Ministry of Economy and Finance
The Republic of Mozambique

THE PROJECT FOR

NACALA CORRIDOR

ECONOMIC DEVELOPMENT STRATEGIES
IN THE REPUBLIC OF MOZAMBIQUE

PEDEC-NACALA

Final Study Report

Analysis Report: Strategic Master Plan on Development of Value Chain for Natural Gas related Sectors

April 2015

Japan International Cooperation Agency (JICA)

Oriental Consultants Global Co., Ltd.
RECS International Inc.
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List of Abbreviation

Abbreviation	English	Portuguese
CNG	Compressed Natural Gas	Gás Natural Comprimido
CO_2	Carbon Dioxide	Dióxido de Carbono
CFM	Mozambique Ports and Railways	Portos e Caminhos de Ferro de Moçambique
DUAT	Land Use Right	Direito de Uso e Aproveitamento da Terra
DRI	Direct Reduction Iron	Ferro de Redução Directa
EDM	Mozambique Electricity Company	Electricidade de Moçambique
ENH	Mozambique National Hydrocarbons Company	Empresa Nacional de Hidrocarbonetos
FEED	Front End Engineering and Design	-
FDI	Foreign Direct Investment	Investimento Estrangeiro Direto
GAZEDA	Special Economic Zones Office	Gabinete das Zonas Económicas de Desenvolvimento Acelerado
GDP	Gross Domestic Products	Produto Interno Bruto
GJ	Gigajoule	Gigajoule
GRDP	Gross Regional Domestic Product	PIB Regional
GTL	Gas to Liquids	Gás para Líquido
H_2S	Hydrogen Sulphide	Sulfureto de Hidrogénio
INE	National Statistics Institute	Instituto Nacional de Estatística
JICA	Japan International Cooperation Agency	Agência Japonesa de Cooperação Internacional
JOGMEC	Japan Oil, Gas and Metals National Corporation	-
LNG	Liquified Natural Gas	Gás Natural Liquefeito
ME	Ministry of Energy	Ministério da Energia
MEF	Ministry of Economy and Finance	Ministério da Economia e Finanças
MIREM	Ministry of Mineral Resources	Ministério dos Recursos Minerais
MIREME	Ministry of Mineral Resources and Energy	Ministério dos Recursos Minerais e Energia
MGC	Matola Gas Company	Matola Gas to Company
MMcfd	Million Cubic Feet per Day	Milhões de pés cúbicos por dia
MPD	Ministry of Planning and Development	Ministério da Planificação e Desenvolvimento
MTBE	Methyl Tertiary Butyl Ether	Eter Metilterb Utilico
MMA	Methyl Methacrylate	Metacrilato de Metilo

MTC	Ministry of Transport and Communication	Ministério dos Transportes e Comunicações
MTO	Methanol to Olefins	Metanol a Olefinas
MTP	Methanol to Propylene	Metanol a Propileno
MTPA	Million Tons Per Annum	Milhões de Toneladas Anuais
MW	Megawatt	Megawatt
NGL	Natural Gas Liquid	Gás Natural Liquefeito
PCD	Cabo Delgado Ports Company	Portos de Cabo Delgado, SA
PEDEC-Nacala	The Project for Nacala Corridor Economic Development Strategies	Projecto das Estratégias de Desenvolvimento Económico do Corredor de Nacala
SAPP	South African Power Pool	Pólo Energético da África Austral
SEZ	Special Economic Zone	Zona Económica Especial
SME	Small and Medium Enterprises	Pequenas e Médias Empresas
Tcf	Trillion Cubic Feet	Trilhões de pés Cúbicos
USD	United States Dollar	Dólar dos Estados Unidos
2P Reserves	Proved plus Probable Reserves	Reservas Provadas e Prováveis
3P Reserves	Proven plus Probable plus Possible Reserves	Reservas Provadas, Prováveis e Possíveis

Introduction

This document was prepared as an analysis report for sharing a study result on a particular theme as part of 'The Project for Nacala Corridor Economic Development Strategies (PEDEC-Nacala)' which is a technical assistance project supported by Japan International Cooperation Agency (JICA) for the Government of Mozambique. PEDEC-Nacala formulated integrated development strategies for corridor development by an integrated approach involving several sectors and also by giving consideration to environmental and social aspects. The actual strategies formulated in PEDEC-Nacala and details of the present situation of the Nacala Corridor Region are compiled into the PEDEC-Nacala Final Study Report[1].

Background: Development of Value Chain for Natural Gas

Natural gas reserves in Mozambique were drastically increased by the discovery of huge gas fields in the offshore Rovuma Basin, in northern Mozambique in 2009. The recoverable reserves in Areas 1 and 4 together of the Rovuma Basin are estimated to be 75 trillion cubic feet (Tcf). Natural gas exploitation and LNG production are planned to start in 2018 at 10 million tons per year. This world-class natural gas production could create 70,000 job opportunities at most (including direct and indirect employment and construction jobs).

