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PROBABILISTIC ESTIMATION OF POTENTIAL GAS RESERVES FOR THE EMERGING NIGERIAN GAS MARKET

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ABSTRACT: *Proved reserves for the Emerging Nigerian Gas Market is estimated to be around 186 trillion cubic feet (Tcf). In the short to medium term, only 54% or approximately 100 Tcf will be available for utilization, the remaining locked up as Gas Cap Gas, only available on the long term (constrained by OPEC production quota and lack of Gas Utilization Infrastructure). The objective of this study was to estimate the growth potential of Associated Gas (AG) reserves and more importantly determine probabilistic estimates for potential reserves additions from the extensive Non-associated Gas (NAG) accumulations in the Niger Delta.The Niger Delta potential AG reserves growth (deterministic) were investigated using historical reserves figures. The current impetus to commercialize gas and improved field development technologies would in all likelihood, alter the trend of the annual AG Reserves Growth Factors, consistent with what obtains in other developed basins. The probabilistic potential reserves additions from NAG was explored using simple triangular distributions. The Society of Petroleum Engineers (SPE) Reserves classification framework was employed to categorize the Proved reserves (1P or P_1) as Associated Gas Reserves and Reserves additions from Non Associated Gas (NAG) as P_2 for Probable reserves (2P or P_1+P_2) generated as a cumulative distribution till 2050. The distribution of reserves obtained will significantly improve future gas reserves availability estimates and plausible production profiles for prospective investors planning to participate in gas to power and other gas utilization projects in the emerging Nigerian gas market.*

KEYWORDS: Gas Reserves, Gas Market, Probable, Proved, Reserves Growth

INTRODUCTION

Estimated size of oil and gas fields' reserves generally increases with time as fields are discovered, developed and produced. This phenomenon is referred to as reserves growth or field growth. Reserve growth models vary from field to field and from basin to basin. Indeed, some fields may show reserves reduction or negative growth. However, for a basin or a region, collective reserves growth is usually positive. International oil & gas fields also show clear evidence of reserves growth. Worldwide reserves growth will become important in future, particularly for gas, as economies demand higher levels of cleaner forms of energy for their expansion. Projections for future growth of reserves thus become vital in resource assessments and economic planning.

Many factors may contribute to reserves appreciation. These include

- Delineation of additional oil and gas in-place, through areal extensions of fields and development of new pools and reservoirs within fields
- Higher recovery percentages of the oil and gas in-place, resulting from infill drilling and the application of improved technology and advanced engineering methods

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- Revisions of reserve calculations (commonly upward), based on experience gained in the course of developing and operating a field.

Many schemes for estimating future reserve growth are based on the following assumptions:

- Age of fields (since discovery) is considered a realistic surrogate for the degree or intensity of developmental activity in the Basin generating the growth.
- Reserve growth is proportional to field size.
- Past reserve growth patterns provide a realistic basis for predicting the future.

LITERATURE REVIEW/THEORETICAL UNDERPINNING

Arrington [1] pioneered the use of reserves growth models to estimate trends in Ultimate Recoveries (UR) in mature petroleum provinces. By careful study of historical data and using the three year moving average of such data, he developed estimates of Annual Growth Factors (AGF) that can be used for individual fields or regions. While largely empirical and statistics based, his method gained wide acceptance because of its simplicity and the fact that estimates generated can be used as a "first pass" for Regional or Basin studies before the development of more precise and costly field level estimates. Till date, many US Geological Survey (USGS) Assessments of Oil & Gas Reserves are based on the original Arrington method or a variant of it. Over the years, several authors have sought to incorporate improvements in the original Arrington method.

Schmoker and Crovelli [2] presented a deterministic Reserve Growth model for the Continental US based on Growth factors calculated based on year since discovery or age of the field. The growth factors are multiplicative constants, applied directly to a known field volume data to estimate Reserves size in future. The important contribution of Schmoker and Crovelli was the extension of the Arrington Method to include probabilities – a range of Reserves sizes could be estimated using their scheme rather than the single point estimate of Arrington.

