wood and fossil fuels, the main energy source for heating in homes and powering our economies, are contributing to climate change and affecting the local air quality (WEC, 2005). Households, industries, and other consumers in Ghana are suffering from serious shortfalls of electricity supply and highly volatile oil prices. This situation usually has its roots in the mix of energy policy miscues, the country's overdependence on hydro power, and the high oil prices that have increased the cost of generating electricity. There are many opportunities for LPG to contribute to improved living standards. The introduction of LPG into this critical domestic market can then be leveraged to extend modern energy services to the wider community and for cultivating commercial and industrial growth in the local economy.

## **Problem Statement**

Most of the LPG available in the Ghanaian market is utilized in the residential sector. There are almost no limitations for LPG use in the industrial sector (WLPGA, 2001), but a limited number of Ghanaian industries use this fuel. The prospects for increased consumption in the other sectors, especially the industrial sector, remain very limited.

Almost no data were available on LP Gas used in the industrial sector. No conclusions are possible on industrial applications of LPG and policy; this is a research gap. It is against this background that this study was carried out to explore the potential of LPG as a viable energy resource for our industries. This study aims to examine the factors that are particularly catalytic in the deployment of LPG as industrial fuel with the aim of providing some insights for industries that have plans to promote the use of gas as fuel in the country. In view of the above, the research seeks to find answers to the following questions:

- Why is the patronage of LPG as industrial fuel low in the manufacturing industries?
- What are the challenges and constraints to the use of LPG as energy source for industries?
- What are the characteristics of LPG that influence the use or non-use by industries?

## **Research Objectives**

The main objectives of the study are to explore the potential of LPG as industrial fuel and to examine the factors that are catalytic in the deployment of LPG as industrial fuel. The specific objectives include the following:

- Examine the critical factors for the low patronage of LPG use by industries
- Assess the characteristics of LPG that makes it a preferred option for some manufacturers
- Make recommendations for policy considerations

The study was conducted in the Tema Municipality of Ghana, with Tema as its capital. The municipality is located in southeast Ghana, 29 km east of Accra, and in the Coastal Savanna zone. Tema was chosen because it is the most industrialized city in Ghana and its industrial sector is the most important revenue generation for the municipality. The only oil refinery in the country is located in this municipality and the West Africa Gas Pipeline Project has Tema as one of the key terminals.

## **Research Methodology**

The objective of this thesis is to describe and analyze a contemporary process and to answer the research questions formulated. According to Yin (2003), if research questions focused mainly on “what” questions, either exploratory research or survey can be adopted. Some types of “what” questions are exploratory, such as, “What are the challenges and constraints to LPG as industrial fuel?” According to Yin (2003), this type of question is a justifiable rationale for conducting an exploratory study, the goal being to develop pertinent hypotheses and propositions for further enquiries. Also, almost no research has been done on this topic; based on this difficulty, it became apparent that the research should be exploratory, attempting to obtain a deeper understanding of why LPG is not used by industries, the challenges and constraints to LPG use, and the characteristics of LPG.

**Case Study Area and Justification**

These ensure high representation of industries in the country and proximity of the industries to the refinery and the pipeline. For the purposes of this study, establishments were chosen as the unit of analysis even though the interviewees were individuals. To give a comprehensive understanding of all issues, evidence from different perspectives were considered. The sampling frame is as shown in table 1.

**Table 1: Sampling Frame**

Name of Population	Sample Frame	Sample Identification
Manufacturing Establishments	65	<ul style="list-style-type: none"> <li>Registered members of the Association of Ghana Industries ( AGI)</li> <li>Registered members of Chamber of Mines</li> <li>Industrial customers of Oil Marketing Companies (OMCs) in Tema</li> </ul>
OMCs	27	Registered OMCs (source: TOR)
Regulatory Bodies	2	Personal Identification
Liquefied Petroleum Gas (LPG) Producers	1	Personal Identification

Source: Authors’ Construct, May, 2006

**Sample Selection**

Regulatory bodies were purposefully selected because of their unique roles they play in the LPG industry. A total count was conducted in the case of the OMCs.

**Table 2: Determining Sample Size for Manufacturing Establishments**

Total Number of manufacturing establishments 65

Confidence level	Sample Size
95 %	<u>56</u>
92%	<u>62</u>
Mathematical formula used: $\text{Sample Size} = \frac{N}{1 + N (\alpha)^2}$	

Where  $\alpha$  is the Confidence Interval

At 95 percent confidence level, 56 establishments will have to be interviewed. To make up for non-response, 60 establishments were included in the survey.

The stratified sampling was used for the selection of manufacturing establishments and sample of units chosen independently from each subset. The idea of stratified sampling is to ensure that every part of the population gets better representation (Ghauri & Grønhaug, 2002). The standard industrial classification was adopted for classifying manufacturing industries. Establishments primarily engaged in food products and beverages, textiles, paper and paper products, basic metals, and petroleum products were considered for the purposes of this study. Establishments were selected at random to reflect the proportions of the various major industry groups. This ensured proper representation of selected industries and enhanced the representation of other variables related to them, thus reducing sampling error (Rubin & Babbie, 2001).

### **Selection of Respondents**

Selection of participants does favor those willing and able to dedicate at least thirty minutes to an unpaid activity. Each of the participants was contacted by means of phone or in person. With non-random sampling of interviewees, respondents may not typify practitioners in the manufacturing sectors they are chosen to represent. Selection bias is toward likely program participants—the subjects of this research.

### **Data Collection Technique**

A multiple approach of data gathering was adopted for the purpose of this research which includes: questionnaires, in-depth interviews, document analysis, and direct observation. The obvious reason for adopting the multiple approaches is the possible combination and integration of strengths and weaknesses concerned with each method. Yin states that no single source of data has a complete advantage over the others and that the various sources of data collection are highly complementary (Yin, 2003).

This not only increases the validity of the study, but increases the enriching and completes the knowledge and increases scope, depth, and consistency of methodological proceedings (Ghauri & Grønhaug, 2003). The techniques used to collect the empirical data were:

### **Documentary analysis**

A literature review of liquefied petroleum gas was undertaken to explain the background of LPG formation. In addition, all relevant information were analyzed to construct a precise summary of background information, which included the nature and origin of LPG and advantages and limitations of LPG with regard to price, availability, safety, and environmental emissions.

### **Questionnaires**

Two types of questionnaires were designed: one for manufacturing industries and the other for OMCs. Both closed and open-ended questions formed part of the questionnaires administered to address the objectives stated in the study.

### **In-Depth Interview**

Data from regulatory bodies were collected through in-depth interviews. Both structured and unstructured interviews were used. This was to ensure that interviews are more scientific in nature for the structured introduce controls that are required to permit the formulation of scientific generalization (Sidhu, 2003). However, to allow for respondents to express themselves fully, unstructured interviews were used in some cases. A brief summary of the interviewee's answer to a particular question was recorded on a sheet of paper and filed for analysis.

### **Direct Observation**

The researchers took field trips to 4 manufacturing industries identified to be using LPG to observe the various applications of the LPG, problems encountered in its use, and safety measures put in place to avoid the occurrence of accidents. Pictures were taken to aid in the analysis of the data.

### **Data Analysis**

Both qualitative and quantitative analyses were employed in this study. Data was edited and coded for entry into the computer using Statistical Package for Social Scientists (SPSS). Data was categorized and cross-tabulated according to concepts in order to address the purpose of the study. Pie charts, pictures, and bar charts were also used. In some cases, chi-square analysis was adopted to test relationships between some variables.

## **RESULTS AND DISCUSSION**

### **Profile of Respondents from manufacturing industries**

**Table 3: Distribution of Manufacturing Subsectors**

<b>Manufacturing Subsector</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Percent</b>
Food and Beverages	12	26.7	26.7
Chemical Products (other than Petroleum)	12	26.7	53.3
Textiles	6	13.3	66.7
Paper Products	1	2.2	68.9
Metals	12	26.7	95.6
Petroleum Products	2	4.4	100.0
Total	45	100.0	

Source: Authors' Field Survey-November 2006

The distribution of manufacturing industries is shown in Table 3. Of the 45 manufacturing industries surveyed, 25 (55.6 percent) were located in the heavy industrial area, 12 (26.7 percent) in the light industrial area, and the remaining 8 (17.8 percent) located in areas outside these two main industrial areas.

Ninety five percent (19) of the large sized industries were cited in the heavy industrial area, while the remaining 5 percent (1) were sited in the light industrial area. None of the small industries were located in the heavy industrial area. 53.3 percent (8) of the medium sized industries were located in the light industrial area, 26.7 percent (4) in the heavy industrial area, while 20 percent (3) were sited outside the light and heavy industrial areas. However, 50 percent (5), forming the majority of the small industries, were located outside these two main industrial areas, while the remaining 50 percent were distributed in the light and heavy industrial areas as 30.0 and 20.0 percent, respectively.

A chi-square test ( $X^2=27.13$ ,  $df=4$ ,  $p<0.000$ ) shows that there is a strong relationship between size of industries and location of these industries- an indication that the citing of an industry is highly influenced by the size.

