LNG IMPORT OPTIONS STUDY REPORT

Client: The World Bank Group
Project: Libya: Supporting Electricity Sector Reform (PI54606) Task B – Consultancy Service
Subject: LNG Import Options Report
Date: 19/12/2017
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1. INTRODUCTION

The World Bank Group (Owner) has provided a Terms of Reference document outlining the key requirements for the provision of consulting services for Selection# 1227307/ Libya: Supporting Electricity Sector Reform (P154606) - Task-B. Fuel (Natural Gas) Availability, Cost Reduction and LNG Import Options Study.

The World Bank team contracted Tractebel-ECS-TAQA consortium to undertake the study.

The study will provide data to GECOL - the energy sector managing group in Libya (Client) and NOC – the National Oil Corporation for use in preparation of their plan for energy cost reduction, increased efficiency and energy market reform in Libya.

The LNG Options study follows on from the earlier Fuel Availability and Cost Reduction Report and uses the data generated by the report to establish the parameters to be considered when assessing LNG Import Options.

This report has been developed to convey the results of a collection of reviews and studies undertaken on the potential options available to Libya for LNG importation.

2. EXECUTIVE SUMMARY

Considerable fuel cost savings can be made if more power stations were run on gas rather than liquid fuel.

There is insufficient domestic gas supply in the future to meet the forecast demand scenarios and therefore alternative gas sources are required.

Imported LNG can compensate for the shortfall and also provide additional security of gas supply.

Supplementing the existing gas supplies in the West of Libya with a new LNG import terminal could save around an average of 1.8 Billion US$/year in fuel costs (note this figure does not consider the costs of additional infrastructure - pipeline and terminal, required to achieve these savings.

The development of the power station locations does not seem to have been aligned with the ease of connectivity to the existing gas pipelines.

The existing gas pipelines are not capable of providing large capacity flow over long distances due to operating pressure limitations (currently operating at around 34barg – design 52barg).
The conversion of the existing Marsa El Brega LNG export terminal to an import terminal is viable based on utilisation of its land and connectivity. However, very little (if any) of the existing facilities are suitable for re-use and a fully new terminal is the logical way to proceed (being built to latest standards and with current technologies).

Various gas consumption scenarios (based on various power generation scenarios) have been reviewed and modelled against the current coastal pipeline system capacities and pressure limitations and the consensus is that the optimum location for the LNG injection point to suit most scenarios would be in the El Khoms area.

Initial conclusions are that an FSRU with jetty would provide the best short-term solution but with recognition that it may need to be transitioned into a conventional onshore LNG terminal in the future.

<table>
<thead>
<tr>
<th>Options</th>
<th>Cost items</th>
<th>FSRU With buoy</th>
<th>FSRU With single fixed jetty</th>
<th>FSRU With twin fixed jetty</th>
<th>Land based terminal</th>
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<td>CAPEX</td>
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<td>59</td>
<td>69</td>
<td>97</td>
<td>562</td>
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<tr>
<td>Leasing (58.4m/year)</td>
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<td>TOTAL over 5 years</td>
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<tr>
<td>TOTAL over 10 years</td>
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<td>653</td>
<td>681</td>
<td>562</td>
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</tbody>
</table>

Note that the twin fixed jetty solution is suitable for future conversion to suit a land based terminal.

It was noted that there are currently no specific Governmental Regulations or Environmental guidelines for LNG facilities in Libya.

CONCLUSIONS

Immediate/Short term: Improve gas system over 0 to 3 years with compressor station upgrades and “looping” to improve gas flows. Commence reduction in gas supplies to Italy (note that the main improvement “loop” is already under consideration with NOC but lacks funding)

Medium term: Establish an FSRU import terminal to be ready for first gas in 3 to 4 years to provide additional gas via LNG
Long term: Establish an onshore LNG import terminal to take over from the FSRU after 8 to 10 years to be expandable for future higher LNG import requirements (if there is no further development of E&P / reserves).

Establish further dedicated LNG import terminals at Tobruk and West Tripoli as stand-alone options for local gas supply.

