A Review of the Causes of Sustainable Supply Deficiencies in Natural Gas Supply in Ghana

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Abstract

Although Ghana produces natural gas and has several gas reserves, the country still depends on supplies from neighbouring countries for power generation due to challenges like fuel supply inefficiencies and increasing cost of gas production. Gas supply is thus a limiting factor for power generation. This study explores strategies to improve gas supplies for sustainable power generation in Ghana. The study examined the underlying factors inhibiting gas supplies in Ghana, investigated the risks in the gas supply industry, and explored strategies for improving gas supplies in Ghana. The study adopted an inductive approach that utilises both qualitative and quantitative research methods. With the use of questionnaires, data were collected from 151 respondents who were selected by purposive and snowball sampling procedures. The collected data were descriptively and inferentially analysed with analytical tools in the SPSS. The study's findings conclude that factors that inhibit gas supply in Ghana include the lack of growth and supply investment in the gas supply industry, power sector debt on the gas market, and the lack of an extensive distribution infrastructure/network. Also, the gas industry in Ghana lacks the requisite investment drive which culminates into inefficiency and ultimately undermines efforts to achieve sustainable power generation. Politics influence in issues relating to gas supplies in Ghana inhibits long-term supply relationships and permanent infrastructure in gas supply, both locally and on the world market.

Keywords

Natural Gas, Supply, Deficiency, Sustainability

1. Introduction

The ability to have an adequate and reliable gas supply is key to achieving im-

provements in power generation in Ghana [1]. The drive to secure adequate and affordable gas supply has become a major concern for all countries because the availability of regular gas supplies is critical to the power generation sections of many countries including Ghana. Ghana has large deposits of natural gas, and this presents a good opportunity for the nation to improve and expand its power generation capacity [2]. Natural gas as a cleaner energy option presents an opportunity for Ghana to develop its renewable sector fully without compromising on future energy demands for industrialization. [3] maintains that the total energy supply in 2016 reflected an increase of approximately 50% relative to the energy supply in 2007 because supply moved from 6404 to 9660 kilotonne of oil equivalent (ktoe). Ten years beyond 2007 has seen an increase in energy consumption from 5259 to 7086 ktoe whereas electricity generation doubled to 13,022 gigawatt-hours (GWh) by 2016 [3]. But, it is considered that the trend of the energy market in Ghana can provide important support for economic growth and development in Ghana [4]. Between the 1990 to 2017 period, oil supply which formed a key part of the energy generation process in Ghana has increased from less than 1000 ktoe to more than 3000 ktoe. Gas supply has also seen steady growth since 2008, that is, over 1000 ktoe in 2017. The hydro energy front has been relatively stable in terms of biomass supplies relative to the increase in supplies for the share of natural gas and oil ([5], p.2).

Sources of primary energy supply available in Ghana include hydroelectricity, renewable sources (including solar), biomass, petroleum fuels and natural gas [6]. At the centre of these sources of energy supply is hydropower, which is also considered cleaner energy. Hydropower though cleaner, prospects may be undermined by environmental hazards including climate change [7]. For example, climate change impacts could translate to reservoir evaporation and droughts which can result in challenges in energy supply hence the call to develop a more sustainable energy supply [8]. The development of renewable energy options has vast potential as has also been encouraged by the Renewable Energy Act of 2011 to form 10% of the energy mix by 2020 [9]. Data from 2018 showed that seven years after passing the Renewable Energy Act, Ghana's renewable energy share remains less than 1% of the total energy mix. Arguments exploring the best form of renewable energy for Ghana have been mix [10]. Hydro and other forms of renewable energy in the long term can promote sustainability and reduced carbon emissions. Biomass another form of renewable energy, has a total energy consumption of 40%; however, traditional Biomass energy has been considered inefficient and dirty [11].