**Table 4: Distribution of Manufacturing Industries according to Location**

Manufacturing Subsectors	Location of Industry			
	LIA (%)	HIA (%)	Outside (%)	Total (%)
Food and Beverages	35.7	50.0	14.3	100.0
Chemical Products (other than Petroleum)	30.0	50.0	20.0	100.0
Textiles	16.7	66.7	16.7	100.0
Paper Products		100.0		100.0
Metals	25.0	50.0	25.0	100.0
Petroleum Products		100.0		100.0
Total	26.7	55.6	17.8	100.0

Source: Authors' Field Survey- November 2006

**NOTE:** *LIA* refers to *Light Industrial Area*

*HIA* refers to *Heavy industrial Area*

35.7 percent of the food and beverage industries were located in the light industrial area, while 50 percent were sited in the heavy industrial area. The remaining 14.3 percent were outside the two main industrial areas. 50 percent of the chemical industries were in the heavy industrial area, 30 percent in the light industrial area, and the remaining 20 percent outside the main industrial areas. 66.7 percent of the textiles were sited in the heavy industrial area and 16.7 percent each in the rest of the areas.

The rest of the distribution is as follows: 50 percent of the metals were in the heavy industrial area, 25 percent in the light industrial area, and the remaining 25 percent sited outside the two main industrial areas. All of the petroleum and the paper industries included in the survey were located in the heavy industrial area.

A chi-square test ( $X^2=3.922$ ,  $df=10$ ,  $p>0.05$ ) shows there is no relationship between the various manufacturing sub-sectors and the location of the industries. This implies no particular area is allocated to only textile manufacturers nor chemicals or any of the manufacturing sub-sectors.

**Table 5: Distribution of manufacturing Industries according to Size**

Manufacturing Subsectors	Size of Manufacturing Industries			
	Large Sized Companies (%)	Medium Sized Companies (%)	Small Sized Companies (%)	Total (%)
Food and Beverages	50.0	28.6	21.4	100.0
Chemical Products (other than Petroleum)	40.0	50.0	10.0	100.0
Textiles	50.0	33.3	16.7	100.0
Paper Products	100.0			100.0
Metals	25.0	33.3	41.7	100.0
Petroleum Products	100.0			100.0
<b>Total</b>	<b>44.4</b>	<b>33.3</b>	<b>22.2</b>	<b>100.0</b>

Source: Authors' Field Survey- November 2006

Of the manufacturing sub-sectors surveyed, 20 representing 44.4 percent of the industries were large sized companies, 15 representing 33.3 percent of the industries were medium sized companies and 10 representing 22.2 percent were small sized companies.

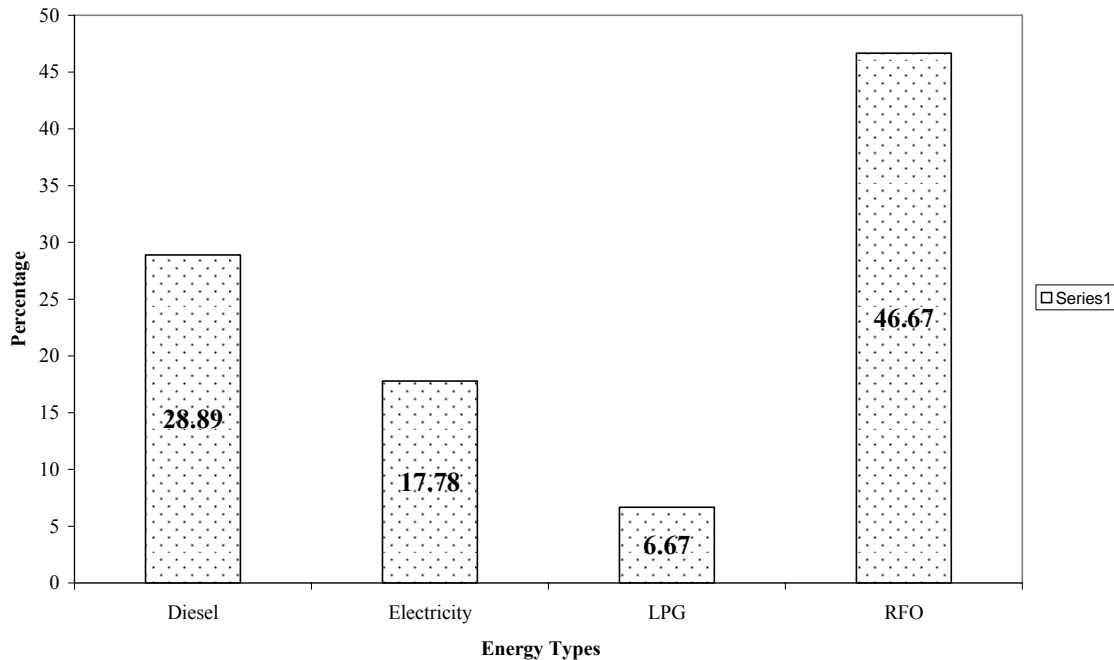
Within the manufacturing industries, results from table 5.0 shows that the petroleum products and paper industries were large sized industries. 50 percent of the food and beverage industries were also large size, 28.6 percent medium sized, and the remaining 21.4 percent were small sized industries. The majority (50 percent) of the chemical industries was medium sized, 40 percent were large sized, and the remaining 10 percent were small sized industries. The rest are 41.7 percent of metals belong to the small sized industries, 33.3 percent were classified as medium sized industries, and the remaining 25 percent classified as large sized companies.

A chi-square test ( $X^2=8.684$ ,  $df=10$ ,  $p>0.05$ ) shows no relationship between manufacturing sub-sectors and size of the industries.

### Main Energy Sources Used by Manufacturing Sub-sectors

Manufacturing is an important part of the Ghanaian economy and energy is a vital input into the manufacturing. In fact, every manufacturing plant uses at least one type of energy in their production process.

**Figure 1: Main Energy Sources Used By Manufacturing Industries**



Source: Authors' Field Survey-November, 2006

Figure 1 depicts the main energy sources being used by the manufacturing sub-sectors. The most highly used fuel is Residual Fluid Oil (46.67 percent), whilst the least utilized fuel is LPG (6.67 percent). 28.89 percent of the manufacturing industries interviewed use diesel, while the remaining 17.78 percent uses electricity.

Most of the industries (91.1 percent) use the energy for process heating, 4.4 percent for process drying, and the remaining 4.4 percent for machine drive. 95.2 percent of the industries that use RFO as main fuel use it to generate heat, while the rest of the 4.8 percent is for process drying. According to the survey results, 100 percent of the industries that use diesel are for process heating. 66.7 percent of the industries that use LPG as main fuel are for process heating, while 33.3 percent is for process drying. However, the industries that use LPG as substitute fuels or alternative fuels use it to drive machines and start ignition in addition to the process heating and drying.

Reasons assigned for the choice of a particular energy source included the design of their boilers and furnaces (40 per cent), its comparatively low price (33.3 per cent) and the readily availability of the energy (26.7 per cent). The distribution is as shown in table 6.0.



**Table 6: Reasons for choice of Main Energy Source**

Main Energy Sources Identified	Reason for choice of Energy Source			
	Cheapest (%)	Readily available (%)	Design of Furnaces & Boilers (%)	Total (%)
Diesel		46.2	53.8	100.0
RFO	71.4	14.3	14.3	100.0
Electricity		37.5	62.5	100.0
LPG			100.0	100.0
TOTAL	33.3	26.7	40.0	100.0

Source: Authors' Field Survey- November 2006

Test shows that most industries (40 percent) choose energy on the basis of the design of their equipment and, for that matter, the purpose for which the fuel is required for. However, another factor considered is the cost of the fuel (33.3 percent) and then the availability of the energy (26.7). To test if there is any relationship between energy type and reason for choice of a particular fuel showed a high significance level of  $p < 0.001$ . Among the petroleum products used by the manufacturers, RFO appears to be the cheapest; this is followed by LPG and diesel. Although LPG and electricity appears to be cost competitive, the relative stability of electricity prices makes it a preferred option for many manufacturers.

A chi-square performed to test whether there is any significant relationship between fuel type used by industries and uses of these industries gave a  $X^2 = 16.398$ ,  $df = 6$  and  $p$ - value of 0.012. This implies the choice of fuels is also influenced by its use by the manufacturer. Size of manufacturing industry and location of these industries did not influence the choice of a particular energy type. All were  $p > 0.05$ .

#### **Distribution of Gas users across the various manufacturing Industries**

Of the industries identified to be using LPG as their energy source, 12.5 percent are in the food and beverage industry, another 12.5 percent belong to the chemical industry, 25.0 percent in the textile industry, 37.5 percent in the metal industry, and the remaining 12.5 percent in the paper and petroleum industry. Results show that LPG users are found in almost all the manufacturing sub-sectors. A chi-square test indicates that there is no association between manufacturing sectors and LPG utilization- an indication that LPG is used in almost all the sectors of the manufacturing industry.

