STUDY ON ECONOMIC PARTNERSHIP PROJECTS IN DEVELOPING COUNTRIES IN FY2012

STUDY ON THE METHANOL PRODUCTION PROJECT UTILIZING INDIGENOUS NATURAL GAS IN THE REPUBLIC OF MOZAMBIQUE

FINAL REPORT

【SUMMARY】

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Prepared for:
The Ministry of Economy, Trade and Industry
Ernst & Young ShinNihon LLC
Japan External Trade Organization (JETRO)

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1) Background of the Project

Following the Pande/Temane gas fields already in commercial production, in the Republic of Mozambique, large natural gas reserves have been identified in recent years in northern seabed (Rovuma Basin). Whereas export by liquefied natural gas (LNG) is studied, it is the intention of the Government of Mozambique (GoM) not only simply liquefy and export gas as it is but also to utilize it as raw material to gas based industries or to devote some portion to domestic fuel and gas to attract the related industries to northern territories. This is based on the national policy to try to utilize natural gas for domestic contribution by development and diversification of the domestic industry, increase of intellectual employments, transfer of technologies and dedicating to domestic demands. This study is intended to investigate the commercialization of chemical methanol production projects using natural gas as raw material in Mozambique.

Methanol is the most basic and large-scale industrial chemical materials to be produced only with natural gas and water. Like Saudi Arabia about 30 years ago, what has been firstly introduced by gas-producing countries aiming at gas-chemical industry is methanol. Its world demand is about 55 million t/y, approximately 70% is consumed as chemical and 30% is as fuel. As chemical appliances, it is processed to and consumed as pharmaceuticals, agricultural chemicals, adhesives, synthetic resins and fibers through various derivative products. As fuels, it is processed to and consumed as dimethyl ether (DME) or bio-diesel (BD) and direct blend of methanol into gasoline or the process has also been established to produce gasoline from methanol. Because of these background, in March, 2012, executives and engineers (Delegation) of Petromoc, ENH and the Ministerio dos Recursos Minerais (MIREM) were invited by the Ministry of Economy, Trade & Industry (METI) of the Government of Japan (GoJ) to Japan solely on this specific Project at METI’s budget and Marubeni’s coordination. Delegation visited Marubeni and its technical supporters, Mitsubishi Gas Chemical Company Inc (MGC), Mitsubishi Heavy Industries Ltd (MHI), Mitsui O.S.K. Lines, Ltd (MOL) and Isuzu Advanced Engineering Center, Ltd (Isuzu) to look at their proprietary state-of-the-art technologies of Japan and the unrivaled know-hows, experiences and records essentially required to successfully implement and operate a new methanol project in Mozambique. Delegation visited also ministries and institutes of GoJ, the METI (where they were met by its deputy minister), Japan External Trade Organization (JETRO), the Ministry of Foreign Affairs (MOFA) and Japan International Cooperation Agency (JICA). The Ambassador of the Republic of Mozambique in Japan joined, too.

2) Background of Implementing Methanol for Emerging Gas-Producing Countries

Methanol (MeOH) is the most basic industrial hydrocarbon and has following characteristics:

a. It is produced from natural gas with only water. Nothing else is needed unlike, for example, producing urea needs gas, water and nitrogen.

b. The output methanol is clean and transparent liquid which is stored and transported relatively more simply and less costly than, for example, urea which is output as hot and sticky solid.
c. A methanol project, therefore, requires relatively smaller investment cost than, for example, a urea project of similar size in terms of gas consumption.

d. Methanol yields various chemical derivatives indispensable to sustain modern human lives for housing (adhesive), wearing (synthetic textile), eating (pesticide) or health (medicine). Its demand ever grows and can be replaced by none in reality.

e. Methanol is extensively transported and traded from gas-producing countries where it is mostly produced to developed countries and recent China where it is mostly consumed. Inter-continentially traded market is remarkably big as a chemical product.

f. A substantial amount of methanol is consumed also as fuels as it is or as processed into synthetic fuels such as BD, DME or gasoline.

For these fundamental features, when gas-producing countries for the very first time aimed at gas-based chemical industry to give added-value to their gas, be transferred technologies and know-hows and give their local people intellectual jobs, methanol has been thought of and often implemented.

3) Methanol in Sub-Saharan Africa

Sub-Saharan Africa has only one methanol plant in Equatorial Guinea. It was commissioned in 2001 with the capacity of 2,500t/d with Japan’s MGC’s license technology (Mitsubishi Methanol Process).

