PLANNING & MODELING UNDER UNCERTAINTY –
DEVELOPMENT OF THE MOZAMBIQUE NATURAL GAS MASTER PLAN

by

Lex Huurdeman, Senior Expert
Oil, Gas and Mining Policy Unit, SEGOM - World Bank
1818 H St NW, Washington, DC 20433
Phone: +1 202 473 4805 Email: ahuurdeman@worldbank.org

Ananth Chikkatur, Manager
ICF International
9300 Lee Highway, Fairfax, VA 22031
Phone: +1-703-218-2593 Email: Ananth.chikkatur@icfi.com

Leonard Crook, Vice President
ICF International
9300 Lee Highway, Fairfax, VA 22031
Phone: +1-703-934-3856 Email: Leonard.Crook@icfi.com

Abstract

Many developing countries have abundant natural gas resources, but they often lack the technical or financial ability to develop these resources, have no indigenous market for gas, or the infrastructure to use the gas. The governments of the developing countries view the newly discovered gas resources as a way to promote greater economic development by integrating gas into their economy. Many international development organizations, including the World Bank, have been encouraging developing countries to produce gas master plans (GMP) to guide public policy and investment to enable the widespread use of gas and promote economic development.

In 2012, ICF International (ICF) developed a GMP for the Government of Mozambique (GOM) under the guidance and support of the World Bank. The Mozambican GMP called for the GOM to make only those decisions at present that are critical to progress the development of the gas sector, and recognize that many other decisions about the gas sector development will benefit from having more accurate information and will have to be made in the future as that information becomes available. Expediting the development of LNG for export is a critical perquisite for promoting economic development and local gas use. Finally, the GMP called for the GOM to develop and implement a communications strategy, with transparency being the primary element for combating misinformation and managing expectations.

More broadly, there a number of lessons for future GMPs that can be based on the Mozambican GMP. These include the inclusion and active participation of key government ministries in the process; assessment of the state of the economic data available for analysis; solicitation of necessary data from international oil companies (IOCs) for resource and supply assessment; active participation by government in the analysis and modelling process; and planning for implementation of GMP decisions, early in the GMP process.

1 The findings, interpretations, and conclusions expressed in this paper are entirely those of the author(s) and do not necessarily reflect the views of the Executive Directors of The World Bank or the governments they represent
Background

Many developing countries have abundant natural gas resources, but lack the technical or financial ability to develop these resources, they have no indigenous market for gas, or the infrastructure to use the gas. Gas discoveries in these countries are often made by international oil companies (IOCs) operating under exploration and production concession contracts with the governments. The IOCs typically aim to develop the gas for LNG export or for large industrial facilities that produce exportable products (e.g., fertilizers, gas-to-liquids, etc.). The governments of the developing countries, which receive royalties and profit sharing from the IOCs, also view the newly discovered gas resources as a way to promote greater domestic development by making gas available to users in the country.

Many international development organizations, including the World Bank, have been encouraging developing countries to produce gas master plans (GMP) to guide public policy and investment to enable the widespread use of gas and promote economic development. A GMP should be seen as a “living” policy document that sets out a vision, objectives, strategic plans, policies, and implementation action plans. In general, the GMP should serve as a roadmap for development of natural gas production, transportation, and domestic natural gas markets in a country. The GMP would however initially not be a complete technical plan for gas sector development, rather, it is should provide a detailed roadmap for strategic, policy and institutional decisions upon which investments can be designed and implemented in a fully coordinated manner.

Natural Gas in Mozambique

In 2010 and 2011, Anadarko Petroleum and Eni—two major IOCs—announced discoveries of over 100 Tcf of natural gas in the offshore Rovuma basin, in the northern part of the Mozambique. These are significant “world class” resources that make possible the development of large LNG liquefaction and export centers in the area around Palma, in the north-western corner of the Cabo Delgado province, close to the Tanzanian border. Two other companies, Statoil of Norway and Petronas, Malaysia’s national oil company, hold off-shore leases to the south of those of Anadarko and ENI. Drilling has not begun in these areas, so the extent of any finds there are still uncertain, but the potential is also thought to be significant. These discoveries have taken place under exploration and production concession contracts (EPCC) signed in 2006 between the IOCs and the Government of Mozambique (GOM).

These projects will be the second major development of Mozambique gas resources. Sasol developed the Pande and Temane onshore gas fields in the early 2000s and with the construction of a pipeline to South Africa, commercial production began in 2004. Pande and Temane, however, have far fewer reserves, estimated at approximately 3.1 Tcf producing approximately 400 million cubic feet per day (MMcf/d). Of this amount about 90 MMcf/d is used in Mozambique. This is the only natural gas used in the country at present. Sasol continues to explore and develop Pande and Temane onshore fields and has initiated exploration activities in the off-shore of Inhambane province.

A potential third gas resource has recently been identified around Tete as coal bed methane. The extent of these reserves is unknown; however, it is believed that they are potentially of commercial size and production potential.

While these gas discoveries are an economic windfall for the GOM, the larger challenge is to develop these resources in a way that brings the greatest benefit to Mozambique—which runs along two main paths: 1) the need to use natural gas development to reduce poverty, and 2) the need to develop a more transparent and responsive process for ensuring these activities are carried out in a sustainable and environmentally benign way. More broadly, there are two ways in which gas can be used to promote development. On the one hand, promoting the development of export-centered LNG projects will greatly add to government revenues through monetization of royalty gas and equity gas. This is revenue that Mozambique can use internally for development. On the other hand, gas can also be used in-kind within Mozambique to promote value-added manufacturing that increases local employment, promotes local businesses, and creates broader benefits across the country. Assessing which of these options (and/or the appropriate combination thereof) was a critical challenge for the GOM.
In 2012, under a contract with the World Bank, ICF International (ICF) conducted an analysis of the strategic options available to the GOM in order to develop a GMP that will identify policy options for maximizing the monetary, social and environmental value of gas to the country. In this paper, we describe the World Bank and ICF’s approach to developing GMP in Mozambique. More details are found in the GMP Final Report (ICF, 2013).

