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Strategies for Improving Gas Supplies for Sustainable Power Generation in Ghana

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Abstract

Technologies for gas conversion have attracted more serious attention, but energy efficiency, supply deficiencies, as well as other risks undermining the gas supply industry, make it difficult to achieve sustainability in gas supply in Ghana. This study explored strategies for improving supplies for sustainable power generation in Ghana. Specifically, the study investigates the risks associated with the gas supply industry and also investigates strategies for improving gas supplies in Ghana. A descriptive study that applied both qualitative and quantitative tools was applied to data collection and analysis to allow for an in-depth analysis of the findings of the research. The population was concentrated on the regulators (Energy Commission) and consumers (VRA and Sunon Asogli, and GNGC/Eni in the supply domains. In all, 357 population was targeted with a sample of 151. Probability (simple random sampling) and non-probability (purposive) sampling approaches were applied to source participants for the study. Statistical inferential tools that guided the analysis included means, standard deviation, Relative Importance Index (RII). The study identified issues of power sector debt due to the weak financial background of the gas supply sector, poor infrastructure, issues of corruption created by delays, poor transparency and weak regulatory framework as key risk factors in the gas supply industry in Ghana. The study also concluded that strategies to support the drive to achieve sustainability in the gas supply industry should involve a planned action towards providing regular and improved infrastructure in transportation and gas supply pipelines to enhance the visibility of the local gas industry and to also meet both domestic and industrial demand for gas products. Again, there should be the establishment and maintenance of functional gas-related policies and regulators, as well as an emergency supply plan to address any shocks that may tend to impact the gas supply industry in Ghana.

Keywords

Gas Supplies, Risks, Sustainability, Regulators, Growth, Supply, Regulation and Infrastructure

1. Introduction

The quest for the use of natural gas as premium oil to gain competitive advantage over other forms of energy continues to assume tremendous importance [1]. As a result, issues of exploring gas conversion have attracted more serious attention. However, energy efficiency, supply deficiencies, cost and cost inflation as well as risks relating to gas management remain barriers for promising alternatives.

Natural gas continues to play key roles in the management of global energy systems by actively contributing to the fortunes of power generation, heating and energy for industry [2]. Natural gas helps to supply electricity and also serves as the third-largest energy market in places such as Latin America [3]. For example, the natural gas industry in Canada has enormous potential to supply the Chinese market with energy to meet both domestic and industrial demand [4]. But, the prospects of the gas industry are undermined by factors including prices of the gas product that differ from region to region as each contract is now between the consumer and respective producer. This challenge is compounded by the fact that state companies control most of the exported natural gas volumes in the world through trade entities including suppliers. However, the pricing of natural gas differs from petroleum which is independent of the global market.

Natural gas pricing is either market-based or regulated. According to [5], the International Gas Union recognizes three market-based views that are dominant in both developed and developing countries. These include oil or product indexation gas-to-gas competition and pricing schemes based on netback from the final product. The regulated natural gas price is used widely on the African continent. This implies government sets prices based on the domestic policy of the country. Among the reasons for pricing, differentials are bottleneck monopolies in the grid, the lack of knowledge and experience on the part of gas producers, and risk-averse buyers who were hesitant to rely on the spot market [6]. Meanwhile, the potential of the natural gas industry globally is determined by many factors including consumption patterns [7] and global trends in natural gas purchase agreements [8].

1.1. Risks Associated with Gas Supplies

Many pieces of literature [9] [10] [11] have made diverse arguments in support of factors that determine the supply of natural gas. Such arguments include temperature, seasonal factors and storage in determining supply consumption and production in natural gas [9]. Again, [10] argues that trade flows, energy in-