It could also offer an opportunity for the Nacala Corridor Region to acquire a new energy source other than the electricity transmitted long distances from Cahora Bassa and to generate new chemical industries, such as those for ammonia and methanol, resulting in diversifying the industrial base of the Nacala Corridor Region.

Natural gas development and LNG production is expected to become a strong driving force in the Nacala Corridor Region. With such an emerging opportunity, this report was prepared to discuss developing a value chain for natural gas related sectors. The value chain for natural gas covers a wide range of activities from 1) gas exploitation, 2) transporting gas to the processing plant (via pipeline, CNG ship, truck etc.), 3) manufacturing products using gas (LNG, ammonium/urea, methanol and GTL), 4) transporting products made from natural gas to consumers (ship, train, truck, etc.), 5) power generation and 6) electrical power transmission.

The Government of Mozambique has formulated a Natural Gas Master Plan and has considered production of various products using natural gas. This analysis report was been prepared based on this Natural Gas Master Plan for Mozambique.[2] The analysis report not only reviews LNG production and export, but also studies possible value chains from perspectives of industrial development and regional development in the northern Mozambique (Nacala Corridor Region) considering locational scenarios for gas related industries and necessary pipelines and seaports.

1 See "Appendix" in this report for the table of contents of the Final Study Report.

2 The Future of Natural Gas in Mozambique: Towards a Gas Master Plan (20 December 2012)" prepared by ICF International

Objective of the Analysis Report on Development of Value Chain for Natural Related Sectors

The objectives of the analysis report are as follows:

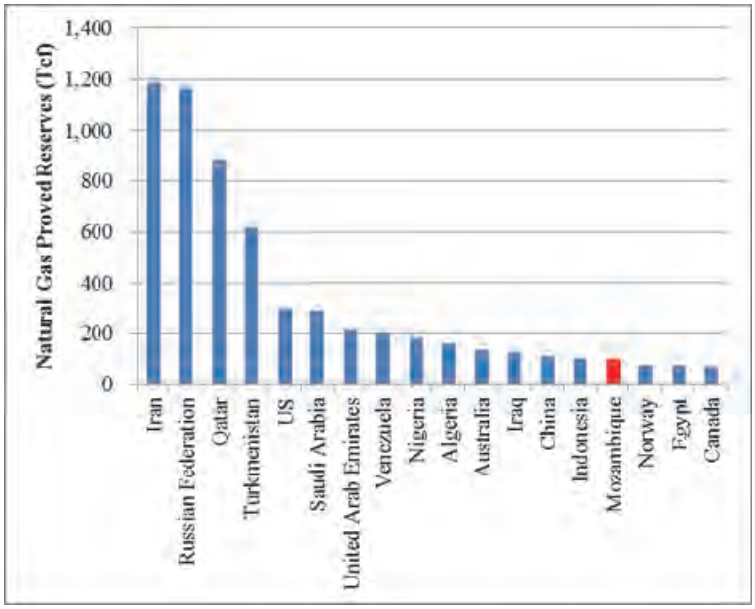
- To project an image of possible natural gas derived value chains using natural gas from Rovuma Basin
- To clarify issues on development of value chains related to natural gas from Rovuma Basin in relation to regional development for the Nacala Corridor Region
- To identify infrastructure and measures necessary for developing the value chain for natural gas related sectors

Chapter 1 Existing Condition of Natural Gas Development in Mozambique

1.1 Natural Gas Reserves in Mozambique

Mozambique will have the 15th largest natural gas reserves in the world if including its possible reserves. It will also have the third largest natural gas reserves in Africa after Nigeria and Algeria.

In Figure 1.1, the value of proved reserves in the large gas producing counties was compared with the probable reserves[3] in Mozambique.[4]



Source: Value of probable reserves for Mozambique is based on data from ICF etc (partly includes proven reserves). Other countries' values are proved reserves at the end of 2012, based on BP Statistical Review of World Energy June 2013.

Figure 1.1 Comparison of Natural Gas Reserves by Country

Mozambique's natural gas production was started by Sasol (South Africa) for Temane gas field in 2004 and for Pande gas field in 2009. Remaining recoverable reserves of Pande-Temane gas fields are estimated to be 2.7 Tcf,[5] which are the remaining balance of reserves after deduction of gas already produced.

However, natural gas reserves in Mozambique increased drastically by the discovery of huge gas fields in the concession areas in the offshore Rovuma Basin, in northern Mozambique. The 2P

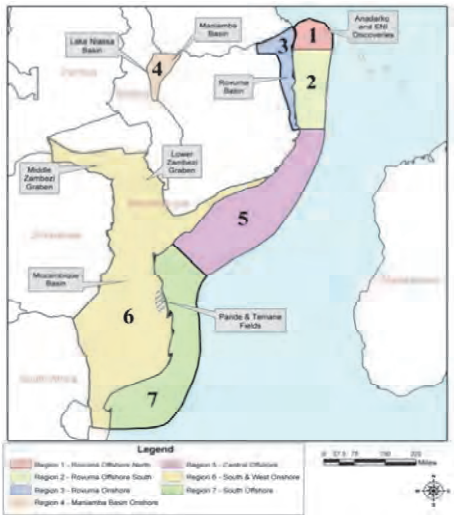
[3] The probable reserves here includes the probable reserves in Rovuma Basin and the proved reserves in Pande-Temane fields.
[4] BP's Statistical Review of World Energy June 2013 reported the proved reserves of natural gas in the 50 major countries as of end of 2012. However, Mozambique was not included in those 50 countries since the large value of reserves found in Rovuma Basin was still probable reserves.
[5] The estimated figure is according to the estimation of ICF International.