**Mozambique Gas Master Plan – Key Elements**

Under the guidance of the World Bank, the GOM set up a Steering Committee consisting of senior officers from various ministries, including the Ministry of Mineral and Natural Resources (MIREM), Ministry of Energy, Ministry of Planning and Development, Ministry of Industry, Ministry of Finance, Ministry of Agriculture, Ministry of Tourism, Ministry of Labor, Ministry of Environment, Ministry of Transport and Communication, and Ministry of Education. The Steering Committee provided guidance to the ICF Team, as well as reviewed the outputs of the GMP. The Committee was chaired by MIREM.

A key element of the GMP approach was extensive stakeholder engagement. ICF conducted stakeholder meetings with all of the various Ministries, as well as other stakeholders including industry, regulators, geological agencies, civil society groups, banks, donor agencies, and other financial institutions. ICF also presented interim reports and findings to the Steering Committee, and incorporated comments in the draft final report.

An important part of the stakeholder meetings was aimed at developing consensus on the “vision” for the gas sector in Mozambique. The consensus vision statement is shown below as Exhibit 1. The analysis of the GMP and the development of the final recommendations were aimed at realizing this vision. ICF recommended that the vision statement needs to be disseminated as part of a broader communication strategy, highlighting how the GoM intends to take actions on realizing the vision.

**Exhibit 1: Mozambique GMP Vision Statement**

<table>
<thead>
<tr>
<th>GMP Vision Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop natural gas resources in a manner that maximizes benefits to Mozambique society by supporting --</td>
</tr>
<tr>
<td>growth in domestic public and private sector institutional competencies;</td>
</tr>
<tr>
<td>growth in domestic industry and businesses, especially small and medium scale industries;</td>
</tr>
<tr>
<td>increased employment across the country, especially in the less-developed provinces;</td>
</tr>
<tr>
<td>infrastructure to support expanded economic activities, especially in less-developed provinces; and</td>
</tr>
<tr>
<td>expanded access to training and education</td>
</tr>
<tr>
<td>in order to improve the quality of life for the people of Mozambique, while minimizing adverse social and environmental impacts.</td>
</tr>
</tbody>
</table>

Following the initial stakeholder meeting and data gathering, ICF conducted an independent assessment of the natural gas resource base, based on publicly available information on exploration and development and geology. The purpose of this was not to verify what had been discovered, but to assess the potential of additional discoveries that could have great bearing on how the country’s resources would be developed and the investment that would be needed. ICF developed gas supply models of the supply basins in Mozambique, and generated cost supply curves for each basin, which is a schedule of how much gas can be produced from each basin at different prices for the gas. It is expected that as additional exploration and drilling take place, these supply curves can be improved upon with additional information. The cost supply curves were an input into ICF’s larger model for assessing alternative development in Mozambique.
One outcome of the discovery of natural gas has been the appearance in Mozambique of international companies interested in developing large commodity production projects premised on the ability to access cheap local natural gas. In Mozambique, these are referred to as “mega-projects.” These mega-projects are viewed favourably, since they could provide anchor loads for gas pipeline development, and more importantly generate employment for Mozambicans. ICF developed a market assessment for each of the proposed industries (e.g., gas for fertilizer, methanol, gas-to-liquids, power generation, concrete, aluminium, and iron/steel), that estimate the future value of the products in the world market and the FOB value of those products if manufactured in Mozambique. ICF characterized industrial facilities in terms of output, technologies used, size of plant (hectares), construction and operating employment. Based on operating costs and financial parameters, ICF estimated the value of gas into those projects that would meet the investment criteria. We then calculated a netback price to the resource where the netback value is derived from the price of the end use product in the market (e.g., methanol), minus the cost to reach the market, minus the cost of production, minus any gas transport costs to the plant. This calculation informed the GOM of the “value” of gas for when it would begin to consider pricing policies.

ICF developed the Mozambique Gas Planning Model (MGPM) to help evaluate alternative development scenarios and quantify the effects of various development scenarios in order to inform the GMP. The focus of the model is on the quantification of the benefits of using natural gas in Mozambique in different combinations of mega-projects at various locations. The model also generates the total employment, and additional revenues to Mozambique arising from the use of royalty gas in Mozambique. It estimates “multiplier-effects” in the economy and contribution to Gross National Product (GNP). The results can be compared across scenarios and cases. Using the MGPM, some of the implications of the trade-offs GOM faces were examined, including tradeoffs between taking government share in-kind or in cash, and further between development of different types of industries. ICF also trained a staff member of the Steering Committee on the structure and operation of the model.

In addition to the model-based analysis, socioeconomic and environmental effects of the alternative development strategies were examined. ICF also conducted an analysis of the fiscal and financial issues associated with the potential investment in the sector, as well as a cross-country analysis of regulations and policies that have promoted and/or hindered gas development across the globe. Based on all of these analyses, a GMP was developed providing key strategic decisions and recommendations for the GOM to take over time. A decision hierarchy and roadmap for implementing decisions was provided as well.

In the following sections, key results from the ICF analysis are presented, including a summary of key recommendations. In the final section, we outline the lessons learned from the Mozambique GMP for other countries intending to conduct similar analyses.