tensity consumption patterns, economic growth are mutually consistent with natural gas supplies, but changes in consumption vary by country. In North America, developments in shale gas have impacted changes in natural gas supply and hence made the demand and financial factors important determinants of natural gas supply [11]. Aside from the driving forces of gas supplies are factors that create supply inefficiencies for natural gas supplies, worldwide. For example, Ghana faces constraints in its efforts to commercialize the gas discoveries because the country lacks the infrastructure and ability to finance projects. As part of mitigation measures, the government of Ghana has developed measures such as a suitable pricing structure, fair access to infrastructure and regulatory oversight by an appropriate authority backed by law [12]. However, there is still a degree of challenge in attracting adequate investments for infrastructure growth in the domestic gas production scene as well as increasing end-users. Again, the lack of a properly working framework of regulations targeting investments and weak institutions are a major constraint to the development of the gas industry in Ghana [13]. In another perspective, [14] identifies problems in the domestic gas sector of Ghana to include the lack of adequately trained and experienced staff and poor institutional development concerning design, regulation and competition. In Ghana, the essential area for utilizing domestic gas is identified to be the power sector. This sector, however, faces several challenges due to debt that has been accumulated [15]. This debt is a major headache for investors eyeing the gas industry as it is likely to be transferred to the gas industry. Also, [14] highlights the issue of delays and transparency in the gas sector development of Ghana. From the construction of the Atuabo Gas Processing Plant, there are political interferences and land ownership disputes; the latter delayed construction for 18 months. The court proceedings revealed non-transparent and corrupt conditions that are also prevalent in the Ghanaian economy; though it is worth noting Ghana is ranked among the top five countries in Sub-Saharan Africa in terms of the ease of doing business index by the [15].

1.2. Sustainability of Gas Supplies

Issues of affordability and sustainability of energy supplies to ensure a long term role of gas supplies are a challenge for future global gas supplies [16]. For example in Ghana, the current installed capacity for power generation is enough to meet the demands of the nation for industrial and residential applications but the sector is unable to fully utilize the opportunity [17]. The thermal power generation sector for example, which holds the majority share in installed capacity for power generation faces challenges such as fuel supplies inefficiencies and increasing cost (oil imports) [18]. But, gas can play a critical role in national development [19].

1.3. Issues of Gas Supplies

Empirical notes have identified a close link between natural gas nexus and eco-

nomic growth. The link was analysed through a sector-based natural gas consumption across regions and in the US [20] through the use of the ordinary least squares and the two-stage least squares approach [21]. In the case of [20], it was found that own price, income and a dummy variable for the embargo on oil in the 1970s were significant. A shortcoming of this study was that the differentiation between long-run and short-run price and income elasticities was not done. The empirical study of [21] went further to overcome the shortcoming of [20] using Short Time Scientific Mission (STSM) for the estimation of the elasticities for gas demand in Ghana. Among other findings, the short-run price elasticity for the aggregate natural gas demand was found to be −0.36 with the income elasticity at 0.38. The long-run elasticity for price and income was −1.81 and 1.95 respectively. As a result, [21] concluded that income changes induce more response in the industrial sector than the residential sector, whereas the residential sector is more responsive to price. Strategies on how to improve supply were however not discussed.

As part of contributing to the debate on gas supplies [22] investigates co-integration and causal relationship between energy consumption and economic growth in 7 selected Sub-Saharan countries including Ghana (1970 and 2007), using econometric procedures such as the Gregory and Hansen threshold method. In sum, [22] observed that energy consumption is co-integrated with economic growth in Ghana in the presence of a structural break. Also, it was observed that economic growth has a positive long-run impact on energy consumption. However, the energy types were not investigated to establish which type is most consumed to allow direction-specific policy formulation. In Ghana, economic growth-granger was found to cause energy use hence the promotion of economic growth by the government would increase energy demand which would affect supply.

1.4. Sustainability in Gas Supplies

The use of long-term contracts has been an obstacle to the creation of a vibrant gas market. The competitiveness of a market is lost when most transactions are conducted in long-term contracts [23]. The preference of suppliers for long-term contracts is, therefore, dependent on the difference between short-run and long-run price elasticities of demand [24]. In another vein, [13] states that transportation of natural gas to the consumer requires huge investment which, therefore, requires long-term contracts. An example is then given on the West African Gas Pipeline in which the investment is so huge that it would be valuable for both policy and decision making in terms of investments if knowledge of factors that can influence the demand of the gas is known. This goes to show that policy can be strong if there is a clear understanding of factors that influence natural gas demand like energy security and access.

