The commercial viability of producing urea by utilizing natural gas discovered in the marginal reservoir Dorado

W. A. C. P. Karunasinghe,[1] N.G.S. S. Gamage ,*[1] and D. T. P. K.Withanage[2]

[1.]*Department of Physics, Faculty of Applied Sciences, University of Sri Jayewardenepura, Sri Lanka*
[2]*Petroleum Resources Development Secretariat (PRDS), Level 06, Ceylinco House, Colombo 01, Sri Lanka*

ABSTRACT

The island nation of Sri Lanka became a plantation economy back in the 19th and 20th centuries,and a significant number of farmers' livelihoods still depend on agriculture itself. With the low cost of transportation and high solubility, urea fertilizer is leading the industry of agriculture. The current local urea demand is completely met by importations. A constant supply of Natural Gas (NG) is essential to manufacture urea locally. This study mainly focuses on introducing a viable solution for completely importing urea using indigenous gas in place. Amongst the discoveries made around the country, the Dorado reservoir exhibits high quality with a clean, thick deposition. In order to assess the feasibility, the reservoir potential was reviewed and production and supply profiles of NG were analysed by acquiring data regarding local demand quantities. A cost benefit analysis of establishing a urea plant was prepared with the involvement of a German organization. Previously identified economical quantity and price was applied to the Fiscal Regime for the Dorado reservoir with the assistance of PRDS and three case scenarios were proposed. The cases involve developing NG by the investing company with the most economical gas rate identified,*i.e.*, 70 MMScf/d, where around 20 MMScf/d of it will be utilized to manufacture urea. The excess production of NG will either be sold to the government or integrated to a power plant, which is preferred as it introduces additional benefits to the economy. Further analysis can be made depending on different modes and methods of transporting NG and locations of the plants which can manipulate the costs with better focus on achieving higher yield.

Keywords: Urea, Reservoir Potential, Viability, Natural Gas, Dorado Reservoir

INTRODUCTION

Exploration history

The history of oil/ gas exploration in Sri Lanka runs back in time to the 1960s. Since then, several attempts have been made to discover reservoir rocks in the sedimentary basins identified by exploration work. During 1972-1975 the first three exploration wells,Pesalai-1, Pesalai-2, and Pesalai-3,were drilled in the Cauvery Basin of Sri Lanka. Later, Palk Bay-1 and Delft- in 1976 and Pedro-1 and Pearl -1 in 1981 were drilled but there have not been any significant hydrocarbon discoveries except a small discovery in Pesalai-1. Seismic surveys have been carried out to acquire vital data in 2001, 2005, 2009, and 2012. Most recently starting from 2011 four new wells Dorado, Dorado-north, Barracuda and Wallago have been drilled and natural gas discovered from Dorado and Barracuda wells (Figure 1) (Ratnayake *et al*., 2017; Gamage *et al*., 2018).

Corresponding author. E-mail: shanthagamage@sci.sjp.ac.lk

The Petroleum Resources Development Secretariat (PRDS) was established in 2003 with the vision of ensuring all Sri Lankans benefit from the petroleum resources of the country by managing the industry in an equitable, safe and environmentally sustainable manner. The mandate of the Secretariat includes discharging of some functions which are to be assigned from time to time by the Cabinet of Ministers. The Secretariat also acts for and on behalf of the State for all purposes related to Petroleum Resources Agreements entered into, with the State.