**Supply Analysis**

Assessing the current and future supply of natural gas in Mozambique is an important first step for evaluating the potential development scenarios in GMP. ICF gathered data from geological agencies and publically available information from IOCs. In addition to geological information, real data on the size of the resources and the production cost is dependent on drilling data and the information developed from exploration wells. Much of this data was unavailable, given that exploration is still ongoing. Therefore, ICF used in-house economic models based on field-size distributions and relevant assumptions about hydrocarbon makeup for evaluating Mozambique’s gas supply. First, the country’s sedimentary basins were categorized and classified into broad supply regions, as shown in Exhibit 2 below, and then total discovered and total resource base in these regions were calculated (see Exhibit 3).

ICF then estimated the cost of producing natural gas by evaluating eight existing fields (for which information was available) using industry standard cost factors and discounted cash flow analysis. Costs were specified for all major aspects of onshore and offshore development, including exploration and development drilling, production facilities, and operating and maintenance costs. Drilling success rates were also specified. Costs were based originally upon North
America costs, adjusted for Mozambique where necessary based upon investor slides and material reviewed for this study.

For the discounted cash flow analysis, ICF first estimated the cost of drilling on a cost per foot basis by region, and then developed a view of the cost of exploration, development, and production using both capital and operating costs. For new fields, ICF assumes that the larger fields are found first, and are developed. Over time, smaller fields are found which have a higher finding and development costs. The theory behind the find-rate methodology is that the probability of finding a field is proportionate to the field’s size as measured by its areal extent, which is highly correlated to reserves. For this reason, large fields tend to be found earlier in the discovery process than smaller fields. The methodology used by ICF more closely matches the actual discovery histories of established basins.

Exhibit 2: Map of ICF Supply Regions

Exhibit 3: Summary of ICF Analysis of Conventional New Field Resources

<table>
<thead>
<tr>
<th>Region Name</th>
<th>Total Assessed TCFE</th>
<th>3P Discovered TCFE</th>
<th>Undiscovered TCFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rovuma offshore North</td>
<td>199.4</td>
<td>124.4</td>
<td>75.0</td>
</tr>
<tr>
<td>2. Rovuma offshore south</td>
<td>36.0</td>
<td>0</td>
<td>36.0</td>
</tr>
<tr>
<td>3. Rovuma onshore</td>
<td>3.1</td>
<td>0</td>
<td>3.1</td>
</tr>
<tr>
<td>4. Maniamamba Basin onshore</td>
<td>1.2</td>
<td>0</td>
<td>1.2</td>
</tr>
<tr>
<td>5. Central offshore</td>
<td>17.9</td>
<td>0</td>
<td>17.9</td>
</tr>
<tr>
<td>6. South and west onshore</td>
<td>5.7</td>
<td>3.5</td>
<td>2.3</td>
</tr>
<tr>
<td>7. South offshore</td>
<td>13.1</td>
<td>0</td>
<td>13.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>276.5</strong></td>
<td><strong>127.9</strong></td>
<td><strong>148.1</strong></td>
</tr>
</tbody>
</table>

Exhibit 4 shows the results of the analysis for a 45 year production horizon. The resource cost at the wellhead (the cost is expressed in U.S. dollars per barrel of oil equivalent or BOE and in million British thermal units or MMBtu – the common world-wide pricing unit for natural gas) under the terms of the EPCC agreement. Under this agreement, the cost of gas should reflect all of the capital and operating and maintenance (O&M) costs incurred from exploration through production. This establishes the profitability of the gas that is produced from the standpoint of the operators. In addition to the wellhead EPCC resource costs shown below, the costs of gathering pipelines and processing gas for pipeline and LNG needs to be added to get the cost of gas that is ready for delivery into pipelines for various uses. The
results of this analysis are used in the development scenarios to estimate the infrastructure needs to produce natural gas under the different sets of assumptions.

ICF’s independent estimates of undiscovered resources based on field size distribution should be considered as first approximation and needs to be confirmed by further exploration. There is a high degree of uncertainty in ICF’s estimates of undiscovered resources. Nonetheless, the analysis confirmed that Mozambique has abundant natural gas resources with a total resource, conservatively estimated, of about 277 Tcf, of which 128 Tcf has been discovered and 148 Tcf yet to be discovered but is inferred. Much of Mozambique’s resource potential has not been evaluated and expectations are that the amount of gas available in other parts of Mozambique’s offshore may be substantial. Further exploration and drilling is required.

**Exhibit 4: ICF’s Production, Reserve and Resource Cost Estimations for Existing Fields**

<table>
<thead>
<tr>
<th>Name</th>
<th>Recoverable Gas (bcf)</th>
<th>Total Exploration &amp; Development Capital Costs (million USD)</th>
<th>Total O&amp;M Costs (million USD)</th>
<th>Total Capital &amp; O&amp;M Costs (million USD)</th>
<th>Production 45 years (million BOE)</th>
<th>Total Costs per BOE of Production ($/BOE)</th>
<th>EPCC Resource Cost $/BOE, ($/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pande</td>
<td>3,660</td>
<td>350</td>
<td>541</td>
<td>892</td>
<td>740</td>
<td>1.21</td>
<td>2.20 (0.38)</td>
</tr>
<tr>
<td>Temane</td>
<td>830</td>
<td>56</td>
<td>67</td>
<td>123</td>
<td>104</td>
<td>1.18</td>
<td>1.47 (0.25)</td>
</tr>
<tr>
<td>Inhassoro</td>
<td>400</td>
<td>131</td>
<td>89</td>
<td>220</td>
<td>90</td>
<td>2.45</td>
<td>5.25 (0.91)</td>
</tr>
<tr>
<td>Njika</td>
<td>1,000</td>
<td>1,055</td>
<td>496</td>
<td>1,551</td>
<td>181</td>
<td>8.55</td>
<td>33.65 (5.80)</td>
</tr>
<tr>
<td>Prosperidade / Mamba</td>
<td>48,000</td>
<td>12,468</td>
<td>9,813</td>
<td>22,281</td>
<td>8,651</td>
<td>2.58</td>
<td>10.07 (1.74)</td>
</tr>
<tr>
<td>Golfinho / Atum</td>
<td>20,000</td>
<td>6,600</td>
<td>4,451</td>
<td>11,052</td>
<td>3,605</td>
<td>3.07</td>
<td>12.42 (2.14)</td>
</tr>
<tr>
<td>Tubarao</td>
<td>1,500</td>
<td>1,595</td>
<td>538</td>
<td>2,133</td>
<td>271</td>
<td>7.88</td>
<td>38.03 (6.56)</td>
</tr>
<tr>
<td>Coral</td>
<td>5,100</td>
<td>3,064</td>
<td>1,412</td>
<td>4,476</td>
<td>919</td>
<td>4.87</td>
<td>22.25 (3.84)</td>
</tr>
</tbody>
</table>