reserves (proved plus probable reserves) in Mozambique expanded to 96.2 Tcf[6], by adding the estimated probable reserves in Areas 1 and 4 of Rovuma Basin. Furthermore, by adding possible reserves, the 3P reserves in Mozambique is estimated to be 127.9 Tcf. There is also undiscovered reserves of 148.1 Tcf which is estimated to exist in favourable geologic settings. (See Table 1.1)

Total proved reserve of natural gas in the world at the end of 2012 was estimated to be 6,614.1 Tcf. Therefore, the share of natural gas in Mozambique is equivalent to 1.4% of this total amount.

Table 1.1 Total Value of Natural Gas Reserves in Mozambique

Name of Region	Total Evaluated (Tcf)	3P Discovered (Tcf)	Not Yet Discovered (Tcf)
1. Offshore Rovuma North	199.4	124.4	75.0
2. Offshore Rovuma South	36.0	0.0	36.0
3. Rovuma Onshore	3.1	0.0	3.1
4. Onshore Maniamamba Basin	1.2	0.0	1.2
5. Central Region Offshore	17.9	0.0	17.9
6. Onshore South and West	5.7	3.5	2.3
7. Southern Region Offshore	13.1	0.0	13.1
Total	276.5	127.9	148.1



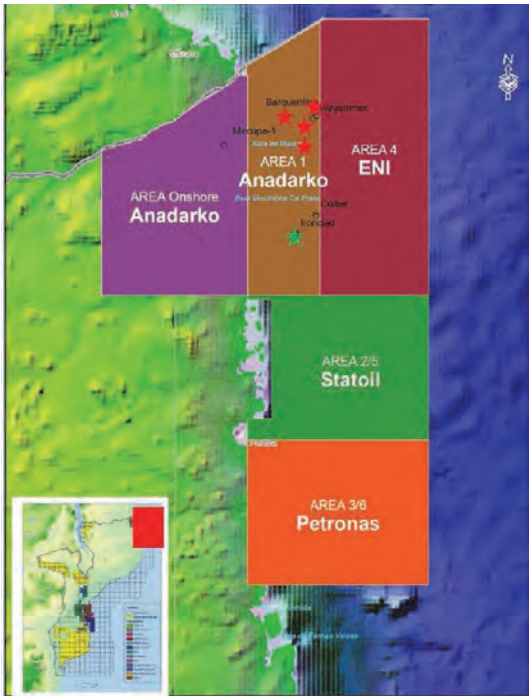
Note: The numbers in front of each region name correspond to the figure (ICF International, 2012, The Future of Natural Gas in Mozambique: Towards a Gas Master Plan, WB) on the right..
Source: Republic of Mozambique, December 2013, Plano Director do Gás Natural

1.2 Exploration Status in the Northern Sea Area

(1) Concession Areas at Rovuma Offshore and Onshore

It has been spotlighted that huge natural gas fields have been discovered in the offshore Rovuma Basin. There are six concession areas there as shown by Figure 1.2.

In the northeast areas, Anadarko Petroleum (US) and ENI (Italia) has concluded the concession contract with ENH for the Area-1 and Area-4, respectively. To the south, Statoil (Norway) has concluded a contract for Area 2 and 5, and Petronas (Malaysia) has concluded it with ENH for Area 3 and 6. In addition to the offshore areas, Anadarko Petroleum has a concession at the onshore area on the west side of the offshore Area 1, but the exploration results have not yet been revealed.



Source: ICF International (The Future of Natural Gas in Mozambique: Towards a Gas Master, Page 4-18)

Figure 1.2 Rovuma Offshore & Onshore Areas

[6] See Section 1.3 in this report for the methodology used for estimating 2P reserves at Rovuma Basin.

(2) Operators and Partners of Rovuma Offshore Concession Areas

A part of the concessions in the six concession areas in Rovuma Basin have been sold to other companies. As a result, the current status of the concessions is as shown in Table 1.2. Anadarko Petroleum, ENI, Statoil, and Petronas, which are the original concessionaires, still have the largest interest and responsibility for operation of each concession area.