Generally, 87.5 percent (7) of all the industries using the gas are large sized companies, with only 12.5 percent (1) being small sized companies. Within the large sized industries, 65 percent of the respondents were not using the gas, while the remaining 35 percent were using the gas. None of the medium sized industries were using the gas. However, one representing 12.5 percent of the small sized industries were identified as using the gas. The distribution is as shown in the table 7.0

**Table 7: Distribution of LP Gas Consumers according to Size of industries**

Size of Industries	Users of LPG		
	Non-LPG Users (%)	LPG Users (%)	Total (%)
Large Sized Companies	35.1	87.5	44.4
Medium Sized companies	40.5		33.3
Small Sized Companies	24.3	12.5	22.2
<b>Total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

Source: Authors' Field Survey- November 2006

Pearson chi-square ( $X^2=7.715$ ,  $df=2$ ,  $p=0.021$ ) shows that size of industry and use of the gas are dependent of each other. Industrial consumers, i.e. manufacturing plants, require bulk tank installations and vaporizers to meet higher delivery rates and consumption. Bulk tank installations come as a more practical option than installing a huge number of commercial cylinders, especially when storage space and area is a major consideration for the consumer. For bulk installation, LPG is delivered to the consumer in bulk by tank trucks. Initial costs of these bulk installations and vaporizers are very high and thus have prevented many medium and small sized industries from the use of the gas, which is stored in the bulk tank. Also, large areas are required for setting up of the bulk tanks; hence, industries with relatively small compounds have found it inconvenient.

**Table 8: Location of Industries that use LPG**

LPG Usage	Location of Industries			
	LIA (%)	HIA (%)	Outside (%)	Total
Non-LPG Users	32.4	45.9	21.6	100.0
LPG Users		100.0		100.0
Total	26.7	55.6	17.8	100.0

Source: Authors' Field Survey- November 2006

From table 8.0, all the industries that use gas are in the heavy industrial area. A chi-square test ( $X^2=7.784$ ,  $df=2$ ,  $p=.02$ ) shows that the likelihood of using the gas declines with distance. This is an indication that the differences in use or non-use of LPG are not due to chance variation, which implies that industries that use LPG or do not use LPG and location of these industries are interdependent. It is well known that LPG has no transportation limitations. That is, LPG can be readily transported by tankers without the need to uneconomically extend pipelines to new geographical regions at an additional cost to the tax payer. Unfortunately, due to transportation costs, customers farthest from the major supply sources were identified not to be using the gas since it adds additional cost to their production cost, hence reducing their profit margin. All the industries that use the gas are sited near Tema Oil Refinery, the production site. This reduces the cost of transportation.

### Environmental Considerations

This section takes a look at CO<sub>2</sub> as emission being generated as a result of energy used in the United Kingdom. In the UK Government's Standard Assessment Procedure (SAP) for Energy Rating for Dwellings (2005), the following information is given.

**Table 9: Alternative fuels CO<sub>2</sub> Emissions**

Fuel	Emissions Kg CO <sub>2</sub> per KWh
LPG	0.234
Oil	0.265
Smokeless Solid Fuel	0.392
Electricity	0.422

Source: UK Government's Assessment Procedure (SAP) for Energy Rating for Dwellings (2005)

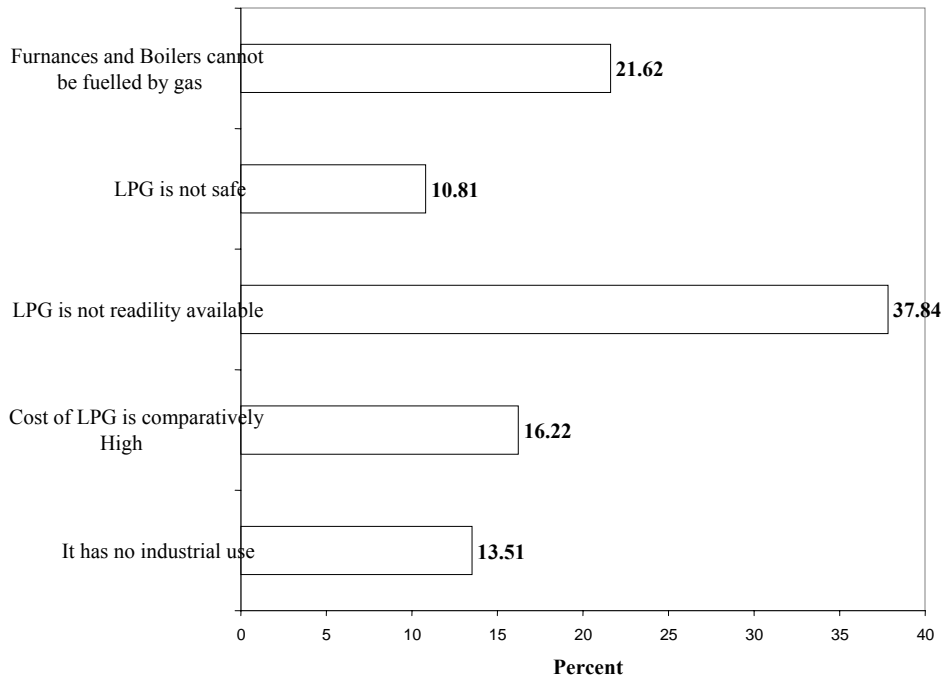
Emissions from energy production and consumption play a major role in air pollution. From table 9.0, it can be shown that the contribution of LPG to global greenhouse gas emission is relatively small. It can be calculated that these fuels emit more CO<sub>2</sub> than LPG; as follows: oil emits 13.2 percent more CO<sub>2</sub> than LPG, smokeless solid fuel emits 67 percent more CO<sub>2</sub> than LPG, and electricity emits 80 percent more CO<sub>2</sub> than LPG.

Though the figures shown are that of the United Kingdom, distances that pollutant gases travel means that pollution is an international problem. Because energy use patterns translate into greenhouse gas emissions, the industrial sector stands as one of the country's environmental culprits. Hence, greater LPG use means projected reduction in carbon dioxide emissions. It is becoming clear that efforts to reduce Green House Gas (GHG) emissions must increase conversion to lower-carbon energy sources.

### Reasons for Non-Utilization of LPG

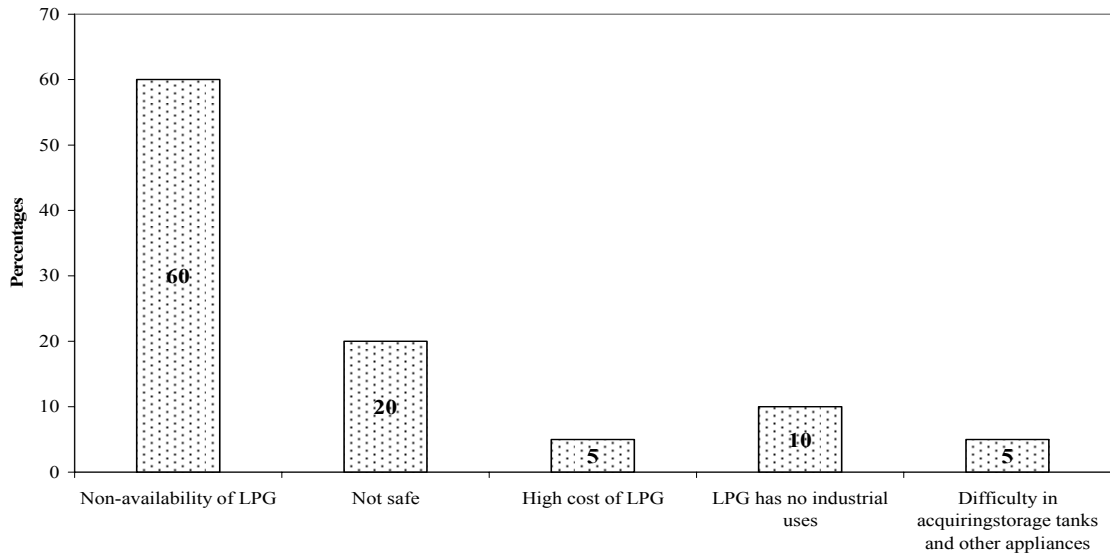
LPG has demonstrated health and environmental benefits compared to other conventional fuels, but the rationales for using LPG-fired units have met serious challenges, especially in the industrial sector. Respondents outlined some of the reasons for none-use of the gas as unavailability of the gas, inability of their furnaces and boilers to be fuelled by the gas, comparatively high cost of the gas, and the fear of the gas catching fire (safety issues). The distribution is as shown in figure 2a:

**Figure 2a: Reasons for non-use of LPG**



Source: Authors' Field Survey-November, 2006

**Figure 2b: OMCs Perspectives On Critical Problems In Using LPG As Industrial Fuel**



Source: Authors' Field Survey-November, 2006

### **Lack of awareness of its applications**

One obstacle to the widespread utilization of LPG in the industrial sector is that most people are unaware of its applications in this sector. Evidence from the study suggests that as much as 13.57 percent of manufacturers were unaware of the industrial applications of the LPG. 10 percent of the Oil Marketing Companies (OMCs) were also unaware of the industrial applications of LPG. Liquefied Petroleum Gas is perceived as fuel for cooking. Even amongst decision-makers, there is lack of awareness of the benefits to the manufacturer and technologies of installation of bulk tanks. Thus, industrial consumption of the LPG in this sector is unheard of to many of the interviewees and this severely limits its utilization in this sector.