*For per unit costs (the last two columns), the figures in parentheses are the equivalent costs per MMBtu.

**Demand Analysis**

Understanding the ways in which natural gas produced in Mozambique can be best utilized is an important element of the GMP. At present, industrial development in Mozambique has been concentrated in the main urban centers (such as Maputo, Nampula and Beira), with urban centers accounting for more than 80% of the country’s entire industrial base. Industries in the urban centers are highly concentrated in terms of production and markets, with little diversification and poor domestic linkages. The 2007 Industrial Policy noted that there are a number of challenges for developing and sustaining industrial development in Mozambique. The policy also focused on agriculture-based industries in various provinces in order to increase employment and promote development across the country. However, with the large discoveries of coal and natural gas in the recent years, industrial infrastructure and social development has now shifted to assessing how best to make use of these natural resources to benefit the overall country.

ICF analysed various potential gas-utilizing industries by assessing the evolution of demand for natural gas in Mozambique, in the regional economy, and in the broader world economy. The analysis primarily focused on the “mega-projects,” who are large industrial users of natural gas that could act as “anchor loads” for development of natural gas transportation infrastructure. Typical anchor loads are those where gas is either used as a feedstock or used to process heat. Feedstock industries include the production of fertilizer (urea), methanol, and gas-to-liquids. Process heat uses include power generation, aluminum smelting, steel production, petrochemicals, refining. These industries also tend to be located near sources of gas. A summary of assumptions for the different anchor industrial facilities is shown below in Exhibit 5.
**Exhibit 5: Summary of the Key Parameters for Industrial Facilities (2011 dollars)**

<table>
<thead>
<tr>
<th>Facility</th>
<th>Product</th>
<th>Output Unit</th>
<th>Size of Typical Facility</th>
<th>Capital Cost of Facility*</th>
<th>O&amp;M Costs</th>
<th>Land Use (Hectares)</th>
<th>Lead Time (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG Train</td>
<td>LNG</td>
<td>Metric Tonnes</td>
<td>5 million metric tons/year</td>
<td>5,380</td>
<td>82.5</td>
<td>250</td>
<td>5</td>
</tr>
<tr>
<td>Power Plant (CT)</td>
<td>Electricity</td>
<td>MWh</td>
<td>150 MW</td>
<td>172</td>
<td>7.4</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>Urea</td>
<td>Metric Tonne</td>
<td>547,500 tonnes/year</td>
<td>782</td>
<td>22.5</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Methanol</td>
<td>Methanol</td>
<td>Metric Tonne</td>
<td>912,500 tonnes/year</td>
<td>1.040</td>
<td>39.2</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>GTL</td>
<td>GTL-Diesel, GTL-Gasoline, GTL-Kerosene GTL-Lub Oil</td>
<td>Metric Tonne</td>
<td>50,000 barrels/day</td>
<td>9,680</td>
<td>165.5</td>
<td>250</td>
<td>5</td>
</tr>
<tr>
<td>Aluminum with Power Plant</td>
<td>Aluminum</td>
<td>Metric Tonne</td>
<td>500,000 tonnes/year</td>
<td>4,018</td>
<td>109.1</td>
<td>263</td>
<td>4</td>
</tr>
<tr>
<td>Steel (DR-EAF)</td>
<td>Cold-rolled steel</td>
<td>Metric Tonne</td>
<td>1,000,000 tonnes/year</td>
<td>359</td>
<td>49.5</td>
<td>303</td>
<td>4</td>
</tr>
<tr>
<td>Steel (Mini Mill)</td>
<td>Cold-rolled steel</td>
<td>Metric Tonne</td>
<td>300,000 tonnes/year</td>
<td>38</td>
<td>10.5</td>
<td>97</td>
<td>4</td>
</tr>
<tr>
<td>Cement</td>
<td>Portland cement</td>
<td>Metric Tonne</td>
<td>1,000,000 tonnes/year</td>
<td>116</td>
<td>8.8</td>
<td>263</td>
<td>4</td>
</tr>
</tbody>
</table>

*Note: Capital cost includes interest during construction.*

The basic economics of pipelines and gas infrastructure require that they are constructed to serve the large anchor loads. However, planners often route pipelines in such a way as to make them accessible to clusters of smaller facilities that can eventually tap into the pipeline and thus grow the gas market along the pipeline route.

For the demand analysis, ICF analyzed the export potential of gas-based products based on world and regional supply-demand balances, along with a determination of the economic feasibility of the projects based on world commodity prices. ICF assumed that the products from Mozambique will be sold into a global market, where they will be price takers. Therefore, ICF used publicly available sources of demand and supply forecast for the products, and investigated the risk associated with these industries, as related to Mozambique.