Table 1.2 Operators and Partners of Rovuma Offshore Concession Areas

Area (Year of Contract)	Operator	Partner	Status
Area 1 (2006)	Anadarko (USA) 36.5%	Mitsui (Japan) 20%; Videocon (India) 10%; Bharat Petroleum (India) 10%; PTT (Thailand) 8.5%; ENH (Mozambique) 15%	Discovered, under appraisal
Area 2 (2006)	Statoil (Norway) 40%	Tullow Oil (UK) 25%; INPEX (Japan) 25%; ENH (Mozambique) 10%	Under exploration
Area 3 (2009)	Petronas (Malaysia) 50%	Total (France) 40%; ENH (Mozambique) 10%	Under exploration
Area 4 (2006)	Eni (Italia) 50%	CNPC (China) 20%; Galp (Portugal) 10%; Kogas (South Korea) 10%; ENH (Mozambique) 10%	Discovered, under appraisal
Area 5 (2006)	Statoil (Norway) 40%	Tullow Oil (UK) 25%; INPEX (Japan) 25%; ENH (Mozambique) 10%	Under exploration
Area 6 (2009)	Petronas (Malaysia) 50%	Total (France) 40%; ENH (Mozambique) 10%	Under exploration

Source: JOGMEC, 21 May 2013, "Current Status of Exploration and Development in the East African Deep Sea Area," page 3

Japanese companies that have concessions in Rovuma Basin are Mitsui & Company and INPEX Corporation.

1.3 Estimation of Natural Gas Reserves in Area 1 and 4 at Rovuma Basin

To date, all of the discoveries have been in Areas 1 and 4. The discoveries are about 15 to 30 miles offshore in water depth of 3,000 to 5,000 feet.

ICF[7] has analysed the discovered gas fields in Areas 1 and 4 in accordance with the information disclosed by operators in the study of "The Future of Natural Gas in Mozambique" outsourced by the World Bank to ICF. Based on this analysis, ICF has estimated initially-in-place[8] and technically and economically recoverable reserves of non-associated gas and natural gas liquid (NGL) as shown in Table 1.3. Recoverable reserves in Areas 1 and 4 are estimated to be 75 trillion cubic feet (Tcf).

Natural gas from Areas 1 and 4 contains ethane, propane and butane, according to ICF. Therefore, NGLs can be produced from the gases in Areas 1 and 4. The percentages of impurities, such as carbon dioxide (CO_2) and nitrogen (N_2), are very low. There is apparently no hydrogen sulphide (H_2S).

[7] Based on "The Future of Natural Gas in Mozambique: Towards a Gas Master Plan (20 December 2012)" prepared by ICF International, section 4.2.2 Rovuma Basin Discoveries

[8] Amount of oil and gas geologically estimated in a specific oil and gas field

Table 1.3 Natural Gas Reserves in Area 1 and 4 estimated by ICF

	Non-associated gas Initially-in-place	Non-associated gas recoverable reserve
	Tcf	Tcf
Area 1	76.5	45.5
Area 4	48.5	29.1
Total	125.0	74.6

Source: ICF International（2012）、The Future of Natural Gas in Mozambique: Towards a Gas Master Plan, Exhibit 4-18 on page 4-22

If analysis of the data obtained from exploratory wells and delineation wells shows that it is technically and economically feasible to extract the reserves of natural gas, the proved recoverable reserves can be estimated.

According to the information published by JOGMEC on 21 May 2013[9], Anadarko Petroleum has estimated Area 1 recoverable reserves of 35 to 65 Tcf, while ICF estimated 45.5 Tcf. ENI revised natural gas initially-in-place up to 80 Tcf in April 2013, while ICF estimated 48.5 Tcf. Recoverable reserves in Area 4 are estimated to increase to 48.0 Tcf from 29.1 Tcf shown on Table 1.1.2. As a result, total recoverable reserves in Areas 1 and 4 are estimated to be 93.5 Tcf.

[9] The present situation of deep sea exploration in East African countries of Mozambique, Tanzania, and Kenia

Chapter 2 Current Status of LNG Projects in Mozambique

2.1 Present Situation of International Trade in LNG

Natural gas is transformed to liquefied natural gas (LNG) by liquefaction at ultralow temperature of minus 162 degrees centigrade. Volume of natural gas is compressed to 1/600 by liquefaction to be suitable for long distance transportation by tanker. If a transportation distance is shorter than 3,000 km, transportation cost of natural gas by pipeline is lower than that of LNG. But, if it is longer than 3,000 km, transportation cost of LNG is lower than that by pipeline, according to ICF[10]. Most LNG is globally traded, since it is a form of natural gas suitable for large distance mass transportation.

Table 2.1 and Table 2.2 show the export and import volume of LNG by country.

Table 2.1 LNG Exports by Country (2012)

Region	Exporting Country	LNG Exports	
		Billion Cubic Feet	%
North America	US	28.3	0.2%
	North America Subtotal	**(28.3)**	**(0.2%)**
South & Central America	Brazil	14.1	0.1%
	Trinidad & Tobago	674.5	5.8%
	Peru	190.7	1.6%
	South & Central America Subtotal	**(879.3)**	**(7.6%)**
Europe & Eurasia	Norway	166.0	1.4%
	Other Europe	113.0	1.0%
	Russian Federation	522.7	4.5%
	Europe & Eurasia Subtotal	**(801.7)**	**(6.9%)**
Middle East	Oman	395.5	3.4%
	Qatar	3,725.7	32.2%
	United Arab Emirates	268.4	2.3%
	Yemen	250.7	2.2%
	Middle East Subtotal	**(4,640.4)**	**(40.1%)**
Africa	Algeria	540.3	4.7%
	Egypt	236.6	2.0%
	Equatorial Guinea	173.0	1.5%
	Nigeria	960.6	8.3%
	Africa Subtotal	**(1,910.5)**	**(16.5%)**
Asia Pacific	Australia	992.4	8.6%
	Brunei	321.4	2.8%
	Indonesia	882.9	7.6%
	Malaysia	1,123.0	9.7%
	Asia Pacific Subtotal	**(3,319.6)**	**(28.7%)**
Total Exports		**11,579.8**	**100.0%**