In the past five years of oil and gas production in Ghana, the issue of power shortages still prevails. Although Ghana has a gas production plant, the country

continues to depend partly on gas from Nigeria to keep some of its thermal stations running [17]. This supply of gas from Nigeria which in most cases is unreliable or inadequate as a result of some pressing financial bottlenecks [25].

The associated and non-associated gas from the oil fields of Ghana presents a real possibility to supply the power generation companies with an adequate and reliable source of fuel all year round [15] [26]. This source of fuel could allow for further expansion of the power industry and provide opportunities to cope with the real energy demands which if managed well, are necessary for industrial growth. This study, therefore, explored strategies for improving supplies for sustainable power generation in Ghana. Specifically, the study investigates the risks associated with the gas supply industry and also explores strategies for improving gas supplies in Ghana.

2. Methodology

The study applied descriptive research to investigate the energy and gas industry policies and their effects on the gas industry as a whole. As part of the application of the qualitative approach to sourcing data, historical data concerning demand or consumption and production, transmission or generation of the natural gas and trends were studied and analyzed. The scope of the study covered the gas industry and focused on the key players including the regulators of the industry and gas consumers in the power sector. The participants included those in the supply chain of the gas industry such as the producers of gas, the refineries and distribution operators and finally the power sector that consumes substantial amounts of the gas. The scope considered was an iterative process as new information and insight required the scope to be reduced or modified in part to suit the research aims and objectives better.

Descriptive research was applied to identify specific answers to the objectives and quantify the answers to the questions to develop a clear picture of the views of the interviewed participants [27]. In all, a mixed-method approach was used in the research to allow for a more informed analysis of data received concerning supply and demand or consumption and also cater for the perceptions and views of participants by use of questionnaires. The quantitative approach was used to support the qualitative nature of the research with statistical inferences.

A non-probability technique, (purposive method) was adopted by the researcher and used to target certain departments within each establishment as participants for the survey.

As qualitative research with an iterative scope process, adjustments to the scope were accommodated as a possibility with a reasonable level of anticipation. Capturing the views of all personnel in the industry with different specialities required a careful approach to develop a study that could sample the views of a selected unit within the industry for which this research found a means to deduce the acceptable sample space.

The population of the study involved engineers and gas industry regulators

with a technical background. These included participants from the upstream sector such as Tullow, Ghana National Petroleum Corporation (GNPC) and ENI; the midstream section, that is, Ghana National Gas Company (GNGC) and the industry analysts and watchers such as the Africa Centre for Energy Policy (ACEP) who also hold a lot of insight and knowledge into the supply security of natural gas.

However, the research concentrated on the regulators as the primary target. The reason being that the regulators (Energy Commission) had a total overview of the industry and worked between the government and the suppliers as well as the operators and owners of the gas pipelines. The regulators are also responsible for policy formulation and advice. On the issue of consumers, VRA and Sunon Asogli who are the major consumers of the gas supplied were considered. These participants provided both private and public views on the consumption or demand aspect. Finally, GNGC/Eni was also targeted concerning the supply of the gas.

This population of the industry was found to be suitable for the research because of the varied skilled labour in the gas sector. The personnel were targeted for their experience and to provide essential and varied insight into the sector. These participants also provided inputs on trends and effects of national policies of the industry including information for consumption and demand trends. The rich experience accumulated by the personnel in the industry over the past years of gas supply was essential for this research.

The operations department of some of the companies were targeted. Others were the gas business section or the gas regulatory section. The population and workforce targets are shown in Table 1.

The purposive sampling technique was decided on and used to identify the departments within the companies that were involved in gas-related operations or business activities. The production or operations department, gas procurement or contracting department, Gas business department and gas regulations department were selected. The departments were selected based on their daily

Table 1. Population for the study.