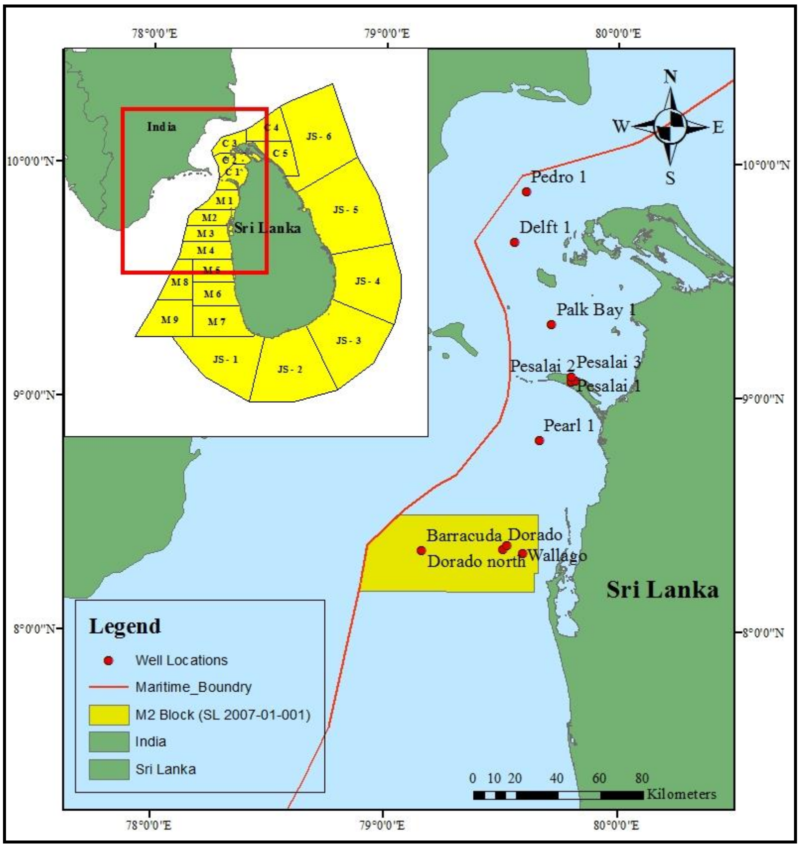

Figure 1. Mannar Basin and the wells drilled in the block SL 2007-01-001 (Block M2)

The Cauvery Basin, Mannar Basin and Lanka Basin are the main prospective offshore sedimentary basins recognized around Sri Lanka. The Mannar basin covers an area of approximately 42,000km^2 with a possible sediment accumulation ofup to 10km in the deep water areas. The very first hydrocarbon discovery in the Mannar basin was made in 2011 in the block SL2001-01-001 popularly known as the block M2. The M2 block covers an area of approximately 2912 km^2. Following the bidding round carried out in 2008, in which several investing companies participated, the block was awarded to Cairn Lanka (Pvt) Ltd. After acquiring, processing and interpreting new geotechnical data, Cairn Lanka (Pvt) Ltdproceeded to drill four wells in the block. Two of those wells showed a significant net gas pay thickness of hydrocarbons and these two reservoir discoveries were named as Dorado and Barracuda (Figure 1) (Ratnayake *et al.*, 2017). Dorado reservoir exhibits high quality, with a clean, thick deposition and straightforward for development. The main objective was set as the Dorado reservoir due to the above reason.

Urea

Sri Lanka is a plantation economy famous for its production and exportation of agricultural crops and a significant number of farmers' livelihoods still depend on agriculture itself. Fertilizers being a crucial factor for agriculture, nitrogenous fertilizers have become the most preferred category among farmers.

With high solubility and high nitrogen content, urea is leading the nitrogenous fertilizer industry. Urea is popularly known as Carbamide in the chemical industry with the molecular formula of NH_2CONH_2. As a country rich with farmers who still earn their living through agriculture, yet categorized as a developing island nation, Sri Lanka is highly in need of urea to establish its economical sustainability.

Sri Lanka completely meets its current urea market demand by importations. In fact, a hundred percent of the urea usage in Sri Lanka is imported from countries such as India, United States, Brazil, Thailand, and Australia. Considering the process of industrial urea production, the following steps can be identified as the major steps. Ammonia and carbon dioxide are initially reacted to form ammonium carbamate and then dehydrated to urea. With this our attention is drawn towards the production of ammonia. Ammonia production process incorporates two main stages.

1. Manufacture of H_2 (Steam Reforming)
2. Synthesis of Ammonia (Haber Process)

A natural gas feedstock needs to be subjected to the process of steam reforming in order to deliver hydrogen. Then hydrogen is combined with atmospheric nitrogen to produce ammonia via the process of Haber-Bosch.