Source: JICA Study Team based on BP Statistical Review of World Energy June 2013

[10] Based on "The Future of Natural Gas in Mozambique: Towards a Gas Master Plan (20 December 2012), Executive Summary Exhibit" prepared by ICF International, page ES-20(page ES-41)

LNG export by country differs greatly depending on the region as shown in the table above. Exports by Middle East countries account for more than 40% of the world exports, and those particularly by Qatar are the largest in the world accounting for 32%. The second largest LNG exporting region is the Asia Pacific Region, accounting for 29% of the world exports. The third one is the African Region that includes Nigeria and Algeria, accounting for 17% of the world exports.

Table 2.2 LNG Imports by Country (2012)

Region	Importing Country	Imports	
		Billion Cubic Feet	%
North America	US	173.0	1.5%
	Canada	63.6	0.5%
	Mexico	169.5	1.5%
	North America Subtotal	**(406.1)**	**(3.5%)**
South & Central America	Argentina	183.6	1.6%
	Brazil	113.0	1.0%
	Chile	144.8	1.3%
	Other S & Cent. America	98.9	0.9%
	South & Central America Subtotal	**(540.3)**	**(4.7%)**
Europe & Eurasia	Belgium	158.9	1.4%
	France	363.7	3.1%
	Italy	250.7	2.2%
	Spain	755.7	6.5%
	Turkey	271.9	2.3%
	United Kingdom	483.8	4.2%
	Other Europe & Eurasia	158.9	1.4%
	Europe & Eurasia Subtotal	**(2,443.8)**	**(21.1%)**
Middle East	**Middle East**	**162.4**	**1.4%**
Asia Pacific	China	706.3	6.1%
	India	724.0	6.3%
	Japan	4,195.4	36.2%
	South Korea	1,755.2	15.2%
	Taiwan	596.8	5.2%
	Thailand	49.4	0.4%
	Asia Pacific Subtotal	**(8,027.1)**	**(69.3%)**
Total Imports		**11,579.8**	**100.0%**

Source: JICA Study Team based on BP Statistical Review of World Energy June 2013

As shown in the table above, LNG import amount also differs greatly depending on the region. Nearly 70% of LNG imports are concentrated in the Asia Pacific Region. In particular, Japan is the largest LNG importing country in the world, accounting for 36% of world LNG imports. It is envisaged that LNG imported into Japan will remain at a high level after the East Japan great earthquake disaster in March 2011 and the subsequent accident in the Fukushima Number One nuclear power plant. In addition to Japan, there are LNG importing countries in the Asian Pacific Region such as South Korea, India, China, Taiwan and Thailand. As stated earlier, companies of such LNG importing countries participate in development of Rovuma offshore concession areas.

LNG is clean fuel with relatively low CO_2 emissions. The role of LNG is quite likely to further expand to meet growing demand in the world. Under such circumstances, development of nonconventional natural gas, such as shale gas, are being stimulated in addition to conventional natural gas.

Natural gas has difficulty flowing in shale that is very tight and has almost no empty space. Therefore, natural gas cannot be collected from shale through conventional wells. At the beginning of the twenty-first century, new technology for extracting natural gas from shale was developed in

the United States. This technical breakthrough brought about the *Shale Gas Revolution* around 2007 and 2008 in the United Sates, where supply and demand for natural gas was drastically changed. Production of nonconventional natural gas is expected to be increased by the *Shale Gas Revolution* to reach 26% of total production of natural gas in 2035[11].

The number of LNG projects that are being developed in the United States and Canada using natural gas increased due to the *Shale Gas Revolution*. As a result of those LNG projects, LNG will be exported by the United States and Canada, even though this almost never happened before as shown in Table 2.1.

2.2 Present Situations of LNG Projects in Mozambique

(1) LNG Projects in Rovuma Basin

In Mozambique, a LNG project is scheduled to liquefy natural gas from Areas 1 and 4 in Rovuma Basis for exporting to consuming countries. An LNG plant with a total production capacity of 20 million tons per year will be constructed in Palma in Cabo Delgado province. Construction of this plant will be divided into first and second phases. Each phase will have two trains capable of five million tons per year.

Front end engineering and design (FEED) for the LNG plant and offshore gas production facilities, were ordered in December 2012. Taking all the considerations including cost and the LNG market into account, the final investment decision for the first phase LNG project will be made.

Although investment decision for the first phase was originally scheduled to be made around the third quarter in 2014, it has been postponed. Although it was envisaged that LNG shipment would begin in 2018, this might also be delayed.