Industry player	Target Workforce Population
Ghana National Petroleum Company	30
Energy Commission	5
Volta River Authority (2 Tema Thermal Plants)	60
Cen Power Generation Company	55
CENIT Energy Limited	48
Aksa Enerji Ghana	35
Sunon Asogli Power Plant	84
ENI Ghana Exploration and Production Limited	40
Total	357

Source: Field work, 2019.

exposure to gas-related operations and decisions including contract and supply activities. This was suitable for the research because the research desired a particular person with experience and knowledge in the gas industry field. The heads of these departments provided access to the personnel within the department and were then selected to respond to the questionnaire. Hence the sampling method was determined along with these factors without forgetting the need to maintain the accuracy and validity of the research. The total population was 357 individuals. The sample size was derived from a table based on sample size calculation as 214 participants [28]. Cochran's correction formula was then utilized to achieve the required return sample size [29].

N1 = N0/[1 + (N0/Population) = 212/[1 + (212/357)] = 133.01 or 133 estimated.

This research anticipated a response rate of 75% (taking into account a projected 25% non-response rate) and therefore a minimum drawn sample size was targeted at 159. Notwithstanding the projections, a total of 151 responses were retrieved. Therefore, this informed the number of questionnaires to be printed and distributed for the survey.

A table developed for Likert scale based questionnaires were consulted for the ideal sample size [28]. The table considered several items for the Likert scale; k, Confidence level; $(1 - \alpha)$, a relative tolerable error; D, a coefficient of variation; C and a pair-wise correlation coefficient; ρ.

Data was collected for the research through the administration of questionnaires and the attainment of historical data. This research ensured that the questionnaires were impartial, systematic and representative of the subjective views and perceptions of the participants. Statements were listed in Likert styled formats and participants were required to state their position on the statement on a basis of a five-point scale ranging from strongly disagree to strongly agree. The questions were built around themes such as risks, growth, supply, regulation and infrastructure. Two open-ended questions were also added to provide clarification for some of the quantitative data. Questions were guided by information from the extant literature. For the historical data, the researcher sought permission and accessed non-confidential information from the gas regulator. The data acquired concerned current gas reserves recoverable and supply data to thermal plants across the country.

A pilot survey was carried out to test the questionnaires if sufficient for the aim of the research before the main survey was rolled out [30]. Pre-testing and piloting surveys were conducted to gain insight, receive suggestions on the questionnaire and obtain clarity and viability of the research design instrument.

The line managers of the selected companies were contacted to voluntarily participate in the research and also to facilitate the participation of subordinates. Some forms were electronically distributed to the line managers who in turn forwarded to subordinates to fill and mailed back for analysis.

Data analysis included methods that assist in describing information, detecting patterns and developing explanations on data or raw figures and features but

before this, the raw data was edited to detect errors [31]. A combination of qualitative and quantitative data tools was used for generating the report. In this research, the raw data was edited to detect errors and omissions to correct such problems appropriately [27]. A multiple data analysis was used to encourage validity as qualitative studies were written in the form of scientific reports [27]. The data used to determine the possible time frame for domestic gas consumption was acquired from the Energy Commission and hence was representative of the industry trends relating to consumption and supply of gas. To confirm the validity of our research instruments, information on trends in the industry were acquired and used to confirm the findings in the report.

The scientific method for data collection and analysis was used in this research to ensure ethical neutrality [32]. The gas industry has public regulators and due to the close relation with power generation, it was of importance to keep the interview from taking a political turn as this would have affected the correctness of the facts. All acceptable practices in the sphere of conducting research were adhered to maintain an ethical approach in this research.

In all, a hundred and fifty-one (151) questionnaires were administered and also retrieved from the study respondents. The completed questionnaires were collated and coded for *in silico* analysis with the Statistical Product and Service Solutions (SPSS v.22.0). The analysis made use of both descriptive and inferential statistical tools including mean, frequency, percentage, standard deviation (SD), standard error of the mean (SE), relative importance index (RII), and one-sample t-test.