Some studies have revealed that knowledge about energy issues plays a central role in influencing attitudes to energy technologies. A London survey on micro generation technologies showed how the lack of knowledge about costs prevented people from considering the installation of micro generation technologies in their dwellings. As argued by Shackley, McLachlan, & Gough, 2004 who, in particular, referred to carbon storage and sequestration technology, major difficulties arise when presenting technical issues, which are remote from people's everyday experience and for which people have no immediate reference point.

While such problems do arise with any new technology or industry, this problem, coupled with unwillingness of policymakers to acknowledge this fuel, is not just for the household. It deters many potential users from considering the use of LPG as industrial fuel.

### **Safety Concerns**

Another obstacle to gas use is safety, or at least the perception that people have towards the safety of working with the gas. The respondents' knowledge of LPG is poor as demonstrated by perceptions of safety. 20 percent and 10.8 percent of OMCs and manufacturers respectively were of the opinion that LPG is not safe for industrial applications. These perceptions are contributing to public opposition to industrial usage of LPG and jeopardizing the ability to increase consumption in this sector.

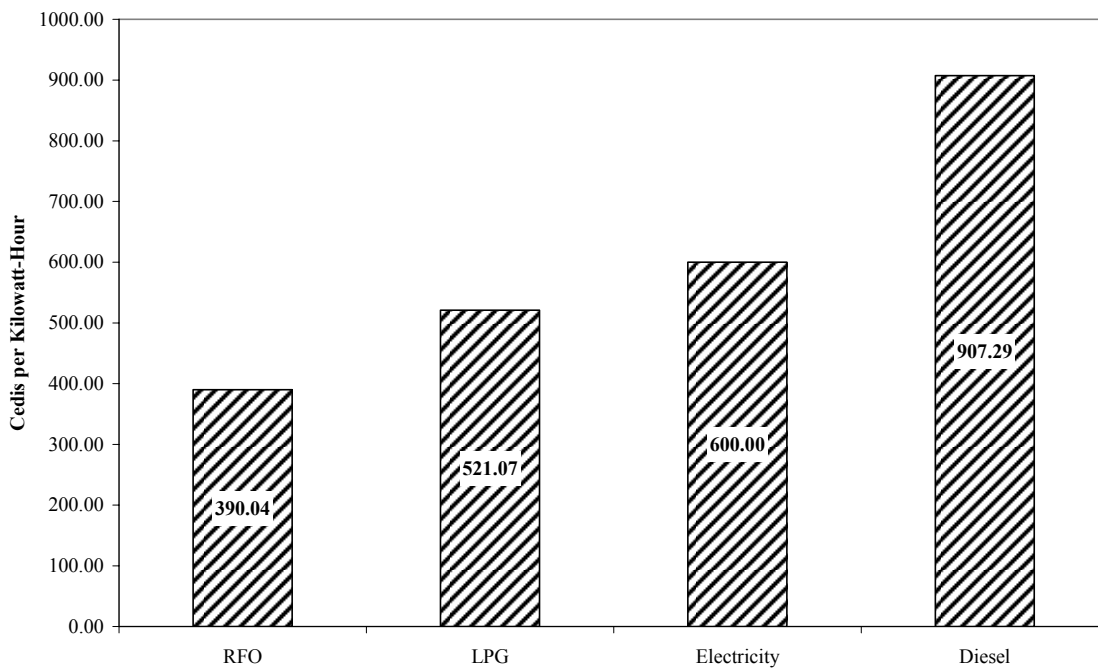
Analysis reveals three main hazards with different degrees of restrictions. For instance, pure LPG is odorless and invisible, distinctive odor is usually added to warn of its presence. Escape of LPG may be noticeable by smell. In one case, when the liquid evaporates, the cooling effect on the surrounding air causes condensation and even freezing of water vapor in the air. This effect may show itself as frost at the point of escape and, thus, make it easier to detect an escape of LPG.

Ninety percent of the OMCs interviewed indicated that no major accidents have occurred at their workplace as a result of the LPG. However, 10 percent have experienced fire outbreak from the leakage of the gas. Some interviewees outlined some precautions in place that are applied to common hazards as the presence of fire extinguishers or protection equipment at the workplace, routine checks on appliances, safe storage of the gas in bulks, and cylinders.

Gathering information from the suppliers or OMCs, some safety systems and procedures put in place include daily inspection of terminals, regular checks of tankers to ensure vehicles, and LPG systems are working correctly, regular site inspection and operation of the automatic shutdown, and alarm to emergency services, training of drivers and employees on safety and operation. Studies reveal that even though these accidents were unlikely to occur, the probability of occurrence increases during the transfer of the product; this, therefore, means that trained and competent personnel should be present during this transfer for prompt action in emergency situations. Also, visitors and employees have been advised not to smoke or use matches or lighters at the workplace; a measure referred to by all respondents.

LPG can be dangerous if not correctly installed, maintained, and used. If these three factors are properly attended to then it is a safe, clean, and efficient energy service. “LPG is a very safe fuel. But as with any energy source, there are steps to take to further ensure safety” (WLPGA, undated).

**Figure 3: Cost per Kilowatt-Hour of Various Energy Sources**

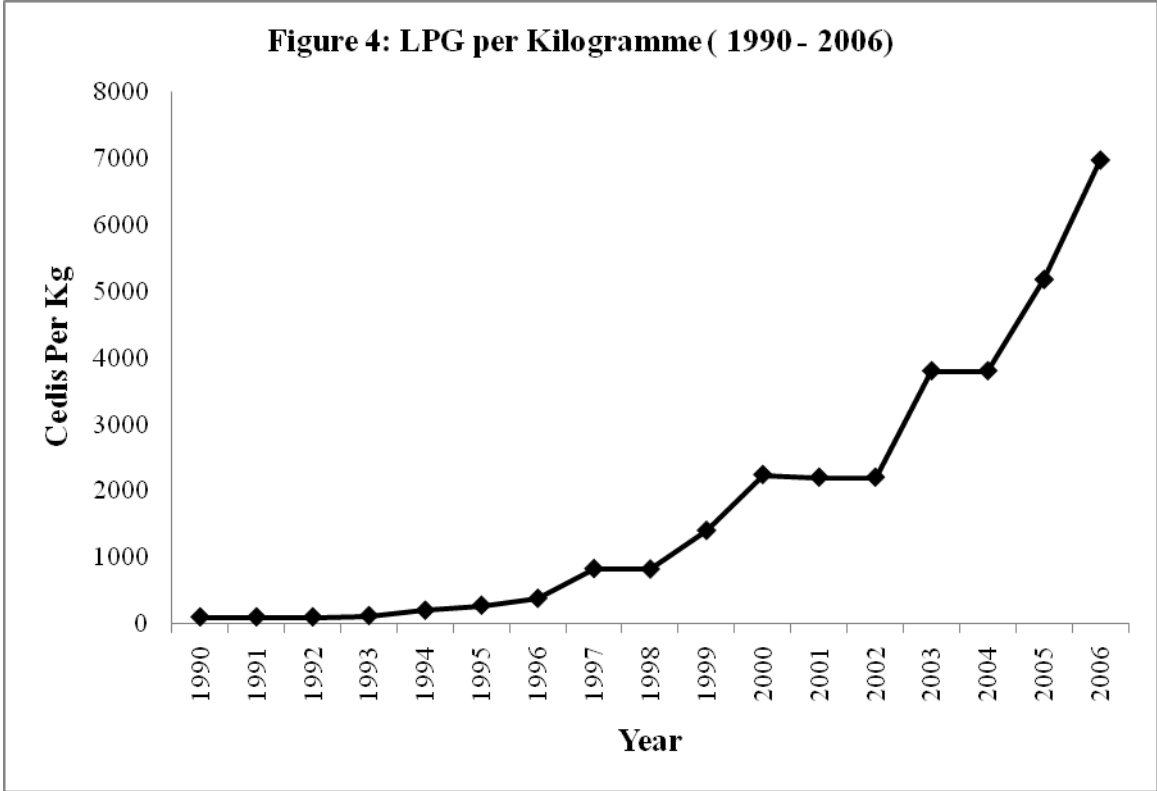


Source: Authors’ Field Survey-May, 2007

Assuming all the energy resources are used to generate electricity in the manufacturing industries, the cost of the unit cost of the various energy sources used by the manufacturer is shown in figure 3. The most expensive fuel used by the industries is diesel (907.29 cedi per kilowatt-hour). This is then followed by hydroelectricity (600.00 cedis per kilowatt-hour), LPG (521.07 cedi per kilowatt-hour), and RFO, which is 390.04 (cedi per kilowatt-hour). From the graph, diesel is almost twice the price of the gas. Also, electricity appears to be more expensive than the gas. Despite the cost advantage of LPG over electricity and diesel, studies showed that the preference for the diesel (28.89 percent) and electricity (17.78 percent) exceeds

that of the gas (6.67 percent). The question, then, is if cost is to influence the behavior of the manufacturers, why, then, will they choose hydro electricity and diesel over LPG?