Then, a netback analysis was developed based on world commodity prices to determine whether the price of gas requested by the developers appears reasonable and also to estimate the maximum price of gas needed to ensure the viability of the projects. If the cost of gas in Mozambique is higher than the netback price, it would render a proposed project uneconomic; on the other hand, if the cost of gas is lower than the netback price that would improve their economics. The netback analysis was based on two world commodity price forecasts: a) International Energy Agency (IEA) 2011 World Energy Outlook (WEO) which had a higher gas price forecast, and b) January 2011 Commodity Price Forecast Update published by the World Bank (WB), which had a lower gas price forecast. Forecasting commodity prices depends on many assumptions and reality always differs from the forecasts. Therefore, ICF used a low and a high price cases to determine how robust the netback values are against potential market price fluctuations.

The netback analysis was based on 20 year a levelized cost calculations for each of the anchor industries using a defined minimum investment criteria (see Exhibit 6).
Exhibit 6: Netback Value of Gas in Each Commodity Market

<table>
<thead>
<tr>
<th>Facility</th>
<th>Consumption (Bcf/year)</th>
<th>IEA Netback Value ($/MMBtu)</th>
<th>WB Netback Value ($/MMBtu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG</td>
<td>246</td>
<td>9.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Power Plant (150MW)</td>
<td>9.5</td>
<td>8.8</td>
<td>8.8</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>15.6</td>
<td>6.8</td>
<td>0</td>
</tr>
<tr>
<td>GTL</td>
<td>159</td>
<td>6.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Methanol</td>
<td>18.0</td>
<td>6.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Steel (DRI-EAF)</td>
<td>11.2</td>
<td>5.3</td>
<td>6.8</td>
</tr>
<tr>
<td>Aluminum w/ Power Plant</td>
<td>63</td>
<td>3.2</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Under both the “high price” IEA WEO price stream and “low price” WB price stream, LNG has the highest netback value among the different facilities. The power sector has the same netback under both price forecasts given that the price of electricity is the same under both scenarios. More efficient power plants (larger plants and combined cycles) will have higher netback prices. Fertilizer, GTL and methanol all have similar netback values under the IEA price forecasts. However, fertilizer is very sensitive to urea prices, and as such under WB price projections, fertilizer has a very low (close to zero) netback value. Similar to fertilizer, methanol and GTL have high prices under the higher price stream of the IEA WEO, but have fairly low values of about $1.5-2/MMBtu for the WB prices.

Therefore, LNG was considered as the anchor project for offshore development of Mozambique’s natural gas resources and must be developed if gas is to be monetized and made available domestically. However, ICF suggested that there is significant LNG supply development in the coming years, and therefore there is a limited time window for GOM to obtain the best contractual and price terms for exporting LNG using the Rovuma basin gas. Mozambican LNG will have to compete with a number of upcoming LNG projects in Africa, Australia, and the United States.

Mozambican gas can be attractive for fertilizer production, although there is competition would be from the Middle Eastern fertilizer plants. South Africa is the biggest market for fertilizer in Southern Africa, but Mozambican fertilizer plants will have to compete with other regional fertilizer plants (including Sasol Nitro). ICF noted that locating fertilizer plants along existing and future transport corridors (e.g., in Beira) would be useful for regional export. GTL plants are relatively new globally and there is a potential for cost overruns. GTL plants also carry market risk, as the product prices are linked to oil prices. On the other hand, GTL would reduce import dependence in Mozambique.

The fairly large disparity in the netback analysis (based on variations within the two price forecasts) was used to suggest to policymakers that they should not select ‘winners’ among the different sectors, as any potential change in market conditions can dramatically alter the ‘priority list’. Exhibit 7 summarizes the current market opportunities and risks for the various sectors for Mozambique. ICF emphasized the need for GOM to constantly monitor and update its views on the various markets. Furthermore, ICF recommended that these types of market risks should be mostly borne by project developers, rather than the government itself, and that participation by GOM in projects will expose the country to the same risks. The government should also evaluate the importance of the various products in the local market before considering any kind of subsidies or incentives to specific sectors. In particular, ICF recommended that the various sectors should be allowed to operate on an even playing field, and any variations should be specific and limited in scope and timeframe.

Small and medium enterprises (SMEs) constitute another gas utilizing sector that was not fully assessed due to lack of information and time—the. SMEs will use natural gas if it is available at a price competitive with their alternative fuel. SMEs can use gas for heating, drying, cooking and other activities and natural gas for transportation – buses, trucks, and automobiles. The gas demand is often small and dispersed. Location of these facilities are influenced by factors other than access to gas supply, such as market access for their products, labor supply, and access to other raw material inputs. These small scale industries tend to be found in more urban areas. ICF refers to these kinds of customers and uses as “opportunistic” loads or markets because they will use gas if it is available, but they by themselves do not usually drive
gas infrastructure development. Similarly, residential use of gas for cooking or hot water heating are also opportunistic—availability of gas-based appliances and the price of gas are critical factors.