Verma and Ulmishek [3] presented a modified form of the Arrington method in which he showed cumulative growth factor smoothing produces a better match with known volume data than annual growth factors. Forbes and Zampelli [4] challenged the premise of the original Arrington method which is based only on geologic factors, independent of the economic environment. They submitted that, given the implicit assumption that growth is systematically affected only by age, the contribution of reserve growth to supply will invariably diminish as fields become more mature. Using data from over 500 fields in the US Gulf of Mexico, they developed an empirical model based on age of the field (as measured by the number of years since first production), the field's reserve size in the year of first production, the real price of natural gas, water depth, and a set of unobserved field-specific factors. They concluded that estimating oil and gas reserve growth using an Arrington based approach may underestimate the response of reserve growth to changes in economic fundamentals.

Forbes and Zampelli [5] examined reserve growth based on aggregation of field data on the year of first production, in contrast to their investigation in 2009 which was based on individual field level. They claimed that the advantage of the approach is its potential to yield insights about the resource potential of a particular geologic province. The results strongly suggest that

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age is not the sole factor in explaining a field's annual reserve growth. In particular, they found out that the annual growth rate in the known petroleum volumes of a field is affected by the economic environment as proxied by price. They concluded that the incorporation of this effect into the modeling process has the potential to improve the accuracy of resource assessments

In this paper, investigation was based on the implicit assumption of the Arrington methodology. While acknowledging the importance of the economic environment (the trend in oil and gas prices due to supply and demand), it was assumed that some of the effects of the economic environment might have been accounted for in the Proved Reserves figures. Published proved reserves figures are the end product of the level of development activities in a field or basin and is reflective of the economic environment. An explicit treatment of the economic environment will be useful if the investigation is aimed at determining the relative contributions of each of the factors contributing to Reserves Growth. However, the main interest of this research was the magnitude of Reserves Growth and the implications for Gas availability for the emerging Gas Business as envisaged in the Nigeria Gas Master Plan.

METHODOLOGY A. DETERMINISTIC EVALUATION

The published Country Reserves Data from *2015 BP Statistical Review of World Energy* [6] was used. Historical Proved Reserves data for Nigeria Gas from 1980 was adopted, so about 35 years of published data was employed. Nigeria Proved Reserves is currently estimated as 186 Trillion cubic feet (Tcf).

Figure 1 shows the actual Nigeria proved gas reserves and 3-year moving average estimates for the published data while Figure 2 shows the calculated Annual Growth factors.