These natural gases are sedimented inside the pores of sedimentary rocks and are trapped under the trap rocks. Natural gas and oil are generated from source rocks only after heating and compacting. The identification of these sedimentary rocks is crucial in the process of oil/gas exploration. Geophysical techniques such as seismic, gravity, magnetic, and electrical surveys are used in prospecting for natural gas resources (Silva *et al.*, 2018).

According to above details, it can be identified that a constant hydrocarbon generation is essential to discover a solution for the national dependence on complete importation of urea. At the same time, the fact that Sri Lanka has discovered a rich hydrocarbon net gas pay thickness has fostered anopportunity. Therefore it is high time to give some serious attention to the matter with a wide focus.

The main objectives of the research study are to identify the feasibility of producing urea using natural gas in the Dorado Reservoir and to introduce a viable solution forcompletely importing urea using indigenous gas in place. Determining numerous commercial options of using the reservoir potential of Dorado Reservoir in Mannar Basin in support of producing urea locally, carrying out a cost-benefit analysis on establishing a urea production plant and the process of producing urea in Sri Lanka and to grab international attention towards the potential of hydrocarbons in Sri Lanka were few other objectives of carrying out the research.

METHODOLOGY

Reservoir Potential and Production Profile

The maximum economical gas plateau rate was anticipated from the production profile of the Dorado reservoir. The most likely economical production profile has been previously anticipated by PRDS for a possible power off-take of close to 630MW (50% PF).Using the same production profile and fiscal regime for this research study was advised by the PRDS. The production profile of a reservoir involves the daily gas rates anticipated throughout the expected economic life time. After reviewing the Reservoir Potential, the value was then used to further analyze the production profile. The daily rate is depreciated over a depleting rate according to the reservoir characteristics and the Reservoir Potential.

The PRDS has come up with the daily rates according to which the Dorado reservoir is expected to be developed over its economic life time. The data regarding the supply rates or the expected developing rates were acquired from PRDS and analyzed with graphs to identify the economically viable indigenous gas solution for urea production.

The maximum economical gas plateau rate was obtained while identifying the economic limit. The variation of the expected daily production gas rate was used to identify the gap between the expected natural gas supply and the daily production of the Dorado reservoir.

Statistical data

[

The data obtained from the Sri Lanka Customs regarding urea importation was used to forecast demand for the year in which the plant is expected to initiate its operations. Extrapolation techniques were followed in this forecasting and the software “Minitab” used to arrive at more accurate figures. The daily gas rate required to fulfill the forecast future demand was calculated using a rule of thumb delivered by Ferrostaal Topsoe GmbH.

The capital and operational costs of establishing a urea production plant was estimated with the involvement of the German organization; Ferrostaal Topsoe GmbH. Using the cost factors and urea production quantities, a descriptive cost benefit analysis was carried out in the form of a Fiscal Model for the urea plant to arrive at the most economical quantity and price.

Applying the Fiscal Regime for Dorado

Two main options were primarily assumed when testing different values on the model. These options were based on the anticipated daily natural gas rate with the assumptions of developing the Dorado reservoir primarily for the sole purpose of urea production at 20MMScf/d or as an integrated project at 70MMScf/d with other possible uses. Under each option, two different case scenarios were considered assuming minimum and substantial benefits to the host government based on the various biddable fiscal terms of the 2013 MPRA (Figure 2).