In 2017, the trend of Ghana's energy mix showed that demand is gradually moving from traditional biomass; which is mostly charcoal and dry wood, to fossil fuels [12]. The use of traditional biomass in most Ghanaian households has been considered as one of the primary drivers of the depletion of the forest cover in Ghana hence considered unsustainable energy [13]. This is significantly so since petroleum energy (including natural gas) had a 45% share of consumed

energy in Ghana in 2016. It is also important to note that transportation and industrial applications may have contributed to the greater share of petroleum use [11]. Products such as diesel, light crude oil, heavy fuel oil used in electric power generation in Ghana are, however, expensive compared to alternative sources [14]. Other implications of activities associated with petroleum are concerns relating to climate change.

Climate change arguments have raised concerns over the heavy reliance on crude oil for energy in the world. In many such arguments against the use of crude oil for energy generation, natural gas is considered to provide an alternative bridge between non-renewable and renewable energy sources. The use of natural gas in power generation has been at the forefront of energy diversification since it could facilitate the transition to renewable energy development [15]. This development is due to carbon emissions from natural gas being fairly lower than other fossil fuels [16]. Recent discoveries of natural gas provide an opportunity for the country to meet energy demands by fully utilizing the current installed capacity [17]. To achieve the potential contributions of natural gas to Ghana's energy fortunes it is imperative issues of inefficiencies in the generation are addressed.

Ghana has several oil and gas reserves including the Jubilee field found offshore in the Western Region of Ghana. The Jubilee field is estimated to hold 335 billion cubic feet (Bcf) of natural gas and ten other fields estimated to contain reserves of 353 Bcf of natural gas [17]. Ghana stands to benefit immensely, from the associated or non-associated natural gas in these reservoirs. There is, therefore, optimism among experts that the oil and gas industry in Ghana could offer a sustainable supply of gas that would, besides, improve the generation of electricity [11].

In Ghana, the average delivered price list for fuel types used in thermal plants showed heavy fuel oil (HFO) and diesel oil in 2018 to be 10 and 14 dollars per million of British thermal units (mmBTU) respectively. Light crude oil (LCO) was at 13 dollars per mmBTU. Natural gas was the least expensive, selling at 7.29 dollars per mmBTU [5]. Ghana National Gas Company (GNGC) limited supplied 81mmsfd of gas as compared to West African Gas Pipeline Ltd supplying 30mmsfd for domestic use including power generation [3] [5]. Annualized, peak demand for power is projected to be increasing at 4.29% and although generation capacity has doubled in the last 10 years, Ghana still experiences power shortages.

The power supply mix has varied over the years. The power demand increased by 7.97 in 2016 alone [18]. As part of efforts to ensure a regular supply of power in Ghana, the West African Gas Pipeline Project was undertaken to improve gas supply for electricity generation. Supplies from Nigeria have, however, been erratic and as a result, frequent power outages occur [13]. Meanwhile, the capacity of a local gas alternative to the Atuabo plant is estimated at 150 mmscfd [19]. Efforts to exploit local gas sources of production have included ENI, an Italian

energy company, that started gas production from the Sankofa field in middle 2018. The field is expected to produce 180 mmscfd for 15 years. According to Eni, that quantity of oil deposits at present is enough to convert half of Ghana's power generation capacity to gas-fueled [20][20].

A cursory look at the energy section in Ghana shows that Energy supplied in Ghana is derived from many various sources: hydro, petroleum and natural gas, traditional biomass and solar energy. Household and industrial demand for power have increased way above supply thus creating reliability and sustainability challenges for the energy market in Ghana [8]. Hydroelectric power generation as compared to the thermal sector has not seen any major growth since the construction of the Bui dam [5]. There is a need to diversify power generation sources as the seasonal drop in water levels affects the maximum power output of hydroelectric plants [8]. The other source of energy has not been without challenges; supply deficiency, inadequate mentorship and production bottlenecks due to poor technologies.

This research, therefore, examines the present state of the gas industry in Ghana and also seeks to identify opportunities in meeting growth in energy demand; hence power generation, through efficient supplies. As a result, the research seeks to explore ways of optimizing the benefits of adequate energy supply from Ghana's gas reserves.

The study would, therefore, assess the underlying factors inhibiting gas supplies in Ghana.