3. TERMS AND ABBREVIATIONS

Terms and abbreviations specific to this study are listed hereafter:

- FSRU: Floating Storage and Regasification Unit
- GECOL: General Electricity Company of Libya
- HYSYS: Process pipeline simulation software
- LNG: Liquefied Natural Gas,
- LNGC: LNG Carrier,
- MTPA: Million Tonnes Per Annum
- MMSCFD: Million Standard Cubic Feet per Day
- NG: Natural Gas,
- NOC: National Oil Corporation
- PWC: Price Waterhouse Coopers
- WB: World Bank

4. REFERENCE DOCUMENTS ATTACHED

Appendix 1: LNG Market Overview
Appendix 2: Existing Libya Gas Pipeline System Assessment
Appendix 3: Conversion of Marsa El Brega to Import/Regasification Terminal Assessment
Appendix 4: Site Visit Report
Appendix 5: FSRU LNG Import Terminal Option
Appendix 6: Review of GECOL Study 2016
Appendix 7: Regulatory and Environmental Overview
Appendix 8: List of Conditions for Establishing an LNG Import Terminal
5. PROJECT DESCRIPTION

A key issue for the electricity sector development in Libya is the availability and reliability of less costly fuels such as natural gas. Thus, GECOL is looking for alternatives to secure natural gas supply, increase the reliability of the system and easing the government expenditures.

LNG may prove a feasible alternative to achieve the goals set by GECOL. The supply is abundant and diversified around the globe. In 2016, around 140 MTPA of liquefaction capacity was under construction of which just 50 MTPA are in Australia, and other 62 MTPA are in the Atlantic Basin (mainly in USA and Cameroon). Moreover, the Gulf of Mexico has planned projects for more than 300 MTPA seeking for off-takers. Also, East Africa (Mozambique and Tanzania) has liquefaction projects for 60 MTPA.

Given the oversupply of LNG in sight for the next years, a high level of competition and consequently relatively low prices could be expected. In this regard, GECOL wishes to assess the options for LNG supply to Libya to replace fuel oils for the existing and future power plants.

6. DOMESTIC GAS SUPPLY / DEMAND FORECAST

From the Fuel Availability and Opportunities for Cost Reduction Report it can be noted that in the future gas availability in the East will increase, therefore higher flows to the west could be expected.

The gas supply projection also assumes that there is enough stability and security in Libya to allow the return of international contractors and service companies and that the necessary funds are available to complete the energy Projects noted in the projections.
7. STUDY OBJECTIVES

The objective of this study is to assess LNG import options in Libya.

In order to achieve this objective, the following tasks have been undertaken:

- Conduct a broad assessment of the LNG market (value-chain, supply/demand, terminal technologies, pricing and commercial/contractual terms) and feasibility of a new LNG import terminal for Libya.
- Review the existing gas pipeline network, gas feed projections and end user gas consumptions and model various scenarios to assess restrictions, flow and most beneficial gas injection point from an LNG import terminal.
- Undertake a site visit at various locations / existing port facilities along the Libyan coast and assess the potential suitability and constraints.
- Review potential LNG terminal configurations that could be applied for the import of LNG to Libya. Make a general comparison of these conceptual configurations and assess an appropriate location for the terminal taking into consideration potential site conditions and constraints as well as the gas pipeline system technical assessment for the gas injection point.
- Review the regulatory and environmental situation in Libya with respect to importing LNG for any potential issues that could be a constraint.
- Review the tasks that need to be completed for the establishment of an LNG import terminal and the data requirements necessary to perform a detailed engineering cost estimate for the facility.
8. LNG MARKET ASSESSMENT

Refer to the attached specific report in Appendix 1 – LNG Market Overview.

According to the Fuel Availability and Cost Reduction report, LNG may prove a feasible alternative to secure natural gas supply, increase the reliability of the system and easing the government expenditures.

There are various positive aspects of importing LNG. On the one hand, LNG provides high reliability since supply is abundant and diversified around the globe, which ensures that it would be available. On the other hand, while LNG may or may not be tied to petroleum its price is usually lower than liquid fuels. Also, it is an environmentally friendly fuel.

However, in order to develop a LNG import solution Libya would need to address issues such as:

Credit: To have an interesting portfolio of potential LNG suppliers Libya needs to demonstrate sustainable credit worthiness.

Security: The lack of security could make LNG traders and FSRU providers extra cautious in order to protect their investments. Thus, projects could be delayed or even cancelled if suitable assurances for all counterparties is not provided.

Developed regulatory framework: Not only regarding third parties’ participation, but also related to how the LNG is dispatched and allocated to power plants to provide a clear and predictable demand and optimize the use of the import terminal.

Stakeholders alignment: To have fast implementation it is necessary to have everybody involved and aligned with the overall objectives and philosophies.

9. GECOL STUDY REVIEW

Refer to the attached specific report in Appendix 6 – Review of GECOL Study 2016.

The actual gas availability and consumption forecast scenarios between the GECOL study in 2016 and those determined by PWC in consultation with GECOL in 2017 for the current study are not aligned and therefore the studies cannot really be compared.
10. GAS NETWORK ASSESSMENT

The above map shows the current natural gas system/distribution network that is largely based on the 34" Coastal Gas Pipeline.