However, such direct cost comparisons ignore the issue of price volatility. LPG is subject to international price trends, which fluctuate on a monthly basis, but overall have been trending upwards as shown in figure 4.



Source: Authors' Field Survey – May, 2007 (estimated LPG Prices as at December of each year)

The price of LPG changed over four times within 2006 alone. Within this period, LPG price increased over 36 percent, with the highest price of 7586 cedi occurring in June, 2006. However, the price dipped by about 8 percent to its current price of 6965.52 cedi as of September 2006. Thus, there is high price volatility with respect to the gas. This price volatility results in uncertainty about the gas price levels that influence investment planning. Uncertainty is the enemy of planned, rational, and forward looking investment in any industry. Firms make investment decisions based on expectations about prices. If decisions are made on the expectation of low (or high) energy prices, and the energy market varies sharply from these expectations, firms may make inappropriate investments and business decisions. This uncertainty has a number of potential implications for firms. For example, it might cause them to invest in different types of equipment than they might otherwise (Henning, Sloan, & De Leon, 2003). Even those firms that expect volatility may be adversely affected by simply putting off a decision until the market is more stable.

This contrasts with electricity, generated domestically from hydro power and, hence, is widely regulated. Consumers can, thus, be confident that electricity prices will remain stable and increase, if at all, in a predictable and modest way. For electricity, the key point is one of stability: electricity prices are largely unchanged over a long period, partially due to it being highly domestically generated and hence, regulated. In these circumstances, it is unsurprising if these price movements have given rise to consumers', dissatisfaction with the price of LPG they purchase. It is, therefore, a significant omission to seek to interpret levels of consumer dissatisfaction with the cost of LPG alone, without taking account of the context of prices volatility.

The high cost and high volatility of LPG prices has been a great concern for some industrial consumers (6.22 percent). Lower profitability, due to high gas prices, might force some industrial units to burn other fuels, such as fuel oil. Higher prices in gas usually cut down industrial usage, especially when fuel cost forms a larger percentage of production cost. Essentially, if prices go high enough, a significant portion of the industrial usage (the most price-sensitive class) will be driven out of the market.

The end product of volatile and soaring energy prices will be inflationary pressures that continue to challenge the country's business as they struggle to the new economic conditions. The rising prices for LPG will result in an increase in input costs for many businesses, both large and small. Since energy is a key input in the production process, businesses face sharp increases per unit in their goods and services (Velázquez, 2006). Establishments' revenues are likely to be impacted in the face of high gas prices. They must shift more of their revenues to cover expenses. This action will decrease their profitability, result in job losses, and reduce the competitiveness of their industries. Facing an increasingly unequal playing field, the extreme volatility of LPG prices will only create larger financial burdens.

Another aspect of the problems of LPG relative to other fuels is that manufacturers must maintain large storage tanks. This can prove to be an added expense beyond the price of the fuel. Appliance installation costs will also have an effect on the total costs. Consumers, when purchasing an appliance, will often put upfront purchasing and installation costs ahead of ongoing running costs in their decision making, and this may be particularly so for small sized industries. This has implications for energy affordability impacting on production cost due to higher running costs resulting from either choice of fuel, and/or efficiency of the appliance. Examination of fuel-switching capability of natural gas in 2002 by value of shipments categories and employment size show that the ability to switch increases on average from smaller to larger establishments. Thus, fuel switching capability out of natural gas seems to correlate with size, regardless of industry. This is in consistent with the results of the study where almost all the industries that were found to be using the LPG were large-sized companies.

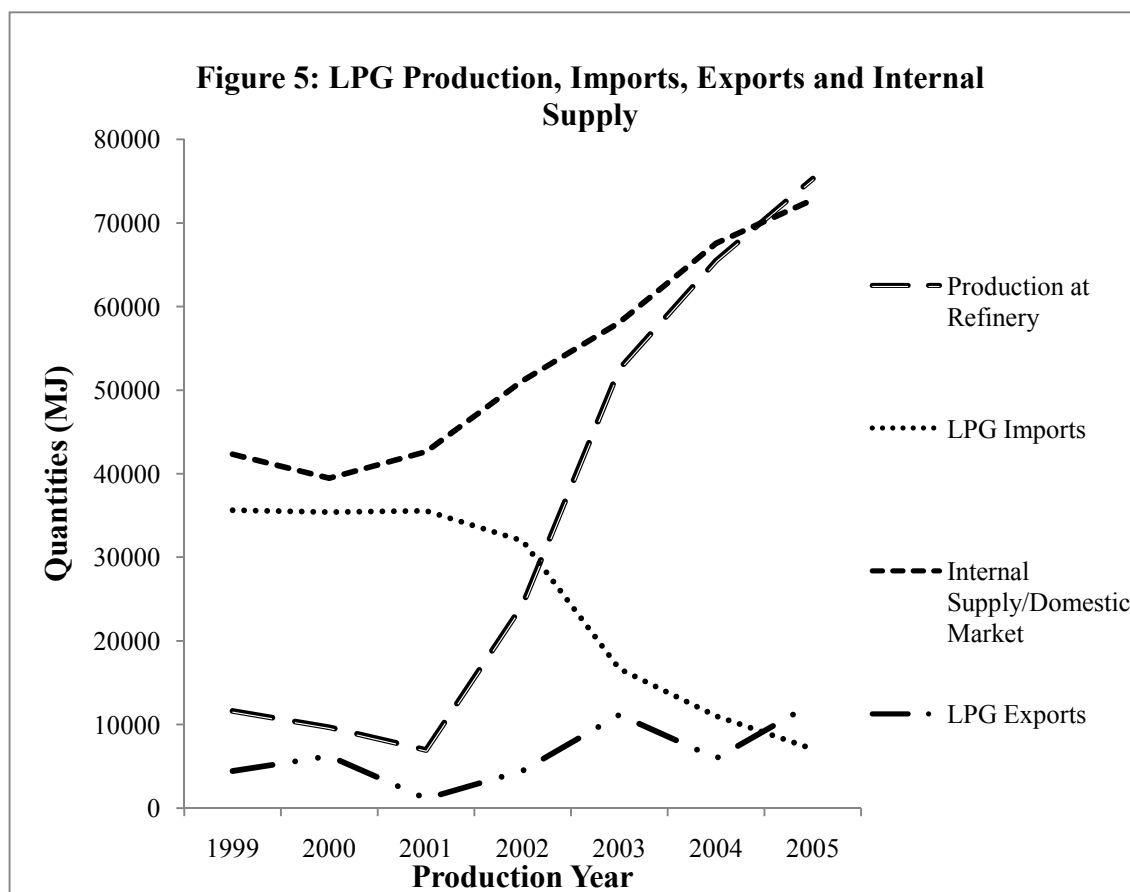
### **Availability of LP Gas**

37.84 percent of manufacturers attributed their inability or unwillingness to use the gas to unavailability of the fuel or uncertainty in the supply of the gas. This fear was confirmed by the OMCs where as much as 60 percent of them identified the availability of the fuel as a major problem to its use in this sector. This confirms Africa Gas Initiative Report that LPG



demand, in most Africa countries, is driven by supply constraints. This is because the refinery, which is the only source for domestic supply production, is limited by the refinery's size and LPG production from the refinery has proved largely insufficient to meet growing demand and has more often than not been complemented by imports through inadequate, costly transported and storage facilities.

From 2003 to 2005, production of LPG from the refinery has more than doubled 2002 production figures, with imports reduced to about only a quarter of 2002 figures. The rise in plant output is also attributed to the installation of the Residual Fluid Catalytic Cracking Unit (RFCC) plant. With the RFCC in place, TOR is able to extract more value-added products, like LPG. It is observed that the yearly consumption of LPG has increased significantly from levels of 42,363 metric tons in 1999, to 72,768 metric tons in 2005. Demand is, therefore, seen to have almost doubled over this period. As illustrated in figure 4.5, total domestic sales of LPG have increased by 84.33 percent comparing 2000 and 2005 figures. The domestic demand of LPG is met by both import and plant production from the refinery of crude oil at TOR. From figure 4.5, import of LPG is seen to have played a key role in meeting domestic demand at the initial stage of introduction of the gas into the country. Between 1999 and 2002, imports of LPG were greater than plant production (production at the refinery). Until 2002, over 70 percent of LPG used in the country was imported. This means more of the country's foreign exchange was spent on the imports of the LPG. The reduction in imports of LPG from 2002 onwards was due to the installation of the RFCC, which adds value to the otherwise low Straight Run Fuel Oil (SRFO). The high import dependence poses a severe burden on the country's foreign exchange earnings and a concern for security of energy supply.