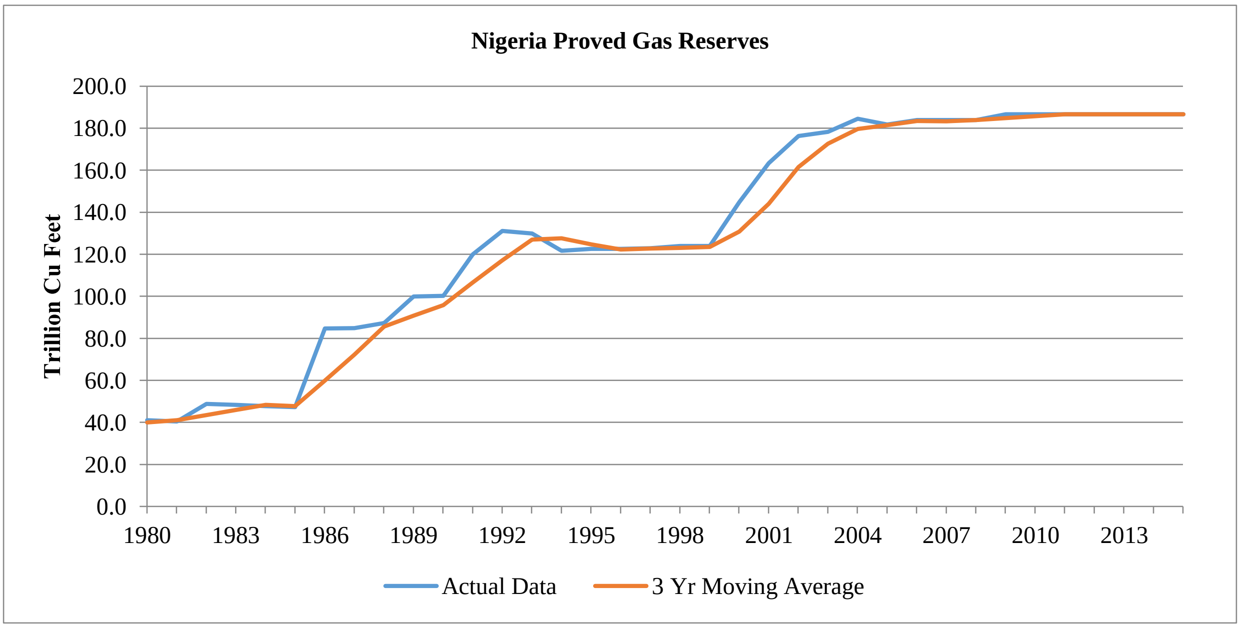

Figure 1—Nigeria Proved Gas Reserves (Actual Data and 3-year Moving Average Estimates)

The annual growth factors show a haphazard trend in the early years and a constant trend towards the tail of the graph. This is indicative of a maturing petroleum environment and lack

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of field activities towards discovery of additional reserves. In the case of Nigeria, Proved Gas Reserves comprises mainly Associated Gas; NonAssociated Gas is ignored due to lack of Gas infrastructure and an undeveloped Gas market. The trend in Figure 2 reflects that the situation for 2010 to 2015 proved Gas Reserves was at 186.1Tcf, showing no growth whatsoever. Regression of the Proved Reserves data using polynomial, power, logarithmic and exponential forms shows the power function having the best fit and may be represented by the following relationship:

$$Gp=-0.101Y^2+8.4417Y+20.943 \qquad (1)$$

$R^2 = 0.955$

where Gp is reserves in Trillion cubic feet and Y is the elapsed year since the reference year (1980) Using eq. 1, projected Proved Reserves is expected to reach 190.54 Tcf in 2030—an increase of about 4 Tcf over 15 years. This is expected due to current lack of significant investment in AG infrastructure, gas gathering and processing in Nigeria, a consequence of the current uneconomic domestic gas price and also the current global depression in the prices of oil and gas. Figure 3 shows the future projection of Nigeria AG reserves using the model in eq. 1.