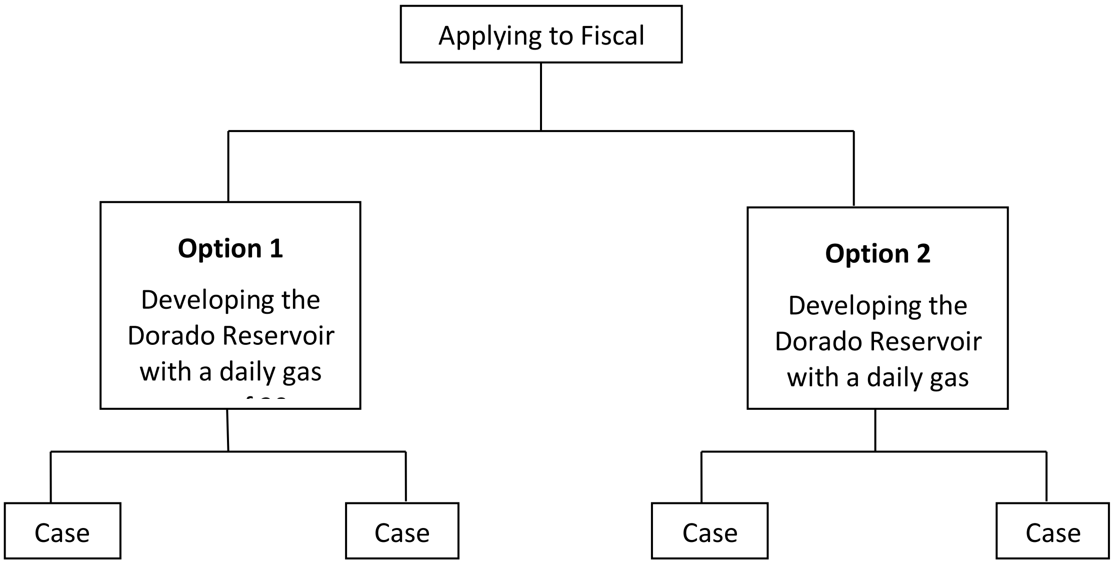

Figure 2. Diagram showing the basis of assumptions made

The Fiscal Regime for the Dorado reservoir is based on several mandatory fiscal terms.

1. Signature Bonus
2. Production Bonus
3. Royalty
4. Cost Recovery
5. Profit Share
6. Tax
7. State Participation interest through an NOC – 15% of the contractor participating interest
8. Other contributions including Local Content Development Provisions

Different case scenarios were proposed based on a suitable commercial approach to launch urea production using Natural Gas resources of Sri Lanka. These were identified based on the output results obtained from the Fiscal Regime for Dorado reservoir.

RESULTS AND DISCUSSION

Results

The production curve for the Dorado Reservoir was further analyzed with the data obtained from PRDS which has been developed anticipating optimum economic benefits (Figure 3). With an identified Reservoir Potential of 334 BCF, the highest gas plateau rate was determined as 67.12 MMScf/d (close to 70 MMScf/d), as possible for a contract rate of sale gas to obtain the most economical field development scenario for the Dorado field considering the fiscal terms mentioned in Appendix (IV) with worst possible assumptions to the host government at a gas price varying from 8 – 12.5 $/MMbtu. This economic gas rate close to 70 MMScf/d proceeds for a span of 8 years and depletes until the economic limit.

Considering depletion of the gas production over the years, the need for an additional natural gas source was identified. If not for an additional source, the excess supply rate will have to be depreciated over the time period. It was identified that the addition has to be incremental starting from the year 2030. The anticipated supply rate to the Urea plant which was calculated based on the Urea plant statistics, was also displayed in the same graph for the convenience of the user to identify the production and supply gap. (Figure 3)

The quantities and prices of urea imported over the years of 2000 - 2017 were obtained from the Sri Lanka Customs. Using trend analysis, the data were extrapolated by the software "Minitab" to arrive at the forecast quantities for the years from 2023 – 2050 considering the estimated economic limit of the Dorado reservoir and future Barracuda/other gas development prospects (Figure 4). The above years were considered because the research focuses on a project over 27 years, to initiate construction by 2023 with a construction period of 2 years. The life span of the urea plant was decided to be 25 years. The following equation was obtained with respect to the trend line by analyzing data with the use of MINITABsoftware.

$$y = 312977 + 1892 \times t$$

The trend line is given by the line with red color dots in the Figure 3 and can therefore be extended further while maintaining the same gradient to obtain the future demand quantities. This method of obtaining forecast values for a given data set is called extrapolation.