4) Japanese Technologies, Records and Know-hows

This group of Japanese companies is capable of providing their own technologies, know-hows and experiences, of the world finest standard, covering the whole value-chain of methanol from its head really down to the toe. No other country is positioned to do so. They cover the conceptual formation of the Project design and construction of plants, critical equipment made in Japan, own license technology and catalyst of methanol synthesis, operation and maintenance of plant, shipping, off-taking, re-distributing and marketing methanol, established customers base, strategies and know-hows of local-contribution and, at the last but not the least, training and transfer of various skills and knowledge to Mozambican employees.
5) Human Resources

To increase employment and expand access to training and education are important challenge for Mozambique and securing skilled local labor is very critical to the success of the Project. Expected employment and transfer of skill in the project are as shown below.

a. JV of methanol production needs to hire about 160 people including 1 general manager, 5 managers, 15 superintendents, 10 engineers, 40 supervisors, 10 secretaries and 80 operators approximately.

b. Around the timing of mechanical completion and plant start-up, 10 or more Japanese engineers will be sent by MGC and MHI and after that about 4 Japanese will stay to supervise the stable operation. Mozambican employees will be progressively trained by and transferred required technical skills from these Japanese engineers and supervisors.

c. At the time of construction, maximum 3 to 4 thousand workers are employed.

6) Local Contribution

Having started and successfully stabilized methanol production, Mozambique may think of policies to dedicate made-in-Mozambique methanol directly to local people and community. Because it produces gas but not oil, methanol could be a tool to transform made-in-Mozambique gas to meet local liquid-fuel demand.

a. Direct Blend of Methanol into Gasoline
   
   - Methanol itself has octane number of 112 and can be considered as an octane booster of gasoline in this regard.
   - However, since methanol is an alcohol mixing with water indefinitely, too much methanol content in gasoline may bring too much moisture into internal combustion systems and cause corrosion. This is dangerous. So,
Mozambican authority may legally put a regulation of maximum methanol content in gasoline and strictly manage it, possibly with reference to experiments or experiences in other countries such as Japan.

b. Dimethyl Ether (DME)

- DME is a very environmentally-superior synthetic fuel which is relatively easily manufactured from methanol to substitute LPG or diesel. DME has even higher cetane number than diesel oil, however, DME which is gas cannot be stored in normal diesel tanks. When DME is used as a mixture with LPG, burning appliances shall be adjusted according to LPG/DME mixture. In these regards, Mozambique can utilize know-how of other countries such as Japan.
- MGC built, owns and operates a commercial plant with MGC's own technology of DME (80,000 t/y) in its Niigata Factory where in March the Delegation visited and looked at.

c. MTG (Methanol to Gasoline)

- MTG is the process to synthesize methanol into gasoline which was originally developed by Mobil Oil of USA.
- Gasoline of about 8,100 BD, and 120 t/d of LPG as a by-product, will be produced from planned 2,500 t/d of methanol.

**Figure 2: Process of Methanol to Gasoline**

7) Required Factors

The Project (2,500 t/d of methanol) requires following factors.

a. Gas: The Project requires about 80MMSCFD (million standard cubic feet a day) or 0.5TCF (trillion cubic feet) over its life of 20 years.

b. Water: Supposing the Project on its own shall supply desalinated water for processing and cooling, it requires intake of about 3,800 t/h and abandonment of 3,300 t/h of sea water.

c. Power: The Project requires to buy about 80,000kWh under stable operation, unless it is better to generate power on its own.

d. Labor: As already mentioned, the Project needs about 160 skilled labor in addition to those who will be directly
engaged in construction works and so on.
e. Land : The Project requires about 20ha.
f. Jetty : Supposing methanol tankers of 45,000DWT off-take methanol from the Project, they need draft of 12 meters or so. These tankers may be accommodated by the Project with its own floating-buoy even if no other permanent quay is provided by some external local infrastructure authority.

(2) Basic Policy of Forming the Project

1) Implementation Policy of the Government of Mozambique
MIREM is developing Natural Gas Master Plan for Mozambique (GMP) to analyze current situation of gas reserves and illustrate the basic principles and implementation strategies of how to utilize the natural gas resource of the country. As gas utilizing projects, fertilizer, gas-to-liquids (GTL), power generation and methanol are listed in addition to LNG in the GMP. This basically says that the GoM must consider not only simply selling gas as it is (LNG) for money (which is of course valuable) but also utilizing gas in Mozambique for its society and people.

2) Issues to be examined to implement the Project
Securement of land, feed gas, measure of landing for machinery and measure of export of products, product marketing and financing are issued to be examined in order to implement the project.

(3) Overview of the Project

Followings are supposed for the project:

1) Required feed gas:
   Around 80 MMSCFD of Natural gas produced in Mozambique for 20 year operation (1 line). Amount volume of the gas for 20 years is 0.5 TCF.