Source: Authors' Field Survey (Prepared on the Basis of TOR Energy Balances (1999 – 2005))

There is inadequate refining capacity in the country to meet the national LPG requirement, as shown in the Figure 4.5 where import has supplemented internal demand. Generally, LPG supply to households is characterized by frequent shortages and long queues in retail outlets. The inability of the capacity of the refinery to meet consumption requirements constitutes a major constraint to the supply of LPG and poses problem of assuring reliability of supply of LPG to industrial consumers, in particular, and the national consumption, as a whole.

The inadequacy of existing bulk storage infrastructure to meet the growth in demand reduces the possibilities to bring the product close to industrial consumers. Current limited storage capacity at the refinery continues to constrain local consumption as well as export. Clearly, if LPG is to be a practical option, then there must be an adequate network of supply depots so that industry operators can be confident that they will have ready access to refuel without significant inconvenience to their operations.

Shift of the industrial consumers to the use of the LPG will result in increasing imbalance between LPG consumption and domestic production, which will result in growing importation of the LPG. The dependence on fossil fuels has created a wide

variety of problems for non-oil producing developing countries, as well as for some industrialized countries and economies in transition (Reddy, Williams, Johansson, 1997). However, because LPG is derived from petroleum refining, utilization by industries will do little to diminish our dependence on these fuels.

**Technical Considerations of Furnaces and Boilers**

Interviews with industrialists illustrated that while prices, supply certainties, and environmental issues were important motivators of behavior change, design of furnaces and boilers is what ultimately facilitated or prevented participation in the use of gas. 21.62 percent of respondents attributed their inability to use the gas to the design of their furnaces and boilers. In industries, existing energy-intensive equipment, such as furnaces, kilns, and boilers, have long lifelines and require substantial amounts of capital to replace, which slows the rate of investment in more energy-efficient technologies. Consistent with the observations of IFC (2007), if firms have made a substantial investment in equipment that has a long service life, they are likely to continue using such equipment until the end of its useful life before replacing it with a more energy-efficient technology. Such barriers are exacerbated when industry production is already at risk due to global competition and other economic conditions. This is the case for many industries addressed in this study.

An examination of the relationship between the use or non use of LPG and constraints identified yielded results as indicated in Table 10.0:

**Table 10: Examination of constraints identified by industries to the utilization of LPG**

LPG Usage	Major Constraints to LPG Use in the manufacturing Subsectors			
	Non-availability (%)	High rises in prices (%)	Conversion of Furnaces & Boilers to gas fuelled (%)	Total (%)
Non-LPG Users	59.5	10.8	29.7	100.0
LPG Users	62.5		37.5	100.0
<b>Total</b>	<b>60.0</b>	<b>8.9</b>	<b>31.1</b>	<b>100.0</b>

Source: Authors’ Field Survey- November 2006

When industries were grouped into non-users and users, the highest number of respondents in both groups identified unavailability of the fuel as a major constraint (59.5 and 62.5 percent, respectively). Non-availability of LPG appears to be the most critical constraint faced by both groups. 37.5 percent of users and 29.7 percent of the non-users mentioned the conversion of their furnaces and boilers as a major constraint. Comparatively, high prices of LPG appear to be the least constraint mentioned by both groups. However, none of the gas users saw the price of the fuel as a major constraint. In the case of the non-LPG users, 10.8 percent saw the price of the fuel as a major constraint. The asymptotic significance of the chi-square statistics is far greater than 0.05. This is an indication that the differences in the use or non-use of LPG are due to chance variation. Thus, an industry that uses LPG or does not use LPG faces the same constraints when it comes to the gas utilization. There is no relationship between the consumption of LPG and constraints of LPG use.

A chi-square test was used to test if the location of an industry, size of an industry, type of manufacturing sub-sector, or the applications of the fuel has any effect on the constraints identified. They gave all  $p > 0.05$ , with the exception of the size industries which have a p-value of 0.023. Thus, constraints identified correlated with size, regardless of industry and location of the industries. The distribution is shown in table 11.0.

Gas use requires larger investments. This has deterred some industries, mostly small and medium sized industries, and has made them opt for easier, smaller investments projects using electricity and oil. This helps to explain why most small industries were not using the gas.

**Table 11: Relationship between size of Manufacturing Industries and major constraints identified**

Major Constraints identified	Size of Manufacturing Industries			
	Large Sized	Medium Sized	Small Sized	Total
Non-availability	55.6	18.5	25.9	100.0
High rises in LPG prices		100.0		100.0
Conversion of furnaces & boilers to gas fuelled appliances	35.7	42.9	21.4	100.0
<b>TOTAL</b>	<b>44.4</b>	<b>33.3</b>	<b>22.2</b>	<b>100.0</b>

Source: Authors’ Field Survey- November 2006

Majority of industries (55.6 percent) who attributed their inability to use the gas to the unavailability of the fuel were large-sized companies. Price hikes were of least concern to these large sized industries. Interestingly, none of the small-sized industries attributed their inability to use the gas to price hikes. Rather they attributed it to unavailability of the gas and the design of their equipment. Greater portion of the respondents who identified the design of their boilers and furnaces as constraint were medium-sized companies.

**Policy Considerations**

The main driving force for the introduction of LPG into the Ghanaian economy was the concern for the household sector, which were solely dependent on biomass (firewood, charcoal, and crop residue). The potential in the market share of LPG, which was, by then, flared at the refinery, would not be limited by supply. Thus, the potential of LPG for improving the security of energy supply and reducing greenhouse gas emissions was evident under the same conditions as other recognized alternative fuels. Promoting gas consumption for industrial use was not a priority for the government at the time. Much of government policies had placed emphasis on domestic or residential consumption of the fuel to the neglect of the other sectors, most especially the industrial sector. Thus, agencies responsible for formulating, coordinating, implementation, and monitoring energy policies have focused solely on residential use of LPG. Thus, until recently, LPG has only been perceived by many as being only good for the household.

Government may well have their constraints on implementing a stricter policy for LPG as household fuel. Understandably, the government was faced with supply constraints. LPG produced at the refinery could only meet the needs of the household sector. Extending its use beyond this sector will mean increased importation of crude oil and its subsequent adverse effect on the economy. In addition, LPG being imported into the country was, until recently, highly subsidized. A rise in oil prices poses a heavy financial burden on the government, thus, increased importation in the face of subsidization would limit the opportunities of public spending and divert funds away from infrastructure development and poverty reduction projects.

### **Linkage between LP Gas users and potential Natural Gas users**

Apparently, there is a strong relationship ( $X^2 = 11.32$ ,  $df=1$ ,  $p < .01$ ) between LPG consumers and potential natural gas users. Of the 37 establishments identified not to be using the LPG at the moment, 35 indicated they do not intend to be users of the natural gas a year after it comes into operation. The remaining two indicated their willingness to use the natural gas a year after it comes into operation. In the case of those using LPG at the moment, the number broke even with 4 indicating their readiness to use the natural gas a year after it comes into operation, with the other four stating that they are not yet ready to use the natural gas. Respondents were further asked about the use of the gas five years after it comes into operation. Result shows that 97.7 percent of the respondents saw themselves as users of the natural gas in the next five years.

The combustion processes that use LPG are very similar to those that use natural gas. Use of LPG in industrial applications may require a vaporizer to provide the burner with the proper mix of air and fuel. LPG is fired as a primary and backup fuel in industrial boilers and space heating equipment and can be used to generate heat and process steam for industrial facilities and in appliances that typically use natural gas. LPG has been used as a precursor in new areas, allowing market development at a lower risk or cost. When natural gas becomes available through the establishment of local distribution networks as the economy matures, LPG is usually displaced. LPG is an option in regions of declining natural gas supply (UNECE, 2004).