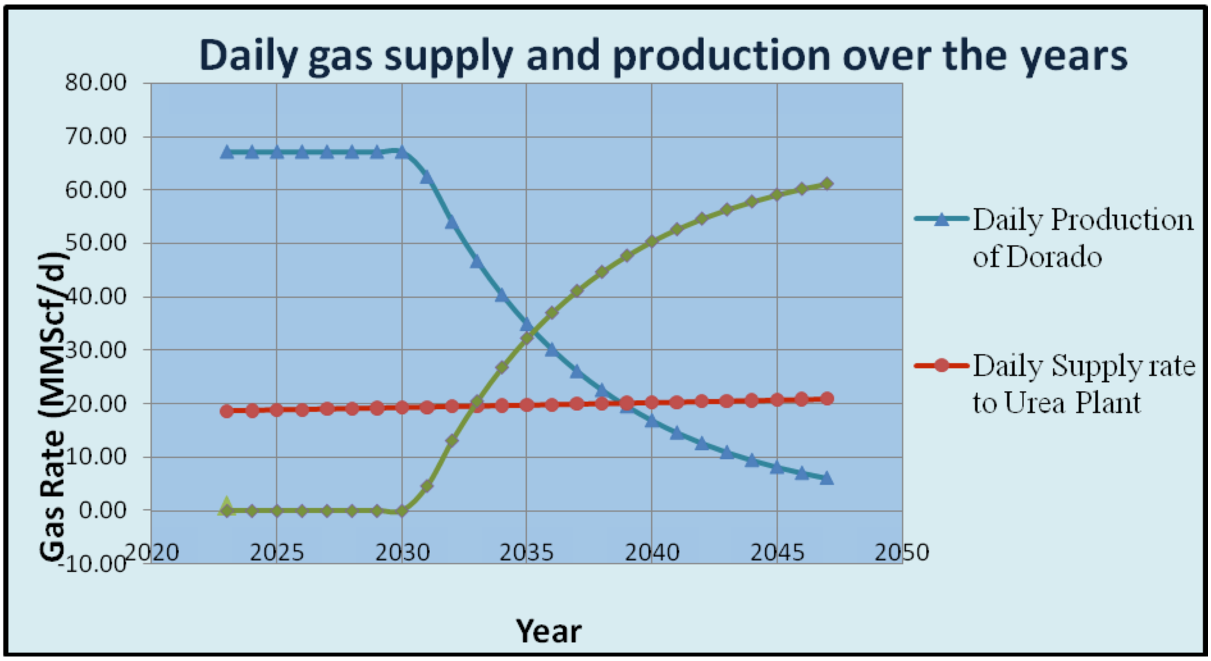

Figure 3. The graph showing the production profile and daily gas supply rate for Dorado reservoir along with the assumed integration of Barracuda reservoir/ other NG source