This gas distribution system suffers from pressure constraints, compression facility problems and lack of connectivity to existing and planned power plants.

The domestic gas supply is also limited and cannot provide the quantities required to fuel the future power demand projections in place of liquid fuel.

Refer to the attached specific report in Appendix 2 – Existing Libya Gas Pipeline System Assessment.

Also refer to the attached report on providing a gas pipeline from Benghazi to Tobruk and to the site visit report on the potential for direct LNG import to Tobruk and West Tripoli.

YEAR BY YEAR ANALYSIS (Summary extract from Appendix 2)

Year 2018 and 2019

Lack of gas supply to be compensated by reducing export to Italy and reducing bottlenecks in existing gas pipeline system.

Prepare Al Washka and Sedra compression stations for operation (to allow potential for gas movement East to West – though this could be a high capital cost investment).

Year 2020 and 2021

No lack of gas supply under average conditions. Potential shortages could occur during peak conditions.
Need to restart compression stations in Sedra and Al Washka

Year 2022 to 2024
There is a lack of gas to supply domestic consumers.

This lack of gas may be compensated by reducing export to Italy or install LNG source (FSRU or on shore). If reducing export to Italy, there is enough gas until 2024 and LNG import should be operational in 2025. Note that the commercial implications of reducing the exports to Italy would need to be evaluated.

Year 2025 to 2030
There is a lack of gas to supply domestic consumers.

This lack of gas cannot be compensated by reducing export to Italy

LNG import is needed to be implemented (FSRU or on-shore): capacity of LNG import depends on reducing export to Italy.

Location of imported gas (LNG) on existing pipeline should ideally be between El Khoms and Tripoli.

Conclusions.
From 2018 to 2024 the issue is the constraints of the gas network system rather than a lack of domestic gas. Efforts should be made on de-bottlenecking the system and restarting the existing compression stations in Sedra and Al Washka plus assessing the extent of gas export to Italy

From 2025 gas import (LNG) is required to compensate for the lack of domestic gas supplies.

If reduction of export to Italy is not acceptable then gas import (LNG) should be in place in 2022.

11. CONVERSION OF EXISTING LNG TERMINAL

Refer to the attached specific report in Appendix 3 – Existing Marsa El Brega LNG export / liquefaction terminal conversion to import / regasification terminal.

As the terminal was built around 50 years ago, it is based on old technology and is not designed to current safety standards

The marine facilities are not currently suitable for modern large capacity LNGC’s

The LNG storage tanks, LNG systems, equipment, infrastructure, materials and facilities are at the end of their design life.
The facility has not been used for LNG since 2011 and therefore the tanks and systems have been allowed to warm up to ambient temperature and may be difficult to return to safe cryogenic service after a downtime of perhaps 10 years (assuming return to operation in around 4 years).

The information available on existing LNG facilities suggests that some parts of the existing facilities could potentially be re-used for the new LNG import terminal such as the marine infrastructure, utility systems, sea water system and buildings.

All other components would need to be new build.

The re-use of existing facilities and equipment that has already been in use for almost 50 years and no longer complies with current design codes, standards and international industry standards is not recommended.

It would be difficult to integrate new equipment and systems with old and could lead to breakdowns and reduced safety levels.

The site is viable as a suitable location for the new import terminal and the area is sufficient and already developed for the key marine requirements (with modification).

However, from the gas system analysis the Marsa El Brega location is not the most suitable additional gas injection point and therefore it is not recommended to site an LNG Import Terminal there. The high gas demand is in the West and it also requires high capital cost investment to send gas East to West.
12. SITE VISIT

NOC and GECOL target is to have an injection point for natural gas through the gas transmission system rather than direct feed to a specific power plant.

This way they will guarantee a security of supply and can feed most of their other power plants.

Having a dedicated LNG terminal for a single power plant at Sirte or Tripoli West was initially considered as they are large consumers, but this was rejected as not being the optimum solution.

Ideally NOC and GECOL prefer to connect the LNG injection point(s) to some point on the coastal side with some suggestions of having a bi-directional facility into the pipe line to make it possible for each side (East and West) to handle the amount of gas to be transferred but still keeping within the technical operational and pipe line capacities requirements.

Initial discussions with GECOL/NOC on potential locations resulted in 4 proposed sites to review:

- Marsa El Brega: Conversion from export to import terminal at existing site
- Misurata: FSRU
- Al Khoms: FSRU
- Mellitah: FSRU

It was determined that the Mellitah site would not provide the potential for injecting gas from the LNG Project to the Eastern part of the pipeline and was therefore not considered further.