2. Literature Review

2.1. Natural Gas Usage and Categories

Natural gas is identified as a significant energy source used for important economic endeavours such as power generation, activities associated with the chemical industry and household or residential functions and transportation. Natural gas a conventional gas, can be utilized to produce fertilizers or cement, to heat homes or fuel natural gas vehicles [17]. Natural gas is grouped into two categories, that is, conventional (produced from traditional means of extraction) and unconventional gas (made available through the application of modern technology) [21].

Natural gas composed of a combination of hydrocarbons and non-hydrocarbon is normally determined recoverable from underground reservoirs whereas other forms are obtained from animal and plant decomposition over several thousand years deep in the earth crust and composed mainly of methane and other hydrocarbons [22] [23].

2.2. Natural Gas as Energy Source

Natural gas an alternative source of energy with clean, high thermal value and good combustion properties is readily available [24]. The use of natural gas has become popular in many economies because of the reduced emissions of carbon

as well as the positive impact that it could have on capital cost reduction in energy production [25]. Households consumption of natural gas as a substitute for charcoal has increased due to improved household income and government subsidies [26]. [26] further notes that unlike crude that is traded on the world market, natural gas is traded regionally and Africa has no gas market which undermines natural gas trading on the continent. The demand for natural gas would continue to increase in the coming decades as a result of increased usage within emerging and developing countries such as China and Turkey; increased use of natural gas in the transportation industry; the adverse effects of the Fukushima Daiichi nuclear disaster in Japan [27] [28] and the rapid expansion of the capacity of global supply for liquefied natural gas in places such as Tanzania, Algeria and Ghana (LNG) [16].

Issues of increased demand for natural gas, and the 1990s' demand surge for electricity generation coupled with relatively constant natural gas production and supply led to price hikes in North America [29]. Gas consumption in Africa has been growing at a rate of 6% each year starting from 2000 [26]. The need to understand issues of natural gas infrastructure development, investment and regulation on gas supply is important for addressing the underlying causes of sustainable supply deficiencies in natural gas supply in Ghana.

2.3. Importance of Infrastructure, Investment and Regulation on Gas Supply

Some studies have identified a strong correlation between regulation, structure and investment decisions in gas supply dynamics [30]. For example, [31] notes that when the structure of the industry is set or defined, regulations can be established which then can stimulate investment decisions [32]. Despite the theoretical literature and policy-oriented discussions, there was no consensus over the exact effects of regulation on infrastructure investments and hence supplies. But, there are existing case studies of the relationship between the regulatory framework and the development of investment LNG terminals, and interstate pipelines and storage facilities. However, most of these studies centre on developed countries such as the United States; thus advocating for the adoption of a more-market-oriented approach to supply security of natural gas [32].

Arguments vary from classical arguments on over-investment in a rate-of-return regulated natural monopoly which differs from theories of underinvestment [33]. [34] in their view explained that having a guaranteed return higher than the market rate makes companies utilize more capital input in place of labour. This causes an inefficient allocation of resource leading to overinvestment. On the other hand, [33] argued that an abuse of power by the use of regulation may cause underinvestment. Excessive and near-complete public or governmental involvement in the gas market stifles investment by the regulated company. A lack of investment affects infrastructure and hence growth and natural gas supplies.

Ghana shares the regulatory mandate of the downstream gas sector between a technical regulator and an economic regulator. This idea is considered to be distinctive and an exception in the regulation of gas, globally [35]. However, according to [17], industry experts do not advise on the use of this method of regulation because of the extended time required to make important and key decisions. Arguments for this system border around the fact that such dual regulation promotes specialization and equal attention to economic and technical regulation while fostering competition between the two regulators.

Research is, however, skewed towards the study of investment under uncertainty. [36] suggested that investment delayed is beneficial when there is uncertainty even if the project may cover its costs. [37] suggested that over-reliance on traditional regulation for the establishment of market prices that are considered competitive have the potential to present adverse effects on innovation and new investment. This is because the significant unrecoverable costs incurred by the incumbent may be neglected. [32] digests this argument further by explaining that the investor in the infrastructure may have forgone profit from investing in the present since he could have waited to gather more data to invest in the future or decide entirely against the venture. Under the regulation, access prices are calculated based on long-run marginal costs of the incumbent and this development creates a disadvantage for the incumbent if compared with the merchant. One observation that stands out in these research spheres is the need for a vibrant gas supply market as this type of market encompasses infrastructure which is made up of production, storage, transportation, transmission and final utilization or consumption.