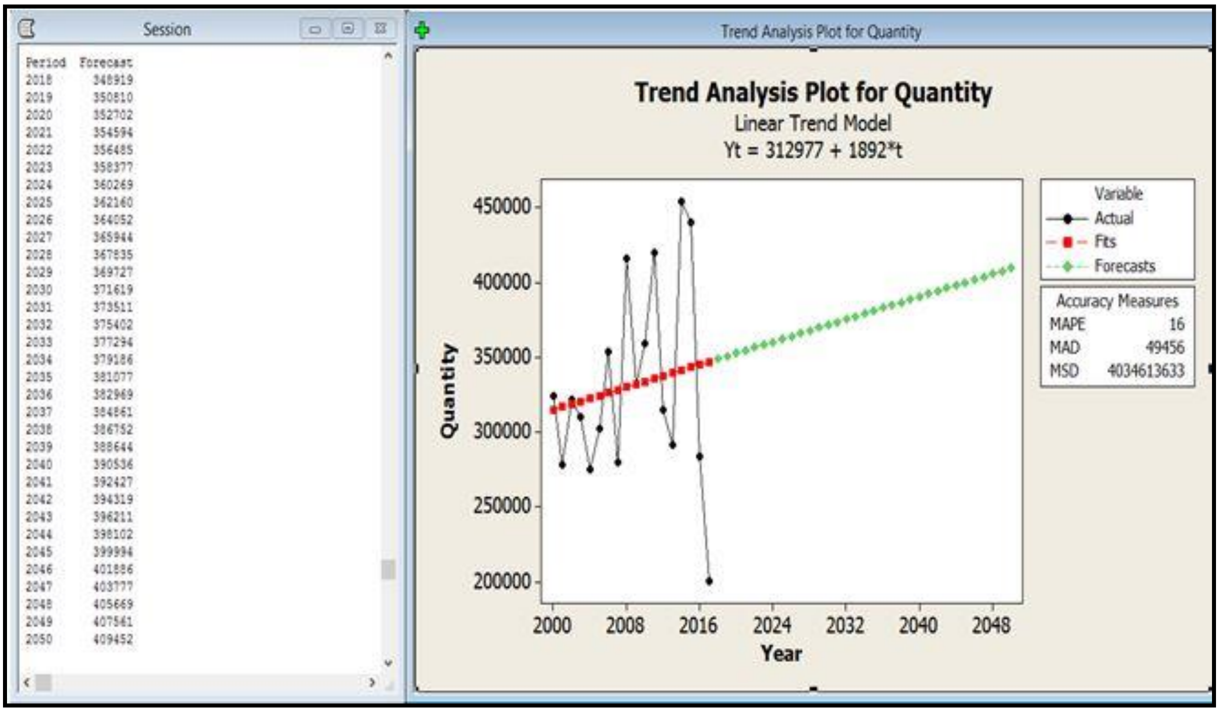

Figure 4: Forecast demand quantities

The quantity of gas needed to meet the forecast demand was then calculated with the information obtained from FerrostaalTopsoe GmbH. A descriptive fiscal model for the ureaplant was prepared with the use of cost factors obtained from the German company and the demand identified to arrive at the optimum quantity and gas price. The optimum quantity was determined to be 18.8 MMScf/d and the optimum price to be 10$/MMbtu.

These values were tested with the Fiscal Regime of the PRDS based on 2013 Model Petroleum Resources Agreement(MPRA)

The gas supply needed for the respective years was determined using the data obtained from FerrostaalTopsoe GmbH. It is also assumed that there could be a possibility to integrate the Barracuda discovery or any other imported gas/in-house gas prospectsby 2030 maintaining daily gas requirementto operate this urea production plant for 25 years. The assumed incremental proportion that is to be integrated with the Dorado reservoir is also shown in the Figure 2.

Discussion

Considering the results identified above, the following cases are discussed.

Case 1: Investment considering development of gas fields and establishment of a urea plant as an integrated project by a third party investor

Development of the Dorado reservoir for the sole production of urea with a daily natural gas rate close to 20 MMScf/d was considered, as it is the identified daily gas rate required to meet the forecast demand. The plant life was considered to be 25 years in carrying out the calculations. A NPV close to $200 million and an IRR of 20% (at a discount rate of 10%) was obtained from the Fiscal Model prepared for the urea plant for in-house use. Although this scenario is economical for the urea plant, this is not economically viable with regards to the Dorado reservoir. This is due to the resulting negative NPV to the fiscal dynamics of the Dorado for a maximum supply close 20MMScf/d.

Therefore the following optional cases were proposed to utilize the excess of economically viable daily rate close to 70 MMScf/d of gas produced from this reservoir together with urea production.

Case 2: Investment considering development of gas fields and establishment of a urea plant supplying excess gas to existing power plants readily convertible by 2025 as an integrated project.

Establishment of a urea plant by an investing company to produce the forecast demand while supplying the excess Natural Gas quantity close to 50 MMScf/d to an existing readily convertible power plant located at Kerawalapitiya in the Western Province for a period of 25 years or more. Additionally to the costs of the Urea Plant, it is proposed that the cost to transport the excess Natural gas to the power plant via a subsea/onshore will be borne by the investing company or government. Depending on the option, the additional costs will be added to the gas price and gas will be made available at the delivery point to CEB according to an agreed formula indexed to oil or gas as mutually agreed by both parties.

Case 3: Investment considering development of gas fields and establishment of a urea plant supplying the excess to the government for other possible applications

Development of the Dorado reservoir by the investing company with a daily gas rate close to 70 MMScf/d is considered where around 20 MMScf/d of it will be utilized to manufacture urea for in-house usage. The excess natural gas production will be sold to the government. According to the calculations carried out, the Sri Lankan government is currently spending around 16 $/MMbtu for natural gas when importing urea. With this case scenario, government can buy NG at a lower rate, around 10 $/MMbtu and utilize the excess as an energy source or a feedstock in all the other possible sectors: power, transport, industry, household and commerce.