Mean analysis was used in assessing the average of variables in the questionnaire. For a mean calculated with a five-point Likert scale that is set at a 95% confidence interval level to be considered significant, [33] maintain that the mean should be 3.5 or more. Significant in this context implies that the majority of respondents agreed on that test variable. That is, a test variable with a mean value of either 3.5 or more have been agreed on by most of the respondents and a test variable with a mean value less than 3.5 implies that most of the respondents disagreed on that test variable. Standard deviation (SD) which describes the degree of dispersion or variability for a set of data from a sample mean was used together with the standard error of the mean (SE) that described how far the sample mean of the data is likely to be from the true population mean [34]. This is, a small SD or SE value implies a little variation in the respondents' opinions on a test variable whilst a large SD or SE value implies a wide variation in the respondents' opinions on a variable. Relative importance index (RII), and the inferential statistical tool was used to summarise the significance of a test variable relative to other test variables in the analysis. RII is an appropriate tool to prioritize indicators rated on a Likert scale.

$$\mathrm{RII} = \frac{(\Sigma W)}{(A \times N)}$$

where: W is the weight given to each factor by the respondents and ranges from

1 to 5;

A = the highest weight = 5;

N = the total number of respondents.

3. Results and Discussions

3.1. Respondents' Profile

According to [35] the significance of the respondents' profile enhances the credibility of the study findings because it ascertains that the data was collected from the right people. The respondent's profile for this study comprised the gas industry sector where the respondents worked and the years respondents have worked in the industry.

3.2. Supply Risks Associated with the Gas Industry

The first objective of the study was to assess the risks associated with supply in the gas industry. Variables were sourced from literature and presented to the respondents to rank using a Likert scale, on whether those factors are supply risks in the gas industry in Ghana or otherwise. The analyses on the responses received indicated that *Power sector debt* ranked first with a mean and an RII of 4.11 and 0.822 respectively. The issue of public sector debts as identified from the study results corroborate [11] who identified financial factors as key factors contributing to risks in the gas supply sector. *The lack of gas storage options* ranked second with a mean and an RII of 3.98 and 0.796. This result is similar to [11] which identified constraints in infrastructure and inability to finance projects as key risk factors in the gas supply sector in Ghana. *Perceived corruption in the industry* ranked third with a mean and an RII of 3.86 and 0.772. *Delays in the delivery of gas supply projects* ranked fourth with a mean and an RII of 3.81 and 0.762. *An incomplete regulatory framework for the gas industry* ranked fifth with a mean and an RII of 3.75 and 0.750, a key factor supporting [12] [13] that fronted challenges in policy and regulatory frameworks as notable risks in the gas industry. Other supply risks that were identified by the study included the inadequately equipped nature of regulators in the gas supply industry and the costly and non-profitable nature of producing gas locally. However, the study also showed that the *existence of adequately trained and experienced personnel in the gas supply industry* (mean = 3.46), *gas supply environment is stable for investment* (mean = 3.40), and *the government promotes suitable private investment participation in the gas supply industry* (mean = 3.00) are not risks associated with supply in the gas industry as posited by their small mean values (that is, less than 3.5). A perusal of the results in **Table 2** shows that all the variables have small SD and SE values. This implies that there were little variations or dispersion among the views of the respondents in answering the questionnaires. Thus, the findings of the study show a true reflection of the general opinion of the respondents on the supply risks associated with the gas industry. This also corroborates the result of Cronbach's alpha coefficient analysis in that

Table 2. Supply risks associated with the gas industry.

	Mean				
Supply Risks	**Statistic**	**SE**	**SD**	**RII**	**Rank**
Power sector debt	4.11	0.228	0.186	0.822	1ST
Lack of gas storage options	3.98	0.112	0.136	0.796	2ND
Perceived corruption in the industry	3.86	0.096	0.111	0.772	3RD
Delays in the delivery of gas supply projects	3.81	0.125	0.137	0.762	4TH
Incomplete regulatory framework for the gas industry	3.75	0.138	0.136	0.750	5TH
The inadequately-equipped nature of regulators in the gas supply industry	3.71	0.162	0.144	0.742	6TH
The costly and non-profitable nature of producing gas locally	3.65	0.153	0.091	0.730	7TH
Existence of adequately trained and experienced personnel in the gas supply industry	3.46	0.121	0.132	0.692	8TH
Gas supply environment is stable for investment	3.40	0.509	0.928	0.680	9TH
Government promotes suitable private investment participation in the gas supply industry	3.00	0.172	0.158	0.600	10TH

Source: Field survey (2019).

there is consistency in the responses of the respondents.