2.4. Effect of Industry Structure on Gas Market and Supply

Vertical bundling a strategy for management gas infrastructure, is seen in the natural gas industry to create insufficient investment and in effect raises natural gas supply security concerns since it cannot validate support of gas infrastructure. Companies with a vertical integration that own the infrastructure including a trading activity do not have any high incentives or motivation to invest in infrastructure expansion compared to an unbundled infrastructure network company in the industry [32]. The main motive for vertical unbundling is that integration can lead to negative behaviour that is deemed discriminatory against competitors in the downstream sector of the industry [38].

These arguments suggest the existence of fixed cost elements as relates to the restructuring of assets, the formation of structures for regulatory activities and initiation of competition. Hence, there is a good chance for unbundling to be less costly when coinciding with the implementation of other restructurings. The need to be clear as to what unbundling tries to achieve in addition to other changes taking place is critical before embracing unbundling [39]. Theoretically vertical unbundling may benefit the industry by improving transmission company focus on the security of supply and incentivize improved information sys-

tems. In the same way, vertical unbundling may rather create information problems between electricity generators and gas suppliers and transmitters in the absence of better information systems as stated by [39], and inspired by [40]. A market-based approach is considered the ultimate path to deliver at a level of security of supply that is at par with the expectations of the domestic and commercial customers; price inclusive.

In Ghana, the institutional and regulatory framework of the gas sector shows an industry controlled in the majority by state institutions including the Ghana National Petroleum Company (GNPC) and the Bulk Oil Supply and Transport Company (BOST) [17]. [41] identifies the current gas industry structure and regulatory framework in Ghana as a state-controlled monopoly. A government or public monopoly is a form of coercive monopoly. In such a condition, a government agency or state corporation is the sole provider of certain goods or services. Competition is prohibited by legal instruments since is a monopoly created by the government.

[39] concludes that "ownership unbundling" of electricity and gas transmission or supply networks is a key feature of jurisdictions with the most successful energy market reforms based on the EU and US experiences. Even in this, Pollitt stated that the circumstantial and case study nature of the evidence did not prevent it from looking consistent with the observation made. [38] consider an alternative solution to vertical integration (bundling) and vertical (ownership) unbundling termed legal unbundling in which the price of the essential commodity or input (gas) is usually regulated irrespective of the vertical structure of the industry. Legal unbundling prefers the essential input to be regulated and controlled by a legally independent entity with a self-governing management team while an active company in the downstream industry is still allowed ownership of the entity. The downstream firm is allowed to receive the entity's profits but not allowed to interfere in the operations of the entity as did apply to the cases of the EU and the US.

On the other hand, [41] observed that Ghana's gas value chain is predominantly state-controlled. Public players such as the Ghana National Gas Company (GNGC) and Ghana National Petroleum Corporation (GNPC) control most of the value chain. Volta River Authority (VRA) and other private companies make up consumers. [41] noted that this does not provide a fair playing field for the private sector and hence poses a risk to related investments. Institutional capacity problems among industry players surfaced when Energy Commission, the industry regulator, awarded a gas transport and operation contract for a pipeline constructed by GNGC to Bulk Oil Storage and Transportation (BOST) Company causing pipeline operation conflict. There seems to be no clarity on which player is operating where and what is being managed or operated.

2.5. Gas Supply Markets

Initial energy supply models concentrated on only one side of the problem. The

models focused on energy supplies security, costs or environmental impacts of the consumption and production of energy. These supply models also considered only one energy sector or one energy system or form. But, the models of energy can be classified based on an analytical approach, the methodology, purpose of analysis, mathematical approach and more [42].