Marsa El Brega provides a very suitable site for an onshore LNG terminal (and potentially for an FSRU terminal) and a study was undertaken to assess what would be required to convert the export terminal to a long term onshore import terminal. – Refer to separate report in Appendix 3.

Misurata and Al Khoms were considered as the most suitable pipeline entry point locations and therefore the potential site areas were investigated further for placement of an FSRU terminal.

Following further discussions, it was agreed that Marsa El Brega was not the most suitable location for a new gas injection point via LNG and therefore it was agreed with GECOL and NOC to visit the following 5 sites:

- TOBRUK PORT: Check if a dedicated LNG import terminal could be established in the area for the local Power Plants
- AI KHUMS PORT: Check if a suitable location was available for an LNG import terminal to tie in to the coastal gas pipeline
MISURATAH PORT  Check if a suitable location was available for an LNG import terminal to tie in to the coastal gas pipeline

AL WASHKA AREA  Check if a suitable location was available for an LNG import terminal to tie in to the coastal gas pipeline

WEST TRIPOLI AREA  Check if a dedicated LNG import terminal could be established in the area for the local Power Plants

From the site survey undertaken of the five potential site areas and a review of the existing Marsa El Brega LNG Terminal assessed against the key LNG import terminal marine requirements of LNGC access, safety distances, mooring and berthing facilities and the minimum 14mt draft required it is evident that the existing port infrastructures are not compatible with the implementation of a fast track LNG Import Terminal.

Each location has constraints or potential connectivity issues.

Refer to the attached specific report in Appendix 4 – Site Visit Report.

It will therefore be necessary to either extensively modify existing port facilities or establish new dedicated facilities for LNG import.

From the review of the sites visited there could be potential locations available to build a new terminal in the same general area, however it is important to establish the LNG import terminal type to suit the likely long term strategy, gas supply demand and gas availability requirements as these factors significantly affect the choice of LNG terminal configuration, and to ensure that the proposed location is suitable for the technical gas system and distribution requirements for capacity, flow and pressure.

13. SITE SELECTION

Following the site visits and the gas system technical review where various gas consumption scenarios (based on various power generation scenarios) have been assessed and modelled against the current coastal pipeline system capacities and pressure limitations the consensus is that the optimum location for the LNG sourced gas injection point to suit most scenarios would be in the Al Khoms area.

Also refer to the attached report on providing a gas pipeline from Benghazi to Tobruk and to conclusions reach in the Fuel Availability and Cost Reduction Report where it is shown not to be economically viable. In such a case it could be viable in the future to develop a specific LNG terminal in the Tobruk area to provide gas directly to the local power stations rather than from the existing gas pipeline network.
A similar problem exists in providing gas to West Tripoli due to the congested, built up area between the gas pipeline network and the power stations – a specific dedicated LNG terminal in that area could be viable.

14. NEW FSRU LNG IMPORT TERMINAL

Refer to the attached specific report in Appendix 5 – FSRU based LNG Import Terminal for general technical information, potential configurations and cost / schedule estimation.

15. NEW LNG IMPORT TERMINAL CONFIGURATION

There are several LNG Import Terminal configuration options:

- Conventional onshore terminal with single LNGC berth and LNG lines on jetty
- FSRU with Fixed jetty – single berth (ship to ship LNG transfer) gas pipeline on jetty
- FSRU with Fixed jetty – twin berth (ship to jetty LNG transfer) LNG and gas lines on jetty
- FSRU with no jetty – buoy and subsea gas pipeline (ship to ship LNG transfer
- FSU with Fixed jetty – twin or single berth and LNG lines on jetty with onshore regasification facilities

Each have their own merits and constraints.

For Libya it is important for GECOL and NOC to determine the most suitable strategy for LNG import prior to committing to a particular configuration.

An FSRU provides the quickest, cheapest and most flexible initial solution but does not offer the best long-term value if the terminal is to be in operation for more than 10 years.

A transitional solution may be the best option whereby the FSRU solution is developed but with a design basis such that it would not impede the transition to a conventional LNG jetty with onshore terminal in the future.

16. REGULATORY AND ENVIRONMENTAL OVERVIEW

Refer to the attached specific report in Appendix 7 – Overview of Libyan Regulatory & Environmental Conditions
There are currently no specific Governmental Regulations or Environmental guidelines for LNG facilities in Libya.

The LNG export plant at Marsa El Brega was designed and operated under the Esso company regulations.