CONCLUSIONS

Sri Lanka is able to meet the forecast local urea demand by utilizing a daily natural gas production rate close to 20MMScf/d discovered in the Dorado Reservoir. But the most economical daily gas rate for the Dorado Reservoir is close to 70MMScf/d. The excess quantity can either be supplied to existing power plants or sold directly to the government.

It is economical to the Sri Lankan government to buy NG as currently they are spending around 16 $/MMbtu of Natural Gas when importing. But under this scenario NG can be bought at a rate around 10$/MMbtu without transportation cost. However, the scenario is highly dependent on the agreement of government and their rules and regulations.

Supplying the excess quantity to a power plant is preferred as the forecast urea demand of Sri Lanka can be undoubtedly achieved while also supplying a 500MW power plant. Three readily convertible CGGT power plants exist in Kerawalapitiya and Kalanitissa. Depending on the option of transporting NG to the power plant, additional costs will be added to the gas price according to an agreed formula indexed to oil or gas on mutually agreed terms.

The project can only proceed for around 17 years if executes solely with the Dorado Reservoir. This is due to the reservoir depleting beyond 2030, resulting in an economical cut off and an investor cut-off. Therefore the addition of an incremental amount to the production is essential. Other means of natural gas are considered to be integrated so that the same rate is maintained throughout the project life span. Integration of the Barracuda reservoir is preferred in order to maintain a constant supply rate. But this depends greatly on the success of the extensive studies which are needed to be carried out. Additionally, the world trend of petroleum is moving towards natural gas,and even Sri Lanka is currently considering importing LNG. Therefore in another 17 years' time, options will be available to afford the necessary gas integration.

The commercialization of urea production confronts a number of challenges, by overcoming which the project can be optimized. Flexibility of Fiscal Regime policies are expected by the contractors, which will attract more investors towards the project. Extensive studies can be carried out by varying the modes and methods of transporting NG to the relevant plants.

REFERENCES

1. Badano, M. and Zardi, F., Casale Group, Ammonia and Urea plants upgrading Technologies, **2005**
2. Official Website of Petroleum Resources Development Secretariat (PRDS)http://www.prds-srilanka.com/exploration/origins.faces (accessed Nov 26, 2018)
3. Premarathne, U., Suzuki, N., Ratnayake, N., and Kularathne, C.**2016.** Burial and thermal history modelling of the Mannar basin, offshore Sril Lanka. *J. Petroleum Geol.*, *39*, 193–213 DOI: 10.1111/jpg.12640.
4. Cairn Lanka (Pvt) Ltd, “Introduction to Petroleum Geology, Exploration and Drilling”, **2010**
5. Cairn Lanka (Pvt) Ltd, “SL 2007-01-001 Integrated Appraisal Plan Dorado & Barracuda”, **2013**.
6. Gamage, S.S.N., Ratnayake,R.M.T.S.,Senadhira, A., Weerasinghe, D.A., and Waduge, V.A., **2018.** Radioactive and Non-Radioactive Element Analysis of Dorado Gas Discovery of Sri Lanka and Their Influence on Natural Environment, *Journal of Tropical Forestry and Environment*,8(1), 55-63.
7. Ratnayake, R.M.T.S., Gamage,S.S.N.,Senadhira, A., Weerasinghe, D.A. &Waduge, V.A., **2017**. NORM Analysis of the Reservoir Sand Section in the Dorado Natural Gas Discovery, Mannar Basin Offshore Sri Lanka, *Journal of Geological Society of India*, 89 (6), 683-688.
8. Silva, K.C.C., Gamage, S.S.N., and Weerasinghe, D.A., **2018**. Digitizing Scanned Seismic Sections of the Southern and North Eastern Indian Ocean Regions Adjoining Sri Lanka. *Proceedings - 34th Technical Sessions of Institute of Physics Sri Lanka, p.51-57.*
9. Toyo Engineering Corporation Sumitomo Corporation, Study on the urea fertilizer complex project in the republic of Mozambique, **2012**.
10. Ratnayake, A.S.,Sampei, Y., and Kularathne, C.W.. Current status of hydrocarbon exploration in Sri Lanka, **2017.**