A study by [43] looked into the case for freeing up gas markets and electricity markets using regression analysis to study several sectors including industrial gas prices against a host of variables such as the reality of a separate transmission operator. Countries were sampled and the report suggested unbundling was highly significant and correlated with significantly lower prices of natural gas. In the report, prices were comparatively lower; up to 15% lower due to unbundling. The report shows that lower gas prices will have the potential to increase consumption as it would then be seen as the preferred fuel choice in many industries seeking to reduce operational cost. [39] ascertains that the causality direction is uncertain and it could have been that countries go for unbundling when there is access to cheaper power anyway.

3. Methodology

This paper sought a non-interfering approach to source participants views concerning the gas industry in Ghana. A mixture of quantitative and qualitative analysis was used to project certain broad-ranging answers or data acquired graphically thus ensuring better interpretation. The descriptive nature of this research focused on the energy and gas industry encompassing policies and the effects of industry changes as viewed by personnel in the gas industry as a whole. Further, this explains the approach outlined in this chapter as the research did not seek to prove or disprove a hypothetical suggestion or experiment on identified variables in the industry but rather explored the state of the industry and opportunities for improvement by exposing aspects that are under par through views of the industry workers or population.

The additional quantitative aspect involved some historical data sourced from the Regulator to assess information on issues of demand or consumption and production, transmission or generation of the natural gas and trends in the gas market. The scope encompassed the domestic gas industry and focused on the key players including the regulators of the industry and gas consumers such as is in the power sector. Along the supply chain of this industry, the study considered industry players such as the producers of natural gas, the refineries and distribution operators and finally the power sector that consumes substantial amounts of the gas. The scope was considered to be 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 adopted to identify specific answers to the objectives and quantify the answers to the questions for developing a clear picture of the views of the interviewed participants. Modern research has seen a cocktail of

more than one research approach being employed to arrive at a desired outcome or conclusion [44]. A mixed-method approach was adopted in the case of this research to allow for 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.

There was no hypothesis as such, but the research aimed to describe a state of an industry by selecting personnel within the industry body in a non-probability technique. Under this non-probability technique, a purposive sampling method was adopted. This explains why the researcher selects certain departments within each establishment for the survey as participants within these departments are directly affected by the gas supply. For this reason, there was an element of subjective judgment by the researcher in detecting the population to be targeted as is the case with non-probability research.

The qualitative research was used with an iterative scope process, adjustments to the scope were accommodated as a possibility with a reasonable level of anticipation. The gas industry has a personnel of different specialization across all fields. The category of people or population considered for this industry was engineers and gas industry regulators with a technical background. Different major stakeholders existing in each sector of the industry were considered. Such as the upstream sector which includes Tullow, Ghana National Petroleum Corporation (GNPC) and ENI Ghana Exploration and Production Limited; these companies are oil producers or owners of the currently producing oil and gas blocks. The midstream section had Ghana National Gas Company (GNGC) receiving and refining the gas for onward distribution. Other midstream players include owners or operators of the gas pipelines such as West Africa Gas Pipeline Company (WAGPCo). On the consumer side, there is the Volta River Authority (VRA) thermal plants and Sunon Asogli Power Plant. There are industry analysts and watchers such as the Africa Centre for Energy Policy (ACEP) who also holds a lot of insight and knowledge into the supply security of an energy resource such as natural gas.

This research concentrated on the regulators as the primary target. The reason being that the regulators that are, the 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 pipelines for policy formulation and advice. Consumers considered were VRA and Sunon Asogli as they were one of the major consumers of the gas supplied showing private and public views in 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 within these sectors with a focus on gas. This personnel had the experience to provide essential and varied insight into the sector of the research topic. They could also provide the needed data to study

trends and effects of national policies so far in 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 was targeted. Others were the gas business section or a gas regulatory section. The population and workforce targeted are shown in Table 1.

The geographical scope of the non-probability sample exercise was determined to be within Accra and Tema as the institutions targeted by the research were mainly located within these areas. Sampling allowed the research team to project the collective answers of the participants involved as arguably a wider view within the industry subjectively. The obvious benefit of this approach of sampling being the reduction in resources required to carry out the research. This required careful consideration and proper planning.