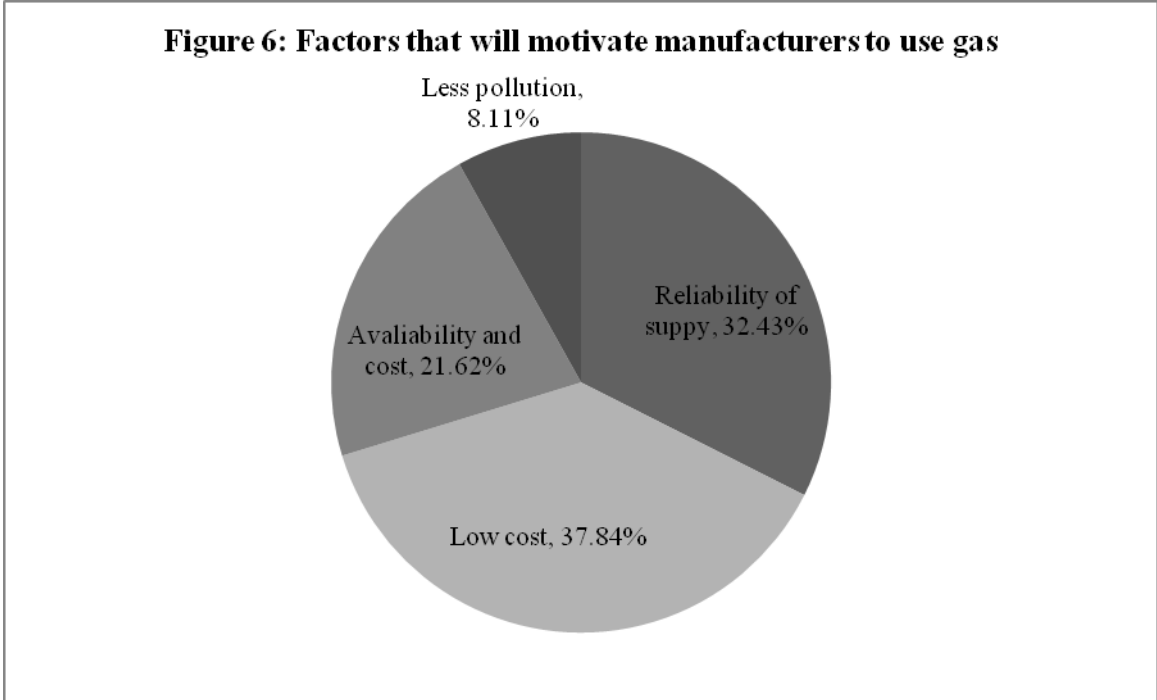
### **Manufacturers' priorities on energy options**

Knowing factors that affect consumer decisions on energy-related purchases and lifestyle behaviors can increase the accuracy of market-penetration estimates and aid in modeling the potential for energy technologies. And whether the nations' energy institutions are linked in the public mind with environmental problems is important information for policy makers seeking to make decisions that accurately reflect the public will (Farhar, 1993).

The research also attempted to investigate priorities on energy options. Respondents outlined a variety of factors that will motivate their choice of gas as fuel for production. Of key importance were gas prices, followed by reliability of fuel supply, and then environmental concerns. 37.8 percent of the establishments will chose to use gas if the price is comparatively less expensive and 32.4 percent will use the gas if supply becomes reliable. Energy investments can be very risky, as such investors prefer places where the uncertainties are minimized (RCEER, 2006). Both energy and non-energy intensive firms make investment decisions based on expectations about prices. Rising energy costs and greater volatility in energy prices can have a negative effect on industries. Hence, it is not surprising most of the industries identified the price of the gas as major

factor to the deployment of the gas. 21.6 percent answered that they will use the gas and take into consideration its reliability of supply and advantageous price.

However, 8.1 percent stated that they will choose to use the gas because of its environmental benefits. Environmental concern among respondents is relatively small. Apparently, it is not one of the topmost concerns. The most important concerns are the cost of the gas, followed by the availability of the gas. The proportion favoring environmental protection over adequate gas supplies and cost of the gas is 8.7 percent. 21.6 percent of respondents believe that adequate supply and lower prices go together. Despite recent high concern for the environment, majority of manufacturers value high costs of the gas (37.8 percent) and reliability of gas supply (32.4 percent) over efforts to conserve the environment. Support for low gas prices and adequate gas supply shows that manufacturers place less emphasis on protecting the environment.



Source: Authors' Field Survey – November, 2006

**Table 12: Cross tabulation of Main Fuels other than Gas and Factors that will motivate manufacturers to use Gas**

Factors that will motivate manufacturers to use Gas	Main Energy Used by Manufacturers			
	Diesel	RFO	Electricity	Total
Reliability of Supply	7	4	1	12
Lower Cost	3	10	1	14
Availability & Cost	0	3	5	8
Less Pollution	0	3	0	3
<b>TOTAL</b>	<b>10</b>	<b>20</b>	<b>7</b>	<b>37</b>

Source: Authors' Field Survey- November 2006

Reducing the cost of energy required to run their business was the primary motivator of behavioral change regarding energy use for interview respondents. Conservation and environmental protection were considerations in decisions about energy use for a few respondents. Interestingly, those who spoke more forcefully about environmental impacts, use RFO as their best available option, despite their misgivings about emissions and fuel consumption. Several respondents are now using RFO in their regular day-to-day operations. While cost is the primary motivator, a few respondents related that the implications of RFO use are more complex than simple economic savings.

## CONCLUSIONS AND RECOMMENDATIONS

Problems of LPG utilization are not confined to just one constraint, although the mixture of constraints that firms face varies from one industry to another. Some of the major factors hindering LPG use in the country are low level of awareness, supply constraints, cost of initial installation, volatile LPG prices, insufficient policy, and institutional framework.

There are gains to be made in the industrial utilization of LPG. Some of the potential benefits include: that LPG can be stored, transported, and used virtually anywhere in the country, it does not require gridlines; LPG burns cleanly without smoke or residual particulate matter, thus avoiding the serious health hazards other fuel might cause to the health of the workers. Manufacturing plants running on LPG produces much less carbon dioxide than the other conventional fuels. The use of LPG would improve the country's energy mix and minimize its dependence on RFO and other polluting fuels.

What is not clear is whether environmental and safety benefits, alone, give the manufacturer enough incentive to use LPG. Government support for the use of the LPG as should be based on the beneficial environmental impact of LPG, as compared to alternative fuels.

## **Recommendations**

It is recommended that the attention should be focused on the following:

### **Short Term**

- **Encourage Scientific Research on Industrial Energy Consumption**

This study is the first attempt to provide reliable and meaningful information on why there is almost insignificant penetration of LPG use in the industrial sector and the potential benefits to be derived from its consumption in this sector. These studies need to be followed by more work, as further improvements are possible. The methodology used here, which is constrained by sample size and data limitations, can be improved.

The government should support scientific research in the field of LPG utilization in the other sectors of the economy, making results available to the public through the various communication channels. It is recommended that cost-benefit analysis, regarding the use of LPG in industry, be conducted.

- **Awareness Creation**

This study has brought to bear the limited knowledge of the industrial applications among Ghanaian consumers. Educational campaigns should be carried out to ensure people become aware of the industrial applications of LPG and also to ensure that environmental, health, and safety regulations are observed. The environmental benefits of LPG should be highlighted through awareness creation. Perceptions about safety remain a deterrent to many consumers. Perceptions based on misinformation needs to be corrected. It is recommended that where LPG is deployed, safety training is particularly important. The government should work in partnership with OMCs and publish information on the safety of LPG. They should allocate funds to develop awareness campaigns in the field of cleaner fuels, in general, and LPG, in particular.

- **Encourage Diversity in Energy Sources**

Fuel diversity is the key to stable energy prices and long-run energy affordability. It is important, therefore, to promote diversity as a long term safeguard against over dependence on any particular energy source. LPG use, in the industrial sector, should be promoted in parallel with natural gas to complement conventional sources and other renewable energy.

### **Medium Term**

- **Revision of Policy**

Another obstacle to the wider use of LPG is that the energy policy rarely recognizes its advantages, reinforcing the view of LPG as a household fuel. It is recommended that the significant role that LPG can play, and should play, in meeting the country's energy needs be recognized. The government could take steps, ranging from national energy policy statement to legislative measures, to extend its use beyond the household. The policy should allow fuels with distinct advantages to compete fairly with other energy sources in order for their benefits to be fully realized.



- **Creation of conducive investment climate**

Another factor affecting gas utilization is capital availability to efficiently build infrastructure. This challenge can be met by promoting foreign investments. The government could encourage utilization of the gas in the industrial sector through policies and strategies that would make it more accessible in the market. Policy makers are urged to pay special considerations to policy measures that improve investments climate through favorable legal and regulatory reforms.

Private sector involvement is essential to mobilize resources for the development of the LPG industry and more importantly, alleviate the budgetary burden on the state. It is important that the government device policy measures provide institutional and other support services to enhance the capacity and capability of the private sector, thereby promoting confidence for the private sector or OMCs to invest in physical infrastructure (storage tanks, transportation, and distribution equipments).

- **Infrastructure Development**

Another important reason for the underutilization of LPG is its availability. The refinery capacity of the country should be increased. Limited capacity of the refinery has led to frequent shortages. There should be new investments in the refinery capacity, either through expansions at existing sites or through construction of new facilities. Additional storage will help insulate consumers from economic effects of volatile prices and from temporary supply disruptions.

Industrial consumers should pre-buy LPG at a certain agreed prices and store it. Such price stabilization programs (advanced purchase and fixed price contracts) will help mitigate the impact of price volatility. Admittedly, they may pay higher or lower prices compared to those who buy the LPG at the market price, but would not be subject to price volatility. They would achieve a benefit from the certainty associated with paying a fixed price. Given the clear benefits of enhanced fuel storage, interest groups (governments, retailers, industries, etc.) should invest in additional storage facilities.