(2) LNG Projects in Pande-Tamane Gas Fields

Since the 1990's the gas from Pande Gas Field has been used for small-scale power generation in Vilanculos District and Inhassoro District in Inhambane Province by constructing a 102km long pipeline. There is no LNG project at Pande-Tamane Gas Field and the gas which is not used for power generation in Mozambique is exported to South Africa via pipeline. There is also Buzi Gas Field near Pande-Tamane Gas Field, which has the potential of developing LNG projects, but the development at Buzi Gas Field is still not certain.

[11] IEA World Energy Outlook 2010, 2012

Chapter 3 Mozambique Natural Gas Master Plan

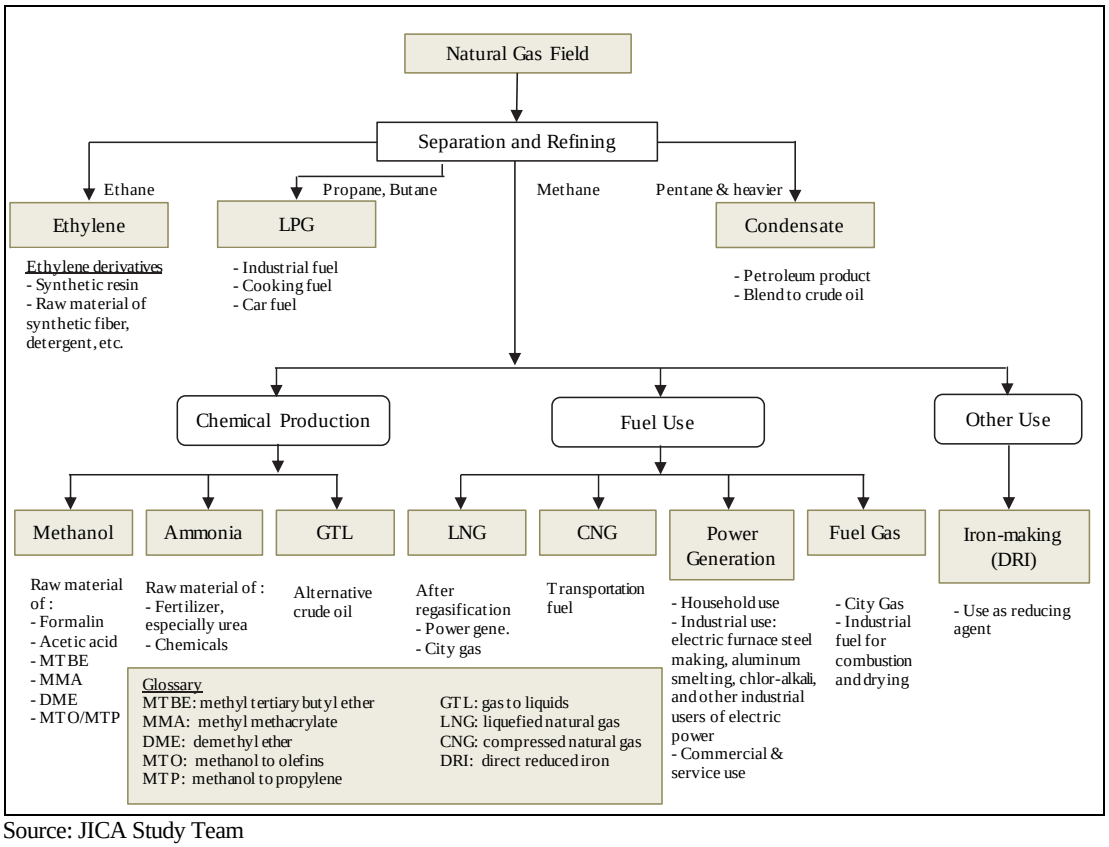
3.1 Overview of Mozambique Natural Gas Master Plan

In November 2013 Mozambique Natural Gas Master Plan (Plano Director do Gás Natural) was submitted to the cabinet council and was approved in June 2014. The Natural Gas Master Plan sets a basic policy so that not only the export of LNG using the natural gas from Rovuma Basin but also the domestic usage of natural gas will become a driving force for industrialization in Mozambique.

In this chapter, the natural gas related industries are systematically described. Based on these industries, a forecast of domestic gas demand and domestic gas price policy is outlined referring to the Natural Gas Master Plan.

3.2 Overview of Natural Gas related Industries

Figure 3.1 systematically shows the natural gas related industries.



Source: JICA Study Team

Figure 3.1 Systematic Diagram of Natural Gas Utilisation

Natural gas produced from gas fields is separated and refined to methane, ethane, propane, butane, pentane and heavier components.

Methane is the main component of natural gas, being used for raw materials for methanol, ammonia (mostly used as urea and other fertilizers) and gas to liquids (GTL); and for fuel such as LNG, compressed natural gas (CNG), thermal power plants, city gas, and industrial gas. A direct reduction iron (DRI) plant reduces iron ore using natural gas. It is an iron reduction method without a blast furnace and is used mainly in natural gas producing counties.