The researchers determined a suitable sample size to be not less than the derived sample space for this research. The reason for this decision was because the industry was diverse and could be viewed as having sub-populations under four main sections; upstream, midstream, downstream and the regulators. A derived sample size made the means of selection fairly methodological and in so doing enhanced the credibility of the research and the usefulness of the data acquired. A non-probability method with a purposive sampling technique was decided on as the right approach to carry out the research. This technique was used by finding the departments within the companies that were involved in the gas-related operations or gas business activities distributing questionnaires to such personnel. 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 exposure

Table 1. Population for the study.

Industry player	Target Workforce Population	Sample
Ghana National Petroleum Company	30	18
Energy Commission	5	3
Volta River Authority (2 Tema Thermal Plants)	60	35
Cen Power Generation Company	55	33
CENIT Energy Limited	48	27
Aksa Enerji Ghana	35	21
Sunon Asogli Power Plant	84	51
ENI Ghana Exploration and Production Limited	40	24
Total	357	212

Source: Field work, 2019.

to gas-related operations and decisions including contracting 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 upon request and selected the personnel for the questionnaire. Time was of the essence especially concerning responsiveness to the application for the survey. 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 [45]. Cochran's correction formula was then utilized to achieve the required return sample size [46] gas-related as shown below.

$$N1 = N0 \Big/ \Big[1 + \left(N0/\text{Population} \right) = 212 \Big/ \Big[1 + \left(212/357 \right) \Big] \Big]$$
$$= 133.01 \text{ or } 133 \text{ estimated.}$$

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 [45]. This considered several items for the Likert scale; k, Confidence level; (1-α), a relative tolerable error; D, a coefficient of variation; C and a pair-wise correlation coefficient; ρ. There was a Likert table in the questionnaire and an average of 10 questions. Therefore, k is 10. The other parameters were assumed for the research outcome desired and per the comments of [46] who suggested a conservative sample size for a research survey. Hence C of 0.5 and ρ of 0.5 were used with an error, D of 5%. With these parameters in mind, an ideal sample size of 212 was acquired.

The data collection instruments used in this research included questionnaires and attainment of historical data. This research ensured 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 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 composed to encompass themes of risks, growth, supply, regulation and infrastructure. Questions were formulated in consideration of the aims and literature of this research. To increase the response rates, participation was requested in advance using a cover letter that stated the purpose of the survey and terms of confidentiality of data including the anonymity. For the historical data, the researcher asked permission for access to gas information in possession of the regulator which was deemed nonconfidential. 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 [47]. Pre-testing and piloting surveys that are performed before the main survey or interviews were very important in establishing consistency in the collection of data [48]. Contacts in some of the companies including Ghana National Petroleum Company and Energy Commission were engaged in this activity. This pre-testing was carried out before the main distribution of forms commenced. The reason for carrying out the pre-test was to 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. The data was collected when questionnaires were completed by participants [49]. Some forms were electronically distributed to the line managers who in turn forwarded to subordinates to fill. The filled forms were then mailed back for analysis. For the historical data, a description of what was required was communicated to the manager or head of the targeted department of the regulating body.

Data analysis included methods that assisted in describing information, detecting patterns and developing explanations on data or raw figures and features but before this, the raw data is edited to detect errors [50]. The planning of the data analysis process remained iterative throughout the research. A combination of qualitative and quantitative data analysis was featured in the report. The intention was to assist the researchers to answer the questions derived from the research objectives. In this research, the raw data was edited to detect errors and omissions to correct such problems appropriately [44]. Both field and central editing were performed. The data was scrutinized for correctness and completeness to be entered in the IBM Statistical Product for Service Solutions (SPSS) statistic.

Issues of validity and reliability were considered for the study. Multiple data analysis was used to encourage validity as qualitative studies were written in the form of scientific reports [44]. 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 with regards to consumption and supply of the gas. The conditions of ceteris paribus represent the ideal situation and this was necessary for the analysis of the data. The research did not seek to go further than having a fair idea of duration with regards to the quantitative analysis as the result was enough for making conclusions. The validity of the quantitative aspects of this research was upheld by obtaining accurate data from the regulatory body. To confirm the validity of our research instruments this research also observed and noted trends in the industry that was in line with the results being acquired from the participants. This was used to confirm the findings in the report. In considering the ethical integrity of the study, the researchers provided adequate and correct statements about the gas industry and also kept the interview from taking a political turn as this would have affected the correctness of the facts [51]. Issues of confidentiality and freedom of partici-

pation in the study were ensured.