### **Long Term**

- **Regional cooperation and integration in the Energy sector**

African energy policymakers and decision makers should set up joint projects in the fields of producing and refining crude oil and natural gas, with the view to create an integrated oil and gas industry in Africa. The uneven distribution of energy resources, the small-size of energy markets, and the difficulties for an individual country to mobilize the huge capital investment required for infrastructure is a major constraint to the optimal development of gas projects. Regional cooperation and integration can help in a cost-effective way to enhance the feasibility of large energy projects through realizing economies of scale.

Potential growing energy demands and the necessity for regional oil producers to utilize natural gas resources have resulted in the development of cross-border pipelines in Africa. A notable example is the construction of the West Africa Gas Pipeline Project. But this needs to be made operational in order for them to achieve the objectives for which they have been created. African countries should promote the exploration of oil. Also, the government should put in place measures to improve the efficiency of public transport, especially reducing the number of over aged vehicles and encouraging the use of energy-efficient ones.

## REFERENCES

- Asante, Kofi (ed.). (2004). *Energy Review: Official Journal of the Ghana Energy Commission*. Accra; Energy Commission.
- Boyle, Grant (2005) *An Overview of Alternative Fuels in Developing Countries: Drivers, Status and Factors behind the Successful Markets*. A Power Point Presentation at the United Nations University, Tokyo. Retrieved from: [http://www.intech.unu.edu/events/workshops/hfc05/boyle\\_ppt.pdf](http://www.intech.unu.edu/events/workshops/hfc05/boyle_ppt.pdf), on November 1, 2006
- CEPA. (2007). Ghana Selected Economic Issues: Current State of the Ghanaian Economy. No.14. 17-19.
- Commonwealth of Australia. (2001). Power for the People: Renewable Energy in Developing Countries. A summary of Discussion at the Renewable Energy Forum. Retrieved from: [www.ais.gov.au/publications/pdf/renewable\\_energy.pdf](http://www.ais.gov.au/publications/pdf/renewable_energy.pdf), on September 6, 2006
- David, M. & Sutton, C.D. (2004). *Social Research: The Basics*. London: Sage Publications.
- Energy Information Administration, Office of Integrated Analysis and Forecasting. (2006). *International Energy Outlook*. Available at: [ftp://ftp.eia.doe.gov/pub/pdf/international/0484\(2004\).pdf](ftp://ftp.eia.doe.gov/pub/pdf/international/0484(2004).pdf)
- ESMAP. (2001). *Africa Gas Initiative, Main Report. Volume I*. Washington, D.C.: World Bank.
- ESMAP. (2005). *The Impact of Higher Oil Prices on Low Income Countries and on the Poor*. Washington, D.C.: The International Bank for Reconstruction and Development/The World Bank.
- Farhar, Barbara C. (1993) *Trends in Public Perceptions and Preferences on Energy and Environmental Policy: Executive Summary*. NREL/TP-461-4857a. Golden, CO: National Renewable Energy Laboratory, March. Available through the National Technical Information Service, Springfield, VA <http://www.eren.doe.gov/greenpower/library.shtml#research>
- Ghana Statistical Service. (2001). *Core Welfare Indicators Questionnaire report. Regional Profiles and CD Rom*. Statistical Service, Accra.
- Ghauri, P. & Grønhaug, K. (2002). *Research Methods in Business Studies: A Practical Guide (2<sup>nd</sup> Edition)*. England: Pearson Education Limited.
- Henning, B., Sloan, M., & De Leon, M. (2003). *Natural Gas and Energy Price Volatility*. Arlington, Virginia: Energy and Environment Analysis Inc. Retrieved from: [files.harc.edu/Sites/GulfCoastCHP/Publications/NaturalGasEnergyPriceVolatility.pdf](http://files.harc.edu/Sites/GulfCoastCHP/Publications/NaturalGasEnergyPriceVolatility.pdf), on 11 June, 2007.
- ICF. (2007). *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*. Prepared for United State Environmental Protection Agency. Retrieved from: [www.epa.gov/sectors/energy/index.html](http://www.epa.gov/sectors/energy/index.html) - 16k, on 8 June, 2007.
- ILPGA. (2001). *How Condensing Boilers and Automotive LPG can help the Environment: Budget Submission and Supporting Data*. Retrieved from: <http://www.ilpga.ie/public/CondensingBoilersAndAutomotiveLPG.pdf>, on 22 February, 2007
- ISSER. (2004). *The State of the Ghanaian Economy in 2003*. Accra, University of Ghana.
- Quaye-Foli, E.A. (2002). *Liquefied Petroleum Gas (LPG) Promotion: the Ghanaian experience*, A Presentation at UNDP/World Bank-Energy and Poverty Workshop. Addis Ababa, Ethiopia (October, 2002).
- RCEER. (2006). *Guide to Natural Gas in Ghana (1<sup>st</sup> Edition)*. 43.

- Reddy, A. K. N., Williams R. H., & Johansson T. B. (1997). *Energy after Rio, prospects and challenges*. New York: United Nations Publications
- Rubin, A. & Babbie, E. (2001). *Research Methods for Social Work* (4<sup>th</sup> Edition). Belmont, USA: Wadsworth.
- Shackley, S., McLachlan, C., & Gough, C. (2004). *The Public Perceptions of Carbon Capture and Storage*. Tyndall Centre Working Paper No. 44. Manchester: UMIST.
- Sidhu, K.S. (2003). *Methodology of Research in Education* (Recent Edition). New Delhi: Sterling Publishers Private Limited.
- Standard Assessment Procedure, SAP. ( 2005). *The Government's Standard Assessment Procedure for Energy Rating of Dwellings*. Published on behalf of DEFRA by: BRE, Garston, Watford WD25 9XX
- Tamakloe, W. (undated). *State of Ghana's Environment-Challenges of Compliance and Enforcement*. Ghana Environmental Protection Agency. Retrieved from: [www.inece.org/indicators/proceedings/04h\\_ghana.pdf](http://www.inece.org/indicators/proceedings/04h_ghana.pdf), on 21 March, 2007
- Tema Municipal Assembly. (undated). *Tema Municipal District Human Development Report 2004*.
- WLPGA. (Undated). *The 2006 Energy Review: A Submission by the LP Gas Association*. Retrieved from: [www.berr.gov.uk/files/file31030.pdf](http://www.berr.gov.uk/files/file31030.pdf), on 3 November, 2006.
- UNECE Working Party on Gas, 2004. Retrieved from: [www.unece.org/ie/se/wpgas.html](http://www.unece.org/ie/se/wpgas.html) on 10 April 2007.
- UN-Energy. (2006). Retrieved from: [esa.un.org/un-energy/meetings.htm](http://esa.un.org/un-energy/meetings.htm) on 10 April 2007
- UK Government's Standard Assessment Procedure (SAP) for Energy Rating for Dwellings,2005) Retrieved from: [www.bre.co.uk/uk/sap2005/pdf/SAP.pdf](http://www.bre.co.uk/uk/sap2005/pdf/SAP.pdf) on 5 April 2007.
- UNEP. (1998). *LP Gas Safety: Guidelines for Good Safety Practice in the LP Gas Industry*. UN Publications.
- UNDP & WLPGA. (2003). *LP Gas Rural Energy Challenge: a Fabulous fuel for Development*. A Public-Private Partnership Initiative between UNDP and WLPGA. Retrieved from: [www.undp.org/energy/lpg.htm-23k](http://www.undp.org/energy/lpg.htm-23k), on 30 December, 2005.
- United States Department of Energy. (2002). *Liquefied Petroleum Gas Fueling Vehicles Around the World*. *Alternative Fuel News*. 6(2). Retrieved from: [www.eere.energy.gov/cleancities/cen/archive/6\\_2cover.html-13k](http://www.eere.energy.gov/cleancities/cen/archive/6_2cover.html-13k), on 5 April, 2007.
- Velázquez, N. (2006). *Impact of Rising Energy Costs on Small Business*. Report by the House of Small Business Committee. Retrieved from: [www.house.gov/smbiz/Reports/ENERGY%20REPORT%202006.pdf](http://www.house.gov/smbiz/Reports/ENERGY%20REPORT%202006.pdf), on 28 February, 2007.
- WEC Statement. (2005). *Delivering Sustainability: Challenges and Opportunities for Energy Industry*. Retrieved from: <http://www.worldenergy.org>, on 8 August, 2006.
- WEC. (2005). *Regional Energy Integration in Africa-A Report of the World's Energy Council*. Retrieved from: [www.worldenergy.org](http://www.worldenergy.org), on 6 September, 2006
- WEC. (2005). *WEC Statement on Delivering Sustainability: Challenges and Opportunities for the Energy Industry*. Retrieved from: [www.worldenergy.org](http://www.worldenergy.org), on 8 August, 2006
- WLPGA. (2001). *LP Gas Business: Guidelines for Good Business Practices in the LP Gas Industry*. Paris: World LP Gas Communication SARL.
- Yin, R.K. (2003b). *Case Study Research: Design and Methods*. Sage. Thousand Oaks, California.

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