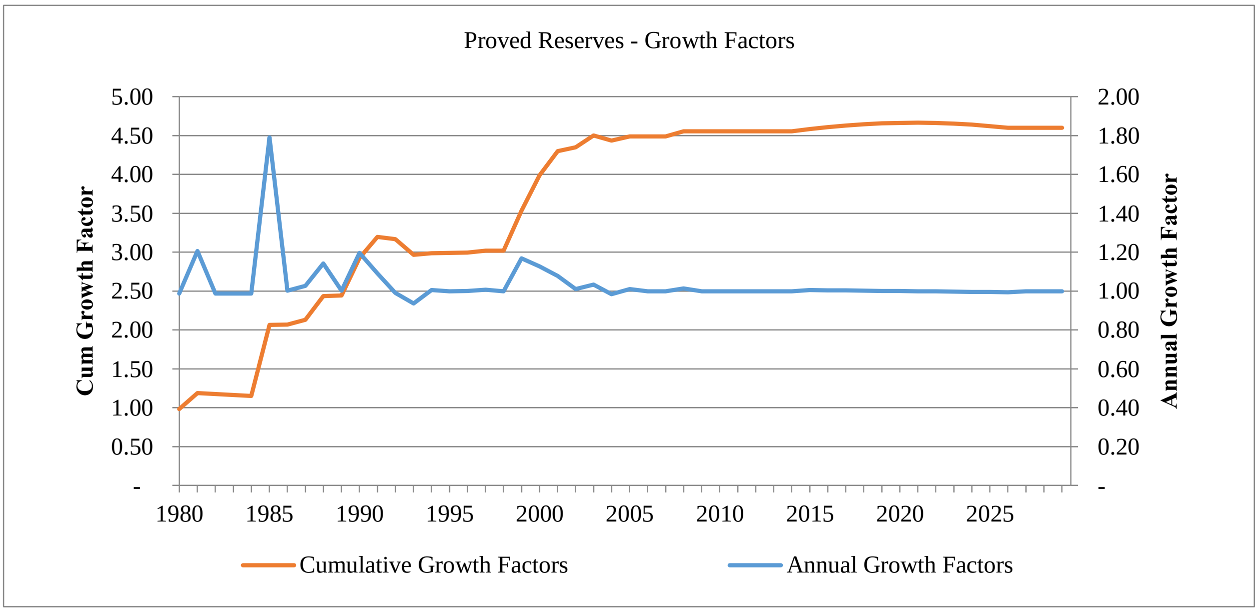

Figure 2—Annual and Cumulative Proved Reserves Growth Factors

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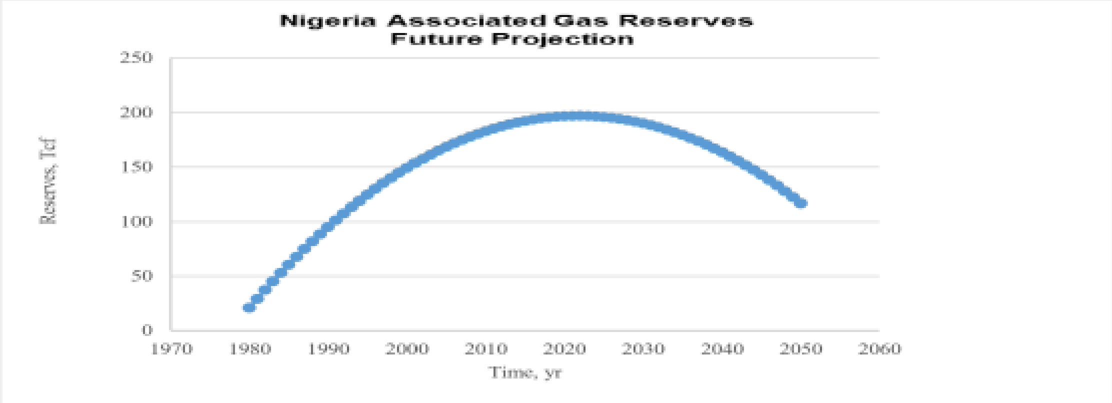

Figure 3— Nigeria Associated Gas Reserves Future Projection using equation 1

Probabilistic Evaluation

In this study, probabilistic evaluation was adopted for the projection of NAG reserves and NAG reserves growth. The triangular distribution was employed in the probability analysis of NAG reserves. A 2015 base NAG Reserves of 18.8 Tcf or 10% of AG Reserves was used as the initial level to capture independent initiatives to augment reserves availability for the NLNG and the Independent Power Projects that are yet to be captured rigorously in Total Reserves. In addition, minimum NAG Reserves growth rate of 2.5%, most likely growth rate of 5% and optimistic NAG growth rate of 7.5% were assumed. The optimistic growth rate of 7.5% was chosen to reflect aggressive development of NAG fields to support the current drive to realize the objectives of the Nigeria Gas Master Plan. Simulation runs with @Risk Software generated reserves profile additions from NAG fields as well as total reserves (AG and NAG) for each of the years, i.e., 2016 through 2050.