Electricity generated by gas turbine generators is used for the manufacturing sector as well as the household, commerce, and services sectors. Abundant supply of cheap electricity would make an attractive investment destination for power consuming industries such as electric arc furnace (EAF) steel making; aluminium smelting; and chlor-alkali industry making chlorine, caustic soda, and their derivatives.

3.3 Industrialization using the Natural Gas of Rovuma Basin

The Government of Mozambique has received many proposals on natural gas utilization projects from foreign developers based on the discovery of large gas fields. The Government recognizes it is necessary to ensure that part of the natural gas to be produced in the Rovuma Basin should be used for the industrialization of the country at a price that allows the feasibility of these industries. It also recognizes the various risks and challenges that these gas related industries face.

(1) LNG

Currently, the main LNG demand is in the Asian market, especially in Japan, Taiwan, South Korea, China and India. The prices of LNG are directly associated with the world price of oil, especially for LNG sold to Asia, and therefore, there are existing risks regarding the long-term LNG prices. Furthermore, the main risk for LNG might come from additional supply of LNG from Australia, other African countries, and the Middle East. Also, there are potentially large unexploited reserves of shale gas in China as well as potential for shale gas development in India and South Africa.

(2) Methanol

Methanol is mainly used as a raw material for various chemical industries. China will become an important market for the methanol once it is produced in Mozambique. The principal investment risk associated with methanol is excess production capacity. Methanol plants tend to be growing larger and, therefore, when a new plant comes into operation, the prices tend to fall as a result of the additional capacity.

(3) Urea

The production of urea continues to grow throughout the world, with demand increasing due to population growth and greater agricultural production. It is expected that about 58 new fertilizer plants will come into operation globally over the next three years. The fertilizer market is not fully open, as some countries, including India and China, have a requirement to have some level of self-sufficiency in the production of fertilizers and therefore they subsidize their factories. The main risks for new fertilizer plants are excess capacity in the short term, competition from low cost

products in the Middle East, and the pressure on prices. Nonetheless, local and regional markets for fertilizers would render their production attractive to Mozambique and help in reducing the current Mozambique's import amount.

(4) GTL

The demand of gas to liquids (GTL) is dictated by the demands for crude oil and petroleum products and their prices. The current demand is even greater in Europe, where the GTL can replace the more expensive diesel, gasoline and aviation fuel. The big uncertainties for GTL are the future global prices of oil, the growth of global demand for diesel, and the expansion plants in Qatar, South Africa and Canada. GTL plants tend to be large scale and capital intensive, although Sasol has indicated that smaller GTL plants can be operated profitably in Mozambique. The production of GTL in Mozambique could replace the current petroleum products which are imported and open up regional African fuel markets to Mozambique.

(5) Electricity Generation

The demand for gas for electricity generation is determined by the local and regional electricity demand, the transmission network and by competitive technologies such as hydroelectric, wind produced electricity, coal fired, renewable energy, and energy efficient technology. The 150-200MW gas electricity generation plants could be used for delivering electricity to local markets and for supporting the transmission network voltage. In recent years, the electricity demand in Mozambique has been growing at more than 15% per year. Larger electricity generation plants could be used for selling electricity to the Southern African Power Pool (SAPP), as the Southern African Region as a whole is entering a period of shortage in electricity generation capacity.

(6) Steel and Aluminium

Manufacturing of steel and aluminium in Mozambique started in 2000 importing alumina and using electricity from SAPP. With its Mozal plant, Mozambique is the second largest aluminium producer in Africa and there is also currently a closed steelworks plant under the ownership of ArcelorMittal, of South Africa. The demand for aluminium continues to increase, but there are new foundries in the Middle East meeting this demand. Therefore, even with the local electricity generation using natural gas, the possibility of expanding the aluminium production matching Mozal would be low. The production of steel seems to be most promising in Mozambique, given the growing demand in Mozambique and in Africa, and the availability of the coal reserves of the country and access to iron ore. However, the potential for gas use in these plants is very low[12], and mainly for process heat.

(7) Cement

Cement production is for local consumption and depends on the growth rates of Mozambique and the region. The use of natural gas in the cement industry is low.

[12] A large volume of natural gas is used for the combination of iron making by Direct Reduction Iron (DRI) and steel making by electric arc furnace (EAF) that use electricity generated by natural gas electricity generators.

3.4 Forecast of Domestic Gas Consumption

The demand for natural gas for the Mozambican domestic market is dependent on the kinds of industries that will develop in Mozambique over time. So far, the proposed domestic mega-projects, with the exception of electricity generation, are all export oriented and thus have exposure to fluctuations in world commodity prices and market volatility. Hence, a detailed forecast of gas demand for these industries remains speculative at this stage.