2) The scale of the plant (production capacity):
   2,500 t/d  (850,000 t/y) which is the current standard world-scale of the Mitsubishi Methanol Process (MMP)\(^1\) and many plants of this size have been designed and constructed by MHI.

3) Synthetic technology of methanol and catalyst
   MMP which is synthetic process developed by MGC and MHI and catalyst produced by MGC

\(^1\) The largest scale of the Mitsubishi Methanol Process on-stream in Saudi Arabia is 5,000 tons per day. It will still be too early to introduce this largest plant in Mozambique which has experienced no chemical industry yet.
4) Plant construction

Engineering, Procurement and Construction (EPC) by Mitsubishi Heavy Industries, Ltd (MHI)

5) Candidate site

There are some candidate sites proposed by partners of Mozambique:

a. Palma: It is a small town located on the most northern coast of Mozambique close to the border with Tanzania. It is adjacent to the Rovuma gas fields. Other gas-based projects such as LNG are also considered in this area. However, there is virtually no modern industrial and civil infrastructure yet today.

b. Nacala: It is a port city located on the northern coast of Mozambique. It has one of the deepest and the best ports on the Indian coast of Africa, about 200,000 inhabitants and some modern industry such as cement. It is going to be the basement of the ProSavana project committed by two governments of Mozambique and Japan and being developed by Japan International Cooperation Agency (JICA). There is no gas fields near this area therefore pipeline from Palma is necessary to implement the project.

c. Beira: This coastal city is located at center of the country which has the second largest number of population. The existing port functions as a key junction of transportation to inland but expansion of capability of logistics will be required to promote new industry. In order to implement the methanol project, new pipeline is necessary to feed natural gas.

d. Vilankulo/Inhassoro: This area is located closely to Pande/Temane gas fields already producing natural gas. Basically all of gas today is committed to export and other civil utilization. However, if some additional volume of gas output can be implemented at Pande/Temane, such gas may possibly be processed into methanol. Both Vilankulo and Inhassoro are located in Inhambane province and have similar condition and environment for the study of the project therefore these sites are considered as a whole.

The final location of the Project will be determined in accordance with their pros and cons and the policy of the government of Mozambique.

6) Evaluation of Environmental and Social Impacts

There is no critical problem in environmental and social aspects for the implementation of the project. However, further studies will be conducted after the project site is decided.
Figure 3: Environmental Impact Assessment (EIA) process

EMP: Environment Management Plan

Source: Illustrated by Study Team based on the document provided by Impact Lda
7) Required Investment Cost (interest during construction excluded)
The required investment costs are projected as follows.

<table>
<thead>
<tr>
<th>CAPEX</th>
<th>Methanol Plant EPC</th>
<th>(million dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Engineering</td>
<td>50.0</td>
<td>620.0</td>
</tr>
<tr>
<td>- Procurement</td>
<td>330.0</td>
<td></td>
</tr>
<tr>
<td>- Construction</td>
<td>240.0</td>
<td></td>
</tr>
<tr>
<td>Owner’s Cost</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>Provisional Sum</td>
<td>152.0</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>778.8</strong></td>
</tr>
</tbody>
</table>

Source: Prepared by Study Team

8) Cash Flow Analysis
The result of preliminary financial and economic analyses is as following.

<table>
<thead>
<tr>
<th></th>
<th>Financial Cash Flow</th>
<th>Economic Cash Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRR</td>
<td>Financial-IRR : 16.0%</td>
<td>Economic-IRR : 16.3%</td>
</tr>
<tr>
<td></td>
<td>(5 Years Coupon Bond : 17%)</td>
<td>(Alternative Project’s IRR : 14%)</td>
</tr>
<tr>
<td>NPV</td>
<td>256 million US$</td>
<td>270 million US$</td>
</tr>
<tr>
<td>B/C</td>
<td>201%</td>
<td>204%</td>
</tr>
</tbody>
</table>

Source: Prepared by Study Team

F-IRR, indicating the financial profitability of this Project, is resulted in 16.0% which is 1% below 5 Years Coupon Bond in local currency (17%). On the other hand, E-IRR, which explains the comprehensive economic profitability given by not only this Project but also the incidental economic activities, was 16.3%. We observe this E-IRR is 2% higher than the 14% of the IRR given by an alternative project, as which we assume the domestic natural gas is utilized for the production and sales of fertilizer in Mozambique. As result, in the case of basic preconditions above (the natural gas price at 3.5 US$/MMBTU and methanol sales price at 417 US$/t), the financial feasibility of this Project resulted little less feasible than the local currency bond. However as it can be observed in the following sensitivity analysis, the feasibility of this Project significantly depends on the gas price and methanol sales price. Hence, it is indispensable to continuously watch the change in supply-demand balance and price trends of natural gas and methanol in the global market, which is an uncontrollable environmental factor.
(4) Implementation schedule of the Project

As soon as this report will be issued to two governments of Mozambique and Japan, Japan side and Mozambique side are supposed to enter into discussion to try to tentatively agree mainly on following issues.