Exhibit 7: Summary of Key Market Opportunities and Risks

<table>
<thead>
<tr>
<th>Market Sector</th>
<th>Key market opportunities</th>
<th>Key market risks</th>
</tr>
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</table>
| LNG           | • Critical for offshore gas development—“anchor industry”
               | • Long term (~20 yr) contracts | • Limited window of opportunity
               |                           | • Competition from other LNG producers in Africa and elsewhere can put a downward pressure on price
               |                           | • Perception that gas being exported and not domestically utilized |
| GTL           | • Reduced dependence on refined petroleum products
               | • Potential for regional export of GTL products
               | • Large user of gas—an anchor load for development and pipelines | • High and uncertain capital costs (e.g., Qatar’s Pearl plant)
               |                           | • Reduced oil prices (due to higher supply or lower demand) can reduce value of GTLs
               |                           | • Competition from other South Africa’s GTL plant and other potential producers in Africa |
| Power Plants  | • Small-to-medium plants (150 MW or more) can be useful to provide local power in Cabo Delgado and Inhambane
               | • Large CC power plants can be an anchor load for development and pipelines
               | • Gas-based electricity is efficient, with limited environmental problems
               | • Electricity is a key social good and critical for development
               | • High potential for export to SAPP | • Cost of gas-based power is strongly tied to gas price
               |                           | • Power and gas price tariff changes can affect gas power significantly
               |                           | • Transmission constraints in Mozambique limit gas-power development
               |                           | • Competition from other sources (coal, hydro, renewables) needs to be assessed |
| Methanol      | • Another pathway for GTL production
               | • Large user of gas—an anchor load for development and pipelines | • Current market is oversupplied, with capacity; low gas prices in North America are inducing previously mothballed capacity there to come online
               |                           | • Prices are linked to global economy, and any economic slowdown in China and rest of the world would reduce prices, as a large amount of demand is in China.
               |                           | • Limited local or regional demand
               |                           | • Project developers have requested fairly low gas prices |
| Urea          | • Important for improving agricultural productivity in Mozambique, with agricultural being Reduced dependence on imported fertilizers
               | • Growing local and regional demand
               | • Potential for regional export of urea and other fertilizer products
               | • Large user of gas—an anchor load for development and pipelines | • Uncertain capital costs (e.g., Sumitomo’s Beira feasibility study)
               |                           | • Dependent on global urea prices
               |                           | • Competition from other African fertilizer plants
               |                           | • Fertilizer, by itself, is not a panacea for Mozambican agriculture. Other issues in the agriculture sector have to be resolved |

The Planning Model and Analysis

The MGPM is a linear programing model in Excel that provides an integrated assessment of the oil and gas field development activities (i.e., the supply outlook) combined with downstream transportation, processing, and transformation include liquefaction, power generation, domestic uses, and energy and feedstock uses in the industrial sector (i.e., demand outlook). The model user can develop multiple scenarios by providing alternative specifications for the development of downstream assets over time. The model then determines the optimal development of the oil and natural gas fields and dispatch of the downstream assets to maximize the net value to Mozambique. The outputs of the model include information on the production of different fields, size of the raw gas pipelines, outputs of the gas processing facilities, optimized size and throughput of pipelines, dispatch of selected industrial assets, price of sales gas
and other products, mass balance of key natural gas components, and net value and employment resulting from all of these developments.

For the purposes of the GMP, ICF developed several different scenarios (along with small variations within them). These scenarios are briefly described in Exhibit 8. The scenario analysis primarily focused on the “northern development area”, which included gas finds in the north of the country (Rovuma basin) and the opportunities to use that gas for industrial development in the Northern provinces.

**Exhibit 8: Description of ICF’s MGPM Scenarios for the Mozambique GMP**

**Scenario 1**
- 2 trains (5 million tonnes each) in 2018, with 5 million tonnes of LNG every two years until the completion of 6 trains in Palma
- 150 MW power plant in Palma in 2018, as part of LNG development
- 150 MW power plant in Rossano Garcia in 2015
- Gas processing and export to Secunda via ROFPCO pipeline
- Gas supply to Matola same as current supply

**Scenario 2**
- Palma LNG and power development same as in Scenario 1
- Fertilizer (2021) and GTL (2022) plants in Palma
- Southern development is same as in Scenario 1

**Scenario 3a**
- Palma LNG and power development same as in Scenario 1
- Fertilizer (2021) and GTL (2022) plants in Pemba
- 150 MW power plant in Pemba in 2020
- Pipeline or LNG shipping between Palma and Pemba by 2020
- Southern development is same as in Scenario 1

**Scenario 3b**
- Palma LNG and power development same as in Scenario 1
- Fertilizer (2021) and GTL (2022) plants in Nacala
- 150 MW power plants in Pemba and Nacala in 2020
- Pipeline or LNG shipping between Palma and Nacala by 2020
- Southern development is same as in Scenario 1

**Scenario 3c**
- Palma LNG and power development same as in Scenario 1
- Fertilizer (2021) and GTL (2022) plants in Beira
- 150 MW power plants in Pemba, Nacala, Quelimane, and Beira in 2020.
- Pipeline or LNG shipping between Palma and Beira.
- Southern development is same as in Scenario 1

**Scenario 4**
- Palma LNG and power development same as in Scenario 1
- Offshore development in Rovuma south
- Gas processing and LNG in Pemba
- One 5 million tonnes train in 2022 and second train in 2024 in Pemba
- Southern development is same as in Scenario 1
These “what-if” scenarios are tools that help policy-makers take a “long view in a world of great uncertainty” (Schwartz, 1996). The scenario process provides a context for analyzing the complex set of options available for the development of the gas sector in Mozambique. While there are a large number of options that can be selected and evaluated, ICF only selected a few that were deemed relevant for the GMP analysis. ICF emphasized that a key point about these scenarios is not that they will actually come to pass, or that the GOM should select one ‘preferred’ scenario, but that these scenarios help illuminate the implicit assumptions and mental models that policy makers need to consider—thereby helping to make better strategic decisions that will be sound for all futures.

The scenario analysis further confirmed that LNG exports is critical for development of offshore fields in Mozambique, and that pipeline transport, although expensive for long distances, can induce gas-based industries along the way, and can be a good option for promoting development across Mozambique.

**Economic Analysis of Scenarios**

ICF also developed economic impacts modeling for the various scenarios described above. Direct impacts are those from the production, processing and commercialization of natural gas. Indirect impacts are those impacts that can be attributed to the development of natural gas, but are not necessarily generated at the same time and location of natural gas production, processing and commercialization.