Generally, the supply risks associated with the gas supply industry of Ghana as identified by the study corroborate the findings of [12] [13] [15]. The study identified and ranked the debt in the power sector as first and this perhaps reflects its significance as a risk associated with gas supplies in Ghana. As the debt in the power/energy sector keeps on accruing, private investors in the gas supply industry fear to lock and even lose their capital in the business. Unfortunately, this fear is reinforced by improper debt restructuring and lack of transparency, hence the undue lingering uncertainty in the minds of investors in the gas supply industry. Secondly, the lack of storage options for natural gas presents a risk to the gas industry. It is worth noting that [36] asserts that the total national gas storage capacity coverage is a challenge since the distributions are largely found in southern Ghana, from Koforidua, Kumasi and along the coast. For instance, in 2015, storage limitations constrained gas supply to around 300,000 tonnes although the potential supply capacity was upwards of 350,000 tonnes due to the expected availability from the Atuabo plant.

Again, [13] maintains that there is still a degree of challenge in attracting adequate investments for infrastructure growth in the gas industry and this hints at the continued challenge of the lack of storage options for gas supply in Ghana. The study revealed that most of the respondents identified perceived corruption

as a risk in the gas supply industry. The perception of corruption, just like corruption itself, has an inverse relationship with the growth of every industry and the gas supply industry is no exception. This is quite similar to [14] that highlighted issues of delays and transparency as having contributed to supply risks in the gas industry. The perception of corruption in the gas supply industry deters prospective investors from investing in the industry. This, in turn, culminates in inadequate infrastructure, absence of competition, and delays in developing other aspects of the industry like production, storage and distribution. Nonetheless, the respondents' perception of corruption in the industry is often adduced by experience in the industry. For instance, the court proceedings on the land ownership disputes concerning the construction of the Atuabo Gas Processing Plant revealed non-transparent and corrupt conditions as well as political interference. This occurrence delayed construction for about 18 months. Corruption and its perception thus present a risk to the gas supply industry. Delays in the delivery of gas supply projects also present a risk to the gas supply industry. Credit facilities constitute the majority of capital used for undertaking projects and this presupposes that a delay in the delivery of the assigned projects increases the likelihood of defaulting the payment of the credit facility.

Also, delays in project delivery in the gas supply industry invariably lead to an increase in the cost of the project through claims and price inflation as well as delays in the services for which the project was implemented. The study evinced that the number of trained and experienced personnel in the gas supply industry is inadequate and it corroborates the findings of [15]. The pace of growth and development of every industry is a function of its human resources, hence, the inadequacy of trained and experienced personnel presents risks to the gas supply industry in the form of high maintenance, a high likelihood of underutilizing and undermining supply infrastructure. Finally, the study revealed that the gas supply environment is not stable as evidenced by inflation, cedi depreciation, and other microeconomic indicators. As indicated in the literature by [37], a favourable investment environment entails the observance of general commercial tenets, the legal system, and the regulatory regime of a region. The absence of such an enabling environment, as is the case of Ghana, results in an unfavourable and unstable investment climate which is a challenge because IPPs and power investors consider investing in areas with an unfavourable and unstable investment climate to a risky environment aside from the associated difficulty in accessing credits from local banks. The unstable environment in the gas supply industry thus presents a risk to investors through the devaluation of their investment.

3.3. Strategies for Achieving Sustainability Gas Supplies in Ghana

The second objective of the study was to explore strategies to improve gas supplies in Ghana. Variables from the literature were obtained and presented to respondents to express the degree to which they agree or disagree with those va-

riables as strategies to improve gas supplies in Ghana. After the responses were collected, the mean, standard deviation, and one-sample t-test analyses have conducted the responses.