RESULTS

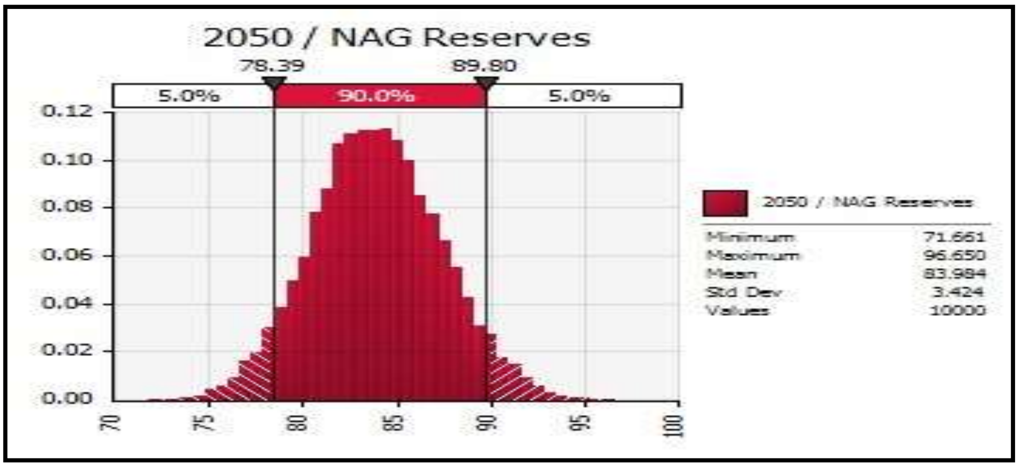

Figure 4—Monte Carlo Simulation Results for NAG Reserves Growth in 2050

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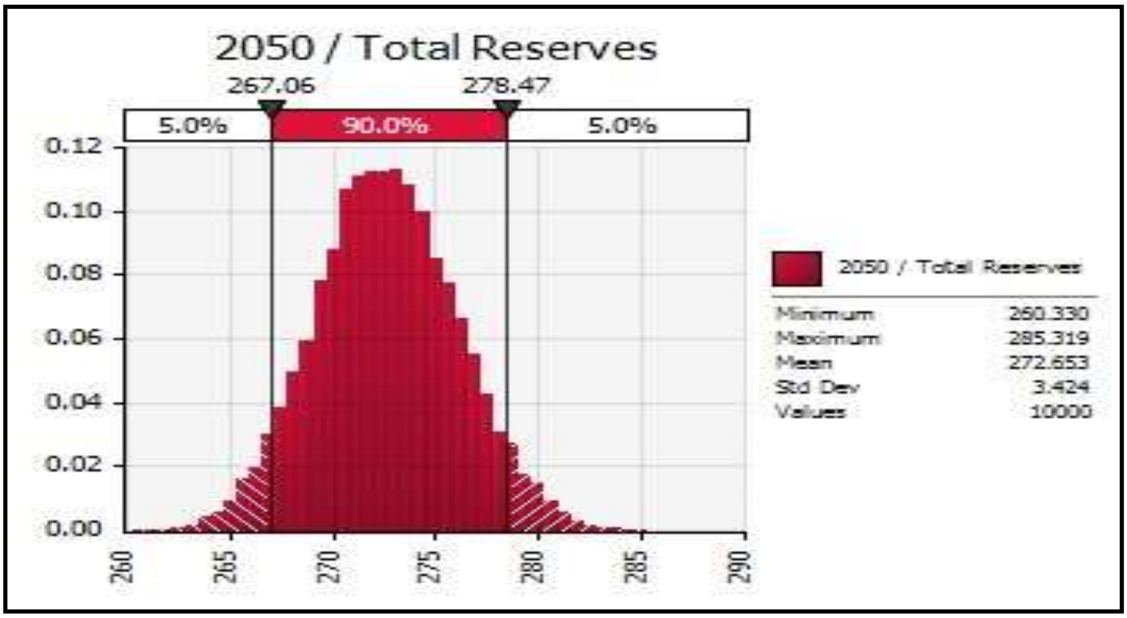

Figure 5— Monte Carlo Simulation Results for Total (Probable) Reserves Growth in 2050