The Energy council for Libya therefore needs to establish its own regulatory framework for LNG facilities.

17. CONDITIONS FOR IMPLEMENTATION OF AN LNG IMPORT TERMINAL

Refer to the attached document in Appendix 8 – List of actions/conditions necessary to develop an LNG Import Terminal Project.

This list was reviewed as part of the training workshop with WB, GECOL and NOC where it was modified to take into account some specific points raised by the team.

18. CONCLUSIONS & RECOMMENDATIONS

Considerable fuel cost savings can be made if more power stations were run on gas.

There is insufficient domestic gas supply in the future to meet the forecast demand scenarios and therefore alternative gas sources are required.

Imported LNG can compensate for the shortfall and also provide additional security of gas supply.

The development of the power station locations does not seem to have been aligned with the ease of connectivity to the existing gas pipelines.

The existing gas pipelines are not designed to suit large capacity flow over long distances due to operating pressure limitations.

Two of the three main compression stations on the 34” coastal pipeline are not working and require upgrading and refurbishment.

Two existing Power stations in the East of Libya – Darna and Tobruk are already over 30 years old and are not considered suitable for conversion to gas.

Residential / industrial demand is not an anchor/driver for the development of gas pipelines in Libya (its demand is low compared with power generation).

The cost for a new gas pipeline from Benghazi to Tobruk is considered prohibitive due to distance and terrain and does not seem to be economically viable. Estimated cost of a new pipeline connection from Bengazi is US$1.5 billion.
The technical viability of installing a new gas pipeline along the shortest route from the existing coastal pipeline to the new power stations in Tripoli is challenging and may not be commercially viable.

The conversion of the existing Marsa El Brega LNG export terminal to an import terminal is viable based on utilisation of its land and connectivity. However, very little (if any) of the existing facilities are suitable for re-use and a fully new terminal is the logical way to proceed (being built to latest standards and with current technologies). However, the gas consumer analysis has indicated that an LNG terminal gas injection point is not required in this area.

A site visit to 5 potential LNG import terminal locations has found that there are no existing infrastructure facilities available that would allow a fast track implementation of an import terminal. Each area would require investment in new import terminal infrastructure.

Several potential LNG Import terminal configurations seem viable:

- FSRU with Buoy and subsea gas pipeline with ship to ship LNG transfer
- FSRU with a single fixed jetty and ship to ship LNG transfer
- FSRU with twin jetty and cross jetty LNG transfer
- FSU with onshore regasification facilities and ship to ship transfer
- Conventional onshore LNG terminal

Each will need to be assessed on a site-specific basis in line with overall LNG import strategy.

Initial conclusions are that an FSRU with jetty would provide the best short-term solution but with recognition that it may need to be transitioned into a conventional onshore LNG terminal in the future.

Various gas consumption scenarios (based on various power generation scenarios) have been reviewed and modelled against the current coastal pipeline system capacities and pressure limitations and the consensus is that the optimum location for the LNG injection point to suit most scenarios would be in the El Khoms area.

Given the above factors is seems that the following points should be considered with regard to LNG Import options:

**SHORT TERM**

- Continue to review gas send-out options to Italy and divert this gas to the power plants
- De-bottleneck the existing pipeline through investment in additional pipeline routes to bypass restrictive areas
- Develop the feasibility and FEED for an LNG Import Terminal (FSRU type due to timeframe requirements and potential flexibility) in the area near El Khoms and fix the configuration and site location

**MEDIUM TERM**
Supplement the existing gas supplies in the West of Libya with the implementation of a new FSRU based LNG import terminal with a design that could allow future expansion and development into a conventional onshore LNG terminal.

LONG TERM

Encourage investment in domestic gas production to provide additional gas where possible

Transition the FSRU type LNG terminal into an onshore LNG terminal

Develop the feasibility and FEED for providing a further dedicated LNG import terminal (FSRU type) to feed the Power plants in the Tobruk area.

Develop the feasibility and FEED for providing a further dedicated LNG import terminal (FSRU type) to feed the Power plants in the West Tripoli.

19. BASE DATA FROM GECOL & NOC

The following information / data have been provided by GECOL and NOC as baseline reference documentation for the development of the study:

From GECOL

LNG Import Study 2016 from GECOL
List of Consultant Required Data Excel Spreadsheet
Power Station Type Excel Spreadsheet

From NOC

34” Coastal Pipeline System Report 21/03/2017
PP Presentation Data for GECOL Study
PP Presentation Data for GECOL Study 2
PP Presentation Data for GECOL Study 3
Libya Natural Gas Supply / Demand Balance Excel Spreadsheet