1) Gas Supply: How much volume of gas can be allocated to this Project in which place by whom over how many years from when under which sort of conditions (price, quality etc)

2) Joint Venture (JV): A JV is supposed to be established by Mozambique and Japan sides to assume the Project. The principles of this JV, such as equity shares, shareholders’ key rights and obligations, JV’s basic strategy of plant construction, product marketing or finance procurement, shall be discussed and agreed by both sides.

3) Project Scope: In addition to methanol plant, if other plants of utilities supplies, for example, shall be constructed, owned and operated by the Project itself or placed outside of the Project shall be discussed and determined.

Suppose these issues will be tentatively agreed in the end of 2013, thereafter the implementation schedules are illustrated by the table below. In such a case, Year-1 means the year of 2013. Therefore, the plant is projected to start in mid of the year of 2018.

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Q</td>
<td>2Q</td>
<td>3Q</td>
<td>4Q</td>
</tr>
<tr>
<td>Pre-Feasibility Study</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
<tr>
<td>Feasibility Study (FS)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
<tr>
<td>Government Approval for FS</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
<tr>
<td>Project Company Establishment</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
<tr>
<td>Gas Supply Agreement (Gas Allocation Approval)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
<tr>
<td>EIA</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
<tr>
<td>Land Lease Agreement</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
<tr>
<td>Development Plan</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
<tr>
<td>EPC Contract Proposal/Clarification/Negotiation</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
<tr>
<td>Financial Arrangement</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
<tr>
<td>EPC Contract Award/EPC Start</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
<td>(based on Info)</td>
</tr>
</tbody>
</table>

Source: Study Team

The Project targets at starting its methanol plant in about 4.5, or maybe 5, years after the time when the allocation of feedstock gas will be given by the Government of Mozambique (GoM) to the Project and other fundamental and major concepts of the Project will be mutually agreed, tentatively but very formally, between Mozambican and Japanese sides.

a. Then, the FEED (front end engineering design), EIA (environment impact assessment), actual financial procurement
and such other fundamental and practical works will start and be complete in 1.5 years as the target.

b. Then, subject to the results of such work, the legally-binding FID (the Final Investment decision) shall be made by the Mozambican and Japanese sides to effectuate the JV agreement, gas supply agreement, EPC (Engineering, Procurement and Construction of plants), finance and other critical contracts.

c. The construction work of plants is expected to be complete in about 3 years after the FID. Building new methanol tankers in basic takes about 2 years after the FID.

(5) Feasibility and, if feasible, further required actions for the Implementation

As mentioned already, the strategy itself of trying methanol by newly emerging gas-producing countries is normal and has many precedents.

This Mozambican case can be supposed to be feasible since the required elements for successful new implementation of methanol in the country, as mentioned already, operational support and bankability, are supposed to be provided by Japan side.

No other country is in the position to be able to provide these elements comprehensively and credibly evidenced by actual records and experiences.

The required actions towards implementation are already mentioned as above.

(6) Superiority of Japanese Technologies, Experiences, Records etc

The Mitsubishi Methanol Process is very well commercially proven technology and has many records in many places of the world. Its ultra-modern reactor, the Superconvertor, and the catalyst manufactured by Mitsubishi Gas Chemical on its own of methanol synthesis perform better than other national technologies and catalysts. More details shall be referred to in other parts of this report.

(7) Required Regulations to be met and Potential Risk of Obstructing the Implementation

From a viewpoint of the location for a proposed site, the following is mentioned as a subject.

1) In Palma, quite sizable gas reserves are found but must be commercially developed from now on. Palma currently has virtually no modern industrial and civil infrastructure.

2) Nacala, on the contrary, has such infrastructure but no gas source near-by. In this case, gas pipe-line must be laid from perhaps Rovuma gas fields for straight distance of about 500km.

3) Vilankulo’s gas reserve is relatively small and already committed. If some additional gas reserve will be confirmed and become available for industrial utilization in Mozambique is not still for sure.
For these reasons, it may possibly take time to take above mentioned action steps. However, this phenomenon could often be the case in many other developing and emerging gas-producing countries and is basically understandable and acceptable to the Japan side.
(8) Map of Candidate Sites (with scale)

Source: Prepared by Study Team based on Google Map
Nacala

Source: Prepared by Study Team based on Google Map
Source: Prepared by Study Team based on Google Map
Vilankulo/Inhassolo

Source: Prepared by Study Team based on Google Map