4. Results and Discussions

In this study, one 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 IBM SPSS (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 is a technique for assessing the average of variables in a questionnaire. For a mean calculated with a five-point Likert scale that is set at a 95% confidence interval level to be considered significant, [51] maintained 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) describes the degree of dispersion or variability for a set of data from a sample mean whilst standard error of the mean (SE) describes how far the sample mean of the data is likely to be from the true population mean [52]. 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) is the inferential statistical tool that is used to indicate or summarise the significance of a test variable relative to other test variables in the analysis [53]. RII is an appropriate tool to prioritize indicators rated on a Likert scale.

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

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.

4.1. Profile of Respondents

This section presents the profile of the respondents who were sampled for the study. [54] avers that the significance of the respondents' profile is to enhance the credibility of the study finding because it ascertains that the data were collected from the right people. The respondent's profile for this study comprised the gas industry sector where the respondents worked and the work experience in terms of the years they have had in the industry.

4.2. Gas Industry Sector

The analysis of the gas industry sector where the respondents worked revealed

that 29.80% of the respondents work in the upstream gas supply sector, 12.58% in the midstream gas supply sector and 57.62% in the downstream gas supply sector. The analysis shows a result that is skewed towards the downstream gas supply sector and this corroborates literature that the bulk of people employed by the gas supply industry are in the downstream sector [55].

4.3. Work Experience

In all, 47.68% of the respondents had 0 to 5 years of experience, 40.40% with 6 to 10 years of experience and 11.92% with more than 10 years of work experience. The work experience of the respondents was assessed because it is a fair indicator to suggest that the respondents have relevant information for the study under how long and familiar they have been working in the gas supply industry.

4.4. Reliability of Responses

Reliability describes the quality of a study to yield similar results when the same study is conducted under similar research conditions. [56] contended that reliability ascribes quality to findings precipitated from a study. By way of ascertaining the reliability of this study, the Cronbach's alpha coefficient analysis was utilised to assess the internal consistency of the data collected with the Likert scale. The Cronbach's alpha coefficient analysis yielded a value of 0.793. [57] asserted that a data is considered reliable when its Cronbach's alpha value is above 0.7, hence the data collected with the Likert scale is reliable.

4.5. Factors Influencing Gas Supply in Ghana

This section assessed the factors that influence gas supply in Ghana. To achieve this objective, variables on the factors that have the potential to influence gas supply gleaned from the literature were given to respondents to assess on a five-point Likert scale ranging from 1 = Strongly Disagree, 2 = Disagree, 3 = Undecided/Uncertain, 4 = Agree, and 5 = Strongly Agree. Respondents' responses were analyzed with the mean, standard error of mean, standard deviation and relative importance index.

Inferring from the results of the analyses as presented in Table 2 it could be seen that *growth and supply impedance from lack of investment* ranks first with a mean of 4.29 and an RII of 0.858. *Power sector debt on gas supply market* ranks second with a mean of 4.21 and an RII of 0.842. *Significance of investment for gas supply* ranks third with a mean of 3.92 and an RII of 0.784. *The lack of an extensive distribution infrastructure/network* ranks fourth with a mean of 3.89 and an RII of 0.778. *The lack of competition in the gas market* ranks fifth with a mean of 3.82 and an RII of 0.764. The significance of Nigerian gas supplies for power generation was also a factor found to have influenced gas supply in Ghana. The study, however, found out that the sufficiency and practicality of the laws in the gas industry, the conduciveness of current public/government ownership structure in the gas supply industry, and the existence of surplus gas at

Table 2. Factors influencing gas supply in Ghana.

