The Technical and Economic Viability of Producing Marginal Oil Fields in the Niger-Delta Using Water Injection

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INTRODUCTION AND OVERVIEW

Marginal fields are economically sensitive to develop which is why marginal fields are faced with challenges ranging from technical to economic challenges. Producing marginal fields conventionally is one of the ways operators of marginal fields cut cost of development and production. Marginal Fields are currently estimated to contribute about 30% to 40% of global oil produced and are gaining ever growing importance due to the natural production decline of large, mature fields. Large International Oil Companies (IOCs) and smaller independent companies are developing skills and capabilities to unlock the potential from marginal fields and small developments. However, since the beginning of Petroleum exploration in Nigeria in the 1930's, many oil fields have been left undeveloped and termed marginal by the International oil companies (IOCs) (Offia 2011). This is as a result of the volume of the oil and gas in such fields (small reserves) and the economic sensitivity attached to developing them.

According to the US Legal.com, marginal field refers to an oil field that may not produce enough net income to make it worth developing at a given time. However, should technical or economic conditions change; such fields may become commercial fields.

Given that the era of easy to find oil is coming to an end and the persistent plunge in crude oil prices, the future of marginal field operators seem less assured due to the economic sensitivity of such fields. This study, therefore investigated one of the ways of increasing production from marginal oil fields within an economic framework through the improvement of recovery factor.

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OVERVIEW OF MARGINAL FIELD POLICY IN NIGERIA

Marginal Fields development is an offshoot of Federal Government policy to kick-off indigenous participation in the upstream sector of the petroleum industry. The government sought to achieve this objective by ensuring the farm out of marginal fields within the concessions of the major multinational oil operators to the indigenous operators.

The principal legislation of the Nigerian Petroleum Industry is the Petroleum Act 1969 Laws of The Federation of Nigeria (The Act) which vests ownership and control of all petroleum to the Federal Government. The Act provides for the grant of three types of interest in oil blocks by the Minister of Petroleum Resources as well as a provision for assignment/ farm out of rights held under such licenses. The licenses are exploration licenses, oil prospecting license (OPL) and oil mining lease (OML).

Marginal oilfield became a policy of Government under the Petroleum (Amendment) Decree No 23 of 1996, which introduced paragraph 16A to the 1st schedule to the Petroleum Act. The legislation provides that the holder of an Oil Mining Lease may with the consent of the Head of State farm-out any oil Field within its leased area or the Head of State may cause the farm-out of a marginal field that has been left unattended to for a period of not less than 10 years from the date of first discovery. This can hardly be regarded as a definition. Furthermore there were serious implications attached to this form of definition - that of the arbitrary classification of fields as marginal. In order to restrict the arbitrary classification of fields as marginal, the Department of Petroleum Resources issued guidelines enumerating the features, which must exist before a field can be classified as marginal. They are as follows:

1. Low stock tank oil initially in place (STOIIP) and therefore low reserves.
2. Long distance from existing production facilities, thereby making them uneconomically viable to put on stream.
3. Fields with crude characteristics that is different from current streams (such as crude with very high viscosity and low API gravity) which cannot be produced through conventional methods.
4. Fields not yet considered for development because of marginal economics under current market and fiscal conditions.
5. Field with one or more wells which have not been developed by the operating companies as

a consequence of the company's ranking including unappraised discoveries and undiscovered fields, but excluding fields with high gas and low oil reserves.
6. Producing fields, which have become uneconomical when close to or passed abandonment limits (DPR, 1996).

METHODOLOGICAL REVIEW

Water injection is an old method of oil recovery and pressure maintenance technique. Water injection can be classified in two ways depending on the objective for injecting the water. Water injection for the purpose of sweep efficiency is called water flooding while water injection for the purpose of pressure maintenance is simply water injection. However, over the years, water flooding has gained more popularity than water injection. Studies have also shown that water injection is more economical than water flooding which is why it can be considered in marginal oil fields which are already characterised with economic sensitivity.

The development of marginal oil fields is of key interest to the government and the Nigerian oil and gas sector. Therefore, one way of economically increasing oil recovery from marginal oil fields is through water injection to maintain pressure and enhance productivity. However, there is a dearth in literature on the technical and economic evaluation of this production technique in the Nigerian marginal oil fields. This study, therefore, investigated the technical and economic viability of increasing oil recovery through water injection from Nigeria's marginal oil fields in the Niger-Delta.