Production of natural gas offshore and its processing and conversion into LNG will employ labor—both domestic and expatriates—and therefore gas development will result in royalties, profit gas, and taxes to the central government. Expenditures made during construction and operations of facilities and associated infrastructure for the production transport and commercialization of natural gas will also employ labor and generate tax revenues. Finally, to the extent that some of the gas is used domestically, whether by large gas users such as power plants and GTL plants or by smaller industrial and commercial and domestic users, these industrial facilities will also spend resources that support employment generation and generate tax revenues.

Government expenditures also support employment generation to the extent that they are done domestically and in labor intensive sectors. The extent to which taxation favors or not employment generation depends, in part, on the relative labor intensity of those sectors taxed and government expenditures. It also depends on the extent to which government revenues become government expenditures.

Some of the key findings of the economic analysis were:

- Total average annual value added for the ICF scenarios range from $14 to $22 billion per year, dominated by the LNG production, with total government revenue including taxes, royalties, and profit gas is about $6-$8 billion per year.

- Large contributions of the gas sector to Mozambican GDP would not necessarily translate into large contributions to national income, unless revenues are transformed into government revenues through taxes, royalties and profit gas.

- The direct and indirect labor ranges between 14,000 (Scenario 1) to 26,000 jobs (Scenario 3c) across the scenarios, with peak employment of 33,000 (Scenario 1) to 83,000 (Scenario 3c). The amount of induced jobs is much higher. On a unit gas consumption basis, the annual direct and indirect jobs created is about 10 jobs per million MMBtu, with annual induced jobs being about 250 jobs per million MMBtu.

- Expenditures made locally and in labor intensive sectors are key for employment generation. The benefits of government revenues depend on how effective the investments are and whether corruption is avoided.

- Because of greater demand, infrastructure and trade linkages, the location of megaprojects in urban centers is more likely to foster additional business development and employment generation.
Financial and Fiscal Issues

For attracting the necessary investment in the Mozambican gas sector, ICF proposed to divide the challenge into three distinct to segregate and direct financing appropriately.

The Primary Segment is the development and financing necessary for the proposed LNG development (exploration, production, processing, liquefaction, export). This financing is expected to occur with corporate financing. Private sector partners may make use of project financing. Mega-projects are expected to be financed similarly as well.

The Secondary Segment involved the gas transportation infrastructure and large mega-projects that will serve as drivers of development and anchor load for the gas transportation infrastructure. Gas pipeline and sea-based shipping infrastructure requires financing that could involve elements of public (i.e. state-based) ownership and funding, purely private ownership and funding, or some combination of Public-Private Partnership (PPP).

The Tertiary Segment includes distribution infrastructure, installations and appliances which will be needed for the gas to reach and be used by a number of smaller local gas users like SMEs, public facilities, eventually residences. Financing for these uses will involve local financing entities: local Government budgets for public facilities; by local commercial banks for smaller industrial and commercial users; and by micro-credit institutions for the very smallest users who may need to finance gas-using appliances and equipment.

ICF also identified several aspects of the investment environment and business climate necessary to general investment in the country:

- Sound, stable macro-economic management, to give investors the confidence that their earnings will not be inflated away, denuded by exchange rate instability or confiscated by unexpected new taxes;
- Investment in infrastructure to enable the delivery of suitable services to investment projects;
- A legal and regulatory framework governing gas development, that gives investors the fiduciary security they need;
- Markets for the gas, such that the large capital outlays to be made in developing the gas will find a sufficient scale of demand for the gas to make the investment worthwhile (markets were addressed above);
- Gas pricing structures that will enable investors to secure an acceptable yield on their investments, given the risks involved; and
- A banking and financial sector that will enable the required local investments to be made as the Mozambique economy continues to grow.

Finally, ICF considered different options in which the revenue generated from the gas sector can be channelled towards broader development of the country and infrastructure investment. ICF recommended that these options be further evaluated in a separate study.

Uncertainties and Unknowns

Despite the extensive analyses conducted by ICF, there remains a large amount of uncertainties and unknowns about the potential ways in which the gas sector in Mozambique may develop—see below. It is expected that some of these uncertainties will be reduced over time with new analyses and studies being conducted over time—including the ongoing work supported by the World Bank.

1. We do not know when, where and how much additional gas reserves will be developed across Mozambique. Drilling by Statoil and Petronas is starting now and if successful they may develop gas fields south of Palma,
closer to the growth areas of the country. On the other hand, these new finds may be in more environmental sensitive areas. The fourth round of leasing for exploration is under way which will ultimately inform GoM of the potential in the central offshore areas of the country. Sasol’s drilling program in the southern offshore also is only now under way. Major finds in the Southern part of Mozambique are likely to result in plans for domestic development in the Inhambane or Zambezi region. Finally, coal bed methane (CBM) opportunities around Tete may be significant. CBM in Tete would be much more accessible to the central and southern parts of the country as well as South Africa and other nearby countries. All of these potential gas developments have serious implications for whether major investments in pipelines or mega-projects in the far north will take place.

2. World gas and oil prices are subject to significant supply and demand uncertainties, with volatility being the current norm. Such uncertainties make LNG and products that rely on natural gas subject to major market price volatility, as LNG and most of the mega-projects rely on oil and gas prices. New supplies of LNG from North America, Australia, Tanzania, Southeast Asia are possible and could affect LNG prices. In addition, shale gas development and production in South Africa, China, and India could reduce needs for these countries to import gas—thereby suppressing global and regional gas prices.

3. The economics of mega-projects in Mozambique are challenging, despite the level of interest evidenced by proponents of mega-projects. Much depends on gas prices and availability, commodity market conditions, and investment climate. Mega-projects may require large tax breaks and other incentives that may not be in the best interest of Mozambique.