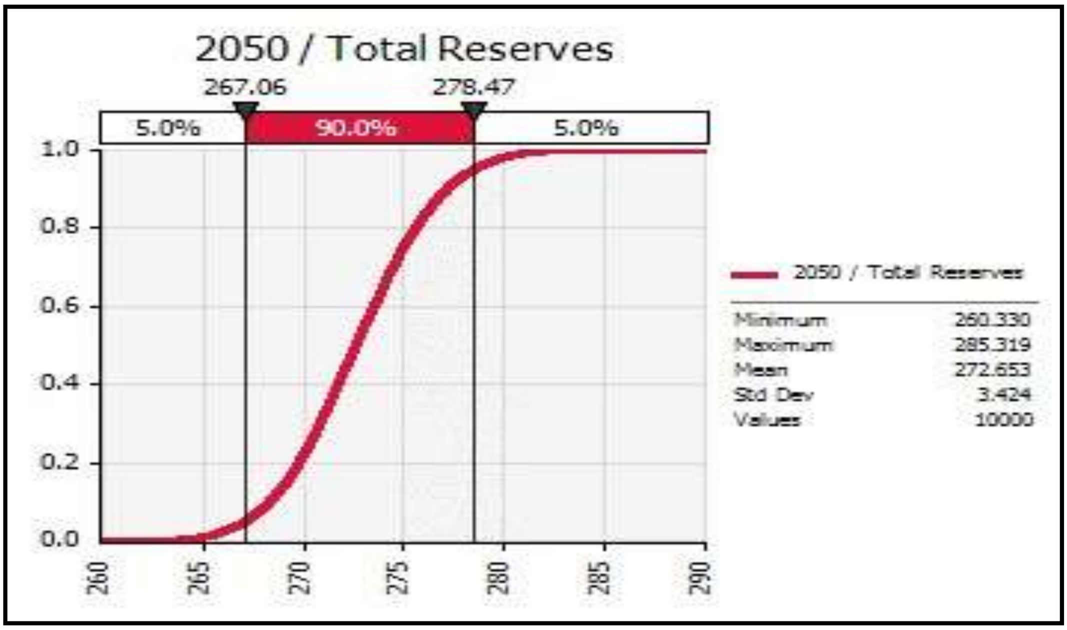

Figure 6 — Cumulative Probability Distribution for Total (Probable) Reserves Growth in 2050

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DISCUSSION

Figure 4 indicates that in 2050, the NAG reserves addition to the proved reserves has a 90% confidence limit of reaching between 78.39 and 89.80 Tcf, and a Standard deviation of 3.42 Tcf. This indicates that there is a 5% chance that NAG reserves addition in 2050 would be less than 78.39 Tcf and 5% chance that it would grow beyond 89.80 Tcf. More so, there is 50% confidence that it woud grow up to 83.98 Tcf. The range gives a picture of the NAG reserves estimate (probabilistic) which would depend upon improvement of gas infrastructure and development of NAG fields.

Figure 5 gives a probabilistic distribution of the total reserves estimate in 2050; a combination of the deterministic power law model for proved (AG) reserves estimate and that obtained from the Probabilistic NAG additions. The 2P reserves estimate in 2050 is expected to lie between 267.06 Tcf and 278.49 Tcf within a confidence interval of 90%. Standard deviation from these values was also estimated to be 3.42 Tcf.

Figure 6 is a representation of the simulation results obtained in Figure 5 as a cumulative probability distribution. About a total reserves of 275 Tcf would lie below the 75th percentile

IMPLICATION TO RESEARCH AND PRACTICE

The findings from these study may be used by prospective investors in the Nigerian gas industry for financial and economic decisions. The distribution of reserves obtained will significantly improve future gas reserves availability estimates and plausible production profiles for prospective investors planning to participate in gas to power and other gas utilization projects in the emerging Nigerian gas market.

The estimated figures may also be reported for analysis of Nigerian gas reserves in the nearest future.

CONCLUSIONS

I. Nigeria in deed, is a country with high gas reserves potential. However, aggressive effort is needed to tap into the abundant gas resources.

II. In this paper, the AG reserves was assumed to be current proved gas reserves and was estimated to grow to approximately 190 Tcf in 2030 and decline to approximately 116 Tcf in 2050. However, additions from the NAG reserves would potentially increase the total reserves to approximately 267 Tcf in 2030 and 278 Tcf in 2050, both within a confidence interval of 90%. This would be subject to improved domestic gas prices compared to what currently obtains and more economically favourable global prices of gas. These fundamental factors would foster aggressive efforts to develop more NAG fields as well as improved infrastructure for gas in Nigeria.

III. In terms of SPE reserves classification, by 2050, 1P for Nigeria gas reserves should be approximately 116 Tcf while 2P should be a value of 285.3 Tcf, as revealed by the estimations from this study. The widely published 600 Tcf possible reserves shows that

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a lot more effort will be needed to tap into the huge gas reserves that Nigeria is endowed with.

FUTURE RESEARCH

The probabilistic estimation of Nigeria oil reserves is an area for future research as it was not covered in this study. It may not be quite easy to do especially in the current era of low oil prices since investments in the oil industry have trickled down. However, past era of low prices can give a clue to predicting future reserves estimates.

Nomenclature

Gp	Gas Reserves, Tcf (Tcm)
AG	Associated Gas
NAG	Non-associated Gas
1P or P_1	Proved Reserves
2P or P_1+P_2	Probable Reserves
3P or P_1+P_2+P_3	Possible Reserves

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