The study's mean and standard deviation analyses show the strategies for improving gas supplies in Ghana include regular maintenance of supply infrastructure (mean = 4.31, SD = 0.976) corroborates [13] which argued for improvements in infrastructure such as effective transportation system for the gas industry, creating a competitive domestic gas supply industry (mean = 3.71, SD = 1.283), expansion of the gas pipelines and networks (mean = 3.92, SD = 0.913) to support [16] [17] that hinges on the need to improve gas supplies to meet both domestic and industrial demands, development of an emergency gas supply plan (mean = 3.60, SD = 1.048), natural gas storage facilities must be introduced to increase the reliability of supplies during periods of potential shortfalls (mean = 3.71, SD = 1.002), and the government must refrain from interfering in activities of the regulatory body (mean = 3.67, SD = 1.011). Table 3 limns the results of the mean and standard deviation analyses on the strategies for improving gas supplies in Ghana.

Table 3. Strategies for improving the gas supplies in Ghana.

Improvement Strategies	N	Mean	SD	t	Sig. (2-tailed)	Mean Difference
Regular maintenance of supply infrastructure	144	4.31	0.976	12.013	0.023**	0.26559
Create a competitive domestic gas supply industry	143	3.71	1.283	6.242	0.000**	0.4519
Introduction of Liquefied Natural Gas (LNG) facilities in the country to secure long term gas supplies	150	3.83	1.03	6.012	0.000**	0.3509
Expansion of the gas pipelines and networks	149	3.92	0.913	5.130	0.041**	0.37531
Natural gas storage facilities must be introduced to increase the reliability of supplies during periods of potential shortfalls.	149	3.71	1.002	5.921	0.000**	0.35287
Consolidate all regulatory functions into one institution	150	3.63	1.081	7.037	0.000**	0.344
Outstanding policies should be treated with urgency and passed into law by parliament	146	3.58	1.083	8.625	0.000**	0.2523
Development of an emergency gas supply plan	143	3.60	1.048	5.311	0.000**	0.2482
Gas price regulation must remain transparent and fair	148	4.00	0.871	9.881	0.010**	0.0688
The government must refrain from interfering in activities of the regulatory body	146	3.67	1.011	4.521	0.000**	0.2523

**Significant and accepted, Source: Field survey (2019).

After the mean and standard deviation analyses were done on the strategies for improving gas supplies in Ghana, the relative significance of the strategies was established with a one-sample t-test analysis. [38] Yockey (2007) avers that a one-sample t-test is an inferential statistical analysis used to ascertain if a sample means has significantly deviated from a hypothesised mean. [38] furthers that for a one-sample mean, the hypothesis is:

$$Ho : U = Uo,$$
$$Ha : U <, > Uo$$

where Ho denotes the null hypothesis;

Ha denotes the alternative hypothesis; and

Uo denotes the hypothesised mean.

More so, [39] records that for a usual one-sample t-test, the parameters that are generally reported include the mean of the test variables, t-value (t) which is the strength of test variables; the p-value which indicates the probability of the test variable being significant (sig. 2-tailed); the mean difference which hints the difference between the upper and the lower intervals; and the degree of freedom (df) which gives an approximate of the sample size. For each test variable, the null hypothesis is that the variable is insignificant (*i.e.* Ho: U = Uo). The Uo is the critical rating above which the test variable is considered significant. In the study, the point on the Likert scale that represents neutral is 3, hence a test variable is considered as consistently agree if the point chosen for that test variable is above 3, *i.e.* 4 and 5 which correspond to "Agree" and "Strongly agree" respectively. Hence, Uo for this study was set at 3.5 which is above the neutral point (3). All test variables whose means are above 3.5 or more are considered as consistently agree to by the study's respondents. The significant level for the study was set at 95%. This is premised on the five-point Likert scale rating where a success variable is considered significant if its mean is either 3.5 or more [39].

From **Table 3**, all the improvement strategies (test variables) had positive t-values implying that all their means are above the hypothesised mean (3.5). Again, all the p-values (significance of the test) are less than 0.5 which also implies that the means of the test variables are not significantly different from the hypothesised mean of 3.5.