4. In the absence of more detailed data on Mozambican sector production, employment and linkages, ICF’s employment estimates are based on considerable assumptions regarding local content, labor productivity and sector linkages and are necessarily very tentative.

5. There are questions about the interaction of gas-driven development with coal-driven development, particularly on the capacity of financial markets to absorb the level of required investment and infrastructure building in these two sectors.

**Recommendations of the Mozambique GMP**

Based on the analyses conducted by ICF and considering the uncertainties and unknowns noted above, ICF developed several recommendations for the GOM. See ICF (2013) for more details.

First and foremost, GOM should focus on making decisions that at present are critical to progress the development of the gas sector, and recognize that many other decisions about the gas sector development will benefit from having more accurate information and will have to be taken over time in the future as that information becomes available. For Mozambique, this means that the development of the Rovuma basin gas fields for LNG export should be expedited, as LNG is the anchor for commercially developing the (deep water) offshore gas resources. On the back of that, gas can be made available for domestic market development. The GOM should consider receiving gas both as “cash” which needs to be used productively for among others infrastructure development, and increasingly “in-kind” for developing domestic industries. The ‘value’ of the gas that is provided as cash should be based on a netback price from LNG sales to ensure higher value for the government and for transparency.

Regarding gas resources, expanding the knowledge base of potential volumes, timing, and location of future developments beyond the Rovuma basin will help prevent uneconomic investments in infrastructure today. Also, more knowledge engenders more confidence in future revenues and therefore flexibility in development plans. It is also important to ensure that not only large fields, but smaller fields in onshore and offshore basins in Mozambique are explored.
There are number of uncertainties regarding gas reserves, LNG markets, and economics of various mega-projects, and as such it is critical to initiate and follow through on getting more information and doing studies that are essential to support further decisions regarding the maximization of value to the country and the development of the domestic market. A list of additional studies was provided in the recommendations.

Mega-projects needs to serve as strategic anchors to promote economic activity, and hence their location needs to be closer to existing economic centers. Having prioritized industries for development, GOM should use a market-based approach to allocate gas for various mega-projects. Such an approach will allow for the private sector to compete for gas resources, while reducing risks for the government and increase its revenues.

Power generation will play an important role in Mozambique’s industrialization, and as such it is critical to conduct an integrated analysis of the power sector not only in Mozambique, but of the entire Southern African Power Pool. The entire energy mix for power generation needs to be evaluated to identify the role of gas-based power in Mozambique for local use and export.

Regarding gas prices, gas should not be priced in the domestic market below cost of production. If domestic prices are set below the netback LNG value, the GoM should make sure that the foregone revenues are offset by the subsequent benefits in the domestic economy.

The development of the gas industry and the mega-projects will need significant goods and services that should be provided as much as possible by Mozambican businesses. The extent to which Mozambican businesses are able to realize this opportunity to grow and hire workers will largely determine the employment benefits generated by the gas sector development.

Finally, GOM should develop and implement a communication strategy, with transparency being the primary arsenal for combatting misinformation and managing expectations. The vision for the gas sector development needs to be communicated broadly. Transparency and access to information regarding GoM strategies, decision-making processes, revenue realization and allocation, and development priorities is critical for sustainable gas development in Mozambique and for reassuring investors.

**Lessons Learned for Future GMPs**

Some of the lessons learned for future GMPs for other countries are:

- The GMP needs to focus on strategic analysis of policies, institutions, and regulations in the gas sector, rather than just technical details and specific build-out plans. The technical and economic analyses are not an end in itself, but must be done to inform the recommendations for policy changes and plans.

- The GMP recommendations must contain an hierarchy of decisions, whereby the government can take specific decisions now and then conduct additional analysis over time that will inform future decisions. The GMP is not meant to define all decisions about the sector, and the master plan should evolve over time based on actual circumstances.

- Government needs to actively plan for implementation of GMP decisions, early in the GMP process. Such an approach will allow for the government to get additional resources for more detailed studies and to plan for policy and regulatory changes, which may require legislative amendments.

- Inclusion and active participation of key government ministries in GMP development, for example, through a Steering Committee or Working Group process, is important for developing a viable and actionable GMP. Buy-in from within the government and making sure that all relevant government stakeholders are involved is critical for the success of the GMP and the implementation of the GMP recommendations.
• Inclusion of the broader stakeholder groups (industries, civil society groups, donor agencies, financial institutions, etc.) during the GMP development process is important to foster an consensus building environment. Understanding the different viewpoints will provide guidance on the development and implementation of the recommendations.

• Government needs to assess the state of the economic data available for analysis. While governments would like to get specific information on the economic impacts (e.g., contribution to GDP, employment, etc.), such an analysis is contingent on the availability of economic data and models. It is also important to recognize the limitations of such economic analysis.

• Government Ministries should gather necessary data from IOCs for resource assessment and supply curve development. In addition to what is publicly available, exploration data from the IOCs may be necessary to develop more refined resource assessment and supply curves. Therefore, an agreement with IOCs to obtain the necessary data would be useful.

• Government agencies should actively participate in the development of modelling (e.g. by providing data and learning to use the models) and use planning tools to enhance their internal understanding of the challenges and the required policy decisions. Such active participation will build internal capabilities and will allow the government to consider new scenarios and options based on future information.

• The power sector is often an anchor load for natural gas, and therefore the GMP and power sector planning processes need to build on each other.

• Policy and regulatory frameworks will need to be adapted to accommodate new gas development. It is important to learn from experiences of other countries as part of the development of new policies and regulations. Gas development will also interact with other sectors (e.g., power, transportation, and industry) and therefore an assessment of the broader institutional and regulatory/policy framework will be necessary.

References