Factors	Mean		SD	RII	Rank
	Statistic	SE			
Growth and supply impedance from lack of investment	4.29	0.062	0.792	0.858	1ST
Power sector debt on the gas supply market	4.21	0.084	0.883	0.842	2ND
Significance of investment for gas supply	3.92	0.023	0.721	0.784	3RD
Lack of an extensive distribution infrastructure/network	3.89	0.079	0.891	0.778	4TH
Lack of competition in the gas market	3.82	0.101	0.608	0.764	5TH
The significance of Nigerian gas supplies for power generation	3.71	0.128	0.795	0.742	6TH
Political influence and actions have positively affected gas supplies	3.52	0.131	2.725	0.704	7TH
The existence of surplus gas at present power generation rates	3.46	0.098	0.089	0.692	8TH
Conduciveness of current public/government ownership structure in the gas supply industry	3.41	0.105	0.998	0.682	9TH
Laws for the gas industry are sufficient and workable	3.22	0.083	0.631	0.644	10TH

Source: Field survey (2019).

present power generation rates did not influence gas supply in Ghana as the means were below 3.5: that is 3.22, 3.41, and 3.46 respectively. These factors did not meet the inclusion criterion for the mean calculated with a five-point Likert scale to be considered as significant.

The findings of the study on the factors that influence gas supplies for sustainable power generation espouse emerging literature and findings on gas supply security on the global stage. As hinted earlier, [32] describes the security of gas supplies to encompass two primary categories: the physical supply of energy resources (which is gas) and supply security concerning the adequacy of investments in gas infrastructure. Within this purview, this study's findings identify growth and supply impedance from lack of investment, power sector debt on gas supply market, the lack of an extensive distribution infrastructure/network, and the lack of competition in the gas market. The growth and expansion of any venture are among other factors dependent on the investment made in that venture. Given that, it holds that lack of investment in the gas supply industry will inevitably eventuate in its inefficiency to achieve its aim, which in this case is sustainable power generation for the country. The lack of an extensive gas distribution infrastructure/network is evidenced by the fact that the pipeline that supplies the country with gas from Nigeria in quite limited and any fault or technical hitch in that pipeline results in the seizure of its function. The lack of an extensive gas distribution network is a repercussion of lack of investment in the gas supply industry [58].

Although the oil and gas industry in Ghana led to an increase in revenues from petroleum activities, for instance, petroleum receipts increased by 99%

from USD362.58 million in 2017 to USD723.55 in 2018 (January to September) given increased oil and gas production and favourable global oil price several authors asseverate that the debt in the power/energy sector of Ghana is quite pronounced [18] [59]. Among the causes of this huge debt are financial misuse, misappropriation, embezzlement, and willful cause of financial loss by some persons. The impact of the power sector debt translates into delays and sometimes nonpayment of gas supplies thus undermining service delivery in the gas supply industry.

Political influence and actions are also identified by the study as a factor that affects gas supply [60]. Politics influences gas supplies in that it affects other factors like long-term supply relationships and permanent infrastructure involved in gas supply both locally and on the world market. [28] hints that political and policy-related factors influence the stability of the supply of natural gas. A case in hand is the government's decision in accepting or rejecting the terms and conditions of some oil and gas prospecting and drilling companies. The successes or failures in the gas industry cannot be isolated from this single decision.

5. Conclusions

The study explored strategies for improving gas supply for sustainable power generation in Ghana.

Generally, factors that inhibit gas supply in Ghana include growth and supply impedance from the lack of investment, debt in the gas supply market, lack of an extensive distribution infrastructure/network as well as the lack of competition in the gas supply market. Among the causes of this huge debt are financial mismanagement, misappropriation, embezzlement, and willful cause of financial loss on the part of certain managers of gas supply. The impact of the power sector debt translates into delays and sometimes nonpayment of gas supplies.

More so, the gas industry in Ghana lacks the requisite investment drive which culminates into inefficiency and ultimately undermines efforts to achieve sustainable power generation in Ghana.

Political influence in activities associated with gas supplies in Ghana would undermine long-term supply relationships and worsen drives to secure permanent infrastructure in gas supply both locally and on the world market.

Conflicts of Interest

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

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