The findings made by this study on the strategies to improve gas supplies for sustainable power generation in Ghana buttress earlier literature [13] [15] [17] [26] on ways to enhance supplies in the gas supply industry. The study identified regular maintenance of supply infrastructure and this strategy offsets the canker created by the lack of maintenance culture that is typical of the Ghanaian setting. Given the inadequate infrastructure in the gas supply industry, it pays to create and maintain a regular maintenance culture. This strategy firstly reduces the likelihood and frequency of infrastructure breakdown and also prolongs the lifespan of supply infrastructure. The study also posits that a competitive atmosphere should be created in the domestic gas supply industry. As hinted earlier, the gas supply industry is quite monopolistic with the government occupying almost all

the market niches in the industry. The absence of competition often discourages the participation of private investors in the industry. This study thus advocates for the creation of competition and this can be achieved through providing tax incentives, opening the supply market through tendering, cushioning the dollar currency risk, provision of subsidies and support to private investors who would like to participate in the supply market. Expansion of gas pipelines and the network was also revealed as a strategy the will improve gas supply for sustainable power generation. As explained earlier, the gas supply pipelines and networks are very limited and this often forces power production processes that depend on gas supplies to halt in cases of faults or technical hitches in the pipelines. It thus behoves us to expand gas supply networks to provide several alternative routes for gas supplies. Fairness and transparency in the regulation of gas prices were also identified as a strategy to improve gas supplies. The gas supply market in Ghana is dollarized to mitigate the effect of inflation [40]. However, this aim is not achieved due to the spate of the cedi depreciation which comes to play when the cedi-equivalent is being paid for gas supplies. This situation is compounded when gas price regulation is perceived to be non-transparent. Natural gas is bought in bulk from the international market and is then retailed to companies that used the supply for production or also retail the gas supplies again. This is where the issue of gas price regulation comes in and when the regulation is unfair and non-transparent, it affects power production by independent power producers (IPPs). The study, therefore, advocates for fairness and transparency in gas price regulation. Lastly, the study revealed that another strategy for improving gas supply for power generation is that government must refrain from interfering in the activities of the regulatory bodies. Although the government can't refrain from influencing the activities of gas supply regulatory bodies, it is also not healthy for the government to unduly interfere in their activities. The government can refrain from its undue interference by making regulatory bodies autonomous and consolidating all regulatory functions into one institution to prevent parallelism in their functions.

3.4. Strategies for Boosting the Supply Side of the Gas Industry in Ghana

The respondents of the study were then asked to suggest strategies for boosting the supply of the gas industry in Ghana. A perusal of the responses given by the respondents reveals that the strategies that were posited include *infrastructure development*; *encouraging investment from both the public and private sectors*; *promoting fair gas prices*; *effective implementation of regulations and policies*; *maintenance of infrastructure*; *capacity building and training of staff*; and *effective communication and efficient chain of command*.

3.5. Key Infrastructure That Should Be Developed, Introduced or Enhanced in the Gas Supply Industry in Ghana

The respondents were finally asked to list the key infrastructure that should be

introduced or enhanced in the supply side of the gas industry in Ghana. A perusal of the responses revealed the following key infrastructure; *LNG facilities*, *storage facilities*, *efficient metering stations*, *transportation*, and *processing and distribution facilities*.

4. Conclusions

In conclusion, the paper identified issues of high power sector debt and weak financial base as some of the critical risk factors in the gas supply industry. Issues of weak infrastructure due to the inability to finance projects in the gas industry are risk issues in the gas industry requiring some urgent attention. Issues of corruption sometimes evident in delays and lack of transparency, needs attention as such practices deter prospective investors from investing in the industry.

Strategizing to achieve sustainable gas supply in Ghana would require a concerted effort at providing regular improvements in infrastructure including transportation and delivery systems and expansion of gas supply pipelines for the gas industry. This development would help create a competitive domestic gas industry capable of serving the ever-increasing domestic and industrial needs for gas and related products. As part of efforts to work towards sustainability of gas supply in Ghana, policy-makers and implementers should consider consolidating all gas-related policies and regulatory functions under one institution as well as creating an emergency gas supply plan to address any shocks that may impact the gas supply industry in Ghana.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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