This study was anchored on the Least Square Method. Thirteen reservoir parameters: original oil-in-place, permeability, initial water saturation, reservoir pressure, oil viscosity, initial water saturation, reservoir thickness, porosity, API gravity, solution gas oil ratio, water viscosity and residual oil saturation were collected from 136 oil reservoirs producing under water drive and 129 reservoirs producing under solution gas drive. Preliminary screening was done to ascertain the impact of these parameters on oil Recovery Factor (RF). New models were developed for Primary oil Recovery Factor under water drive, solution gas drive and Secondary oil Recovery Factor under water injection. All the models were validated with data from producing marginal oil fields. The economic viability of water injection in the marginal oil field was estimated using two approaches; the deterministic and the probabilistic approach. The deterministic approach evaluated the project through a single point analysis with assumptions made for the base case scenario, according to the existing fiscal and regulatory framework in Nigeria. However, the deterministic analysis, decision making only would not have provided insights on certainty value and sensitive parameters which are key to determining the input parameters that impact most on the water injection project.

Therefore, the probabilistic approach was used to determine the effects of each input variable on the output.

KEY FINDINGS

Based on this study, the following observations were made.

- Water injection improve recovery factor by about 60%
- That the project will have a negative cash flow when the recovery factor is below 20%.
- It was also observed that discount rate and oil prices do have impact on the NPV.
- Results obtained from the profitability analysis showed a positive NPV of $198.35 million and an IRR of 38.12% for offshore and a positive NPV of $228.25million and an IRR of 45.71% which is above the hurdle rate meaning the investment is viable.
- The project also has a good payback period of 2 years which will be the total number of years it will take to recover the capital.
- The project also has a discounted profitability index above zero (0) which indicates that the project is economically viable.

With respect to risks and uncertainties, the probabilistic approach gave a 45.5% certainty of having a positive Net Present Value (NPV) of $228.25million for onshore and $198.36million for offshore. However, there is a 95% chance of having an NPV of about $290.42million for onshore and $263.99million for offshore, a 50% chance of having an NPV of $236.17MM for onshore, $206.39million for offshore and a 5% chance of having an NPV of $185.72MM and $154.02million for onshore and offshore. These values clearly show how economical and profitable a water injection project can be in a marginal oil field. The sensitivity analysis outlined discount rate, development cost and nominal price (oil price) as key sensitive parameters in maximising profit while production rate and operating expenses were the least sensitive thereby having little impact on the profitability of the water injection project. This was

also confirmed by the tornado charts which displayed ranges of profit/loss derived through the effect of these parameters and the spider chart which displayed their impact based on the steepness of the slope.

CONCLUSION

In conclusion, water injection project for marginal field is technically and economically viable and will give good returns on investment under the technical and economic conditions established in this study. With the help of the range of the economic indices shown in the results obtained, it is a project that marginal operators will be willing to undertake. However, the discount rate, development cost and oil price are the key to making final investment decision in the project.

KEY RECOMMENDATIONS

Based on the findings from this study, the following recommendations were made:

Firstly, water injection project should be considered as a development plan in developing a marginal field as this study has shown that it will not only increase production and reserve but it will extend the economic life of the field. However, the recovery factor must be above 20%.

Secondly, the water injection model developed in this study should be used as a screening tool in identifying reservoirs that are good candidates of water injection so as to initiate a water injection program early in the life of the reservoir.

Interview with Carlos Andrea Bollino, Professor of Economics, Università degli Studi di Perugia, Perugia

By Melissa Low, Research Fellow, Energy Studies Institute, National University of Singapore

Professor Carlos Andrea Bollino, Professor of Economics, Università degli Studi di Perugia, Perugia expressed thanks to the organizers of the 40th IAEE International Conference held in Singapore from the 18-21 June 2017. He said it was important for the energy research community to have a platform to exchange ideas. He added that the IAEE International Conference is an excellent platform to hear from academics and industry practitioners on the major energy trends at the plenary sessions. By bringing together the academic community with business leaders, it makes for more realistic application of economics research. When asked about the paper he presented at this year's conference, he said that it was on the effect of preferential trade agreements on energy imports from Chinese and exporters' perspective. He added that the paper presents a novel analysis of Chinese trade flows from Chinese partners and overseas parties and looks at the determinants of trade flows by industries.

As a side note, IAEE is pleased to announce that Carlos Andrea Bollino has won the 2017 Outstanding Contributions to the IAEE Award – see picture collage page in this issue of the *Energy Forum*.