The Government in its policy development has assumed the following potential "Gas Master Plan scenario" for domestic gas consumption over the next 10 years:

- Gas from Pande-Temane will continue to be used for export to Secunda in South Africa. In addition it will be used by at least two 150 MW gas power plants, which are expected to come online in the near term by EDM and Sasol.
- In addition to the 3 million GJ/year current Matola Gas Company (MGC) demands, approximately 500,000 GJ/year is supplied for SME use.
- In northern Mozambique, it is likely that two 150 MW gas power plants will be set up in the short term; and these gas power plants will potentially expand to 300-500 MW gas combined cycle power plants in the medium term.
- In Carbo Delgado area, it is likely that one fertilizer (urea) plant with a manufacturing capacity of approximately 500,000 tons /year will be planned to support the agricultural demands for the country and regional economy.
- In the northern Mozambique, it is likely that one 50,000 barrel/day GTL plant will be built.

The expected gas demands for this Gas Master Plan scenario are shown in Table 3.1. In addition to the demands for domestic gas use, a significant volume of gas will still be exported from Pande-Temane fields to Secunda via the existing Sasol pipeline; and a significant volume of gas from the Rovuma Basin will be exported in the form of LNG from Palma.

Table 3.1 Tentative Domestic Demand Estimates

GMP-Scenario Domestic Gas Demand (million GJ/year)									
	Current MGC Demand (from P-T fields)	SME MGC Demand (from P-T fields)	Power Plants in South (from P-T fields)	Power Plants in North (Rovuma)	Fertilizer (Rovuma)	GTL (Rovuma)	Total P-T	Total Rovuma	Grand Total
2014	3	0.2	4				7.2		7
2015	3	0.25	10				13.3		13
2016	3	0.3	10				13.3		13
2017	3	0.37	21				24.4		24
2018	3	0.43	21	10			24.4	10	34
2019	3	0.5	21	10	9		24.5	19	44
2020	3	0.5	21	21	18	90	24.5	129	154
2021	3	0.5	21	21	18	175	24.5	214	239
2022	3	0.5	21	21	18	175	24.5	214	239
2023	3	0.5	21	21	18	175	24.5	214	239
2024	3	0.5	21	33	18	175	24.5	226	251
2025	3	0.5	21	44	18	175	24.5	237	262

Source: Natural Gas Master Plan, December 2013

3.5 Reviewing the Share of Natural Gas Volume for Electricity Generation and Domestic Chemical Industries

LNG development is the driving force for production of gas from the offshore Rovuma Basin given that it has the highest netback value. LNG production will result in availability of gas for domestic use in Mozambique.

Under the Concession Contracts, the Government has the right to take both royalty and profit from the gas in kind and in cash. Such a flexible approach will allow the Government to decide carefully and deliberately on how much and when to appropriate the gas to meet the expected domestic demand.

The Government intends to supply gas to domestic users by use of not only the royalty gas but also the profit gas according to the Gas Master Plan. The Government needs to forecast the domestic gas demand through the first auction and the qualification of large-scale projects, before entering into negotiations with the LNG project developers on the Government's share of royalty and profit gases both in kind and in cash.

Under the Concession Contracts of Rovuma Basin gas fields, the Government has the right to take the royalty and profit gas both in kind and in cash. According to government officials at the meeting in December 2013, the Government will take royalty gas in kind that account for 2% of the produced gas.

It is estimated that 1,500 million cubic feet per day (MMcfd) is required for the first phase of the LNG plant with a production capacity of 10 million tons per year, which is expected to be constructed in Palma and to start exporting from 2018. Royalty gas available for the Government from 2018 is approximately 30 MMcfd, equivalent to 2% of the 1,500 MMcfd. The second phase of LNG plant is also planned to have a production capacity of 10 million tons per year, but a time frame for the starting-up has not been announced.

The amount of gas which the Government will receive from the royalty gas is projected to be 60MMcfd in 2025. However, the estimated demand necessary for electricity generation and the chemistry industries is 589 MMcfd. The gas amount secured for the Government is very limited compared to the demand. The volume of profit gas which the Government of Mozambique can receive from the gas holders is currently unknown.

Based on this review, in order to promote the usage of natural gas within Mozambique, Mozambique will need to purchase gas extracted by private gas holders. Therefore, the possibility to manufacture LNG for export as well as to distribute to domestic electricity generation and chemistry industries is a difficult challenge.

Chapter 4 Study on Natural Gas Derived Value Chain for the Nacala Corridor Region

4.1 Objectives of the Study

The following has been studied to achieve Mozambique's aims of industrialization by using natural gas from Rovuma Basin, and furthermore, develop a natural gas derived value chain by utilizing its national natural gas to grow the domestic industry:

- Demand forecast estimated in the Natural Gas Master Plan
- Usage of natural gas and characteristics of each natural gas based product (including where each facility should be located)
- Locational scenarios for power generation plants and chemistry industries
- Necessary facilities and measures based on the locational scenarios

In this chapter, the natural gas derived value chain using natural gas from Rovuma Basin is studied to project an image and clarify the issues to be addressed in the Nacala Corridor Region. Infrastructure and measures necessary for developing the value chain are also studied.

4.2 Domestic Demand and Usage of Natural Gas

4.2.1 Domestic Demand for Rovuma Gas

Tentative demand for Rovuma gas is estimated, under the Gas Master Plan and is converted into a volume basis as shown in Table 4.1 to be used for the preliminary study as a target for domestically available gas.

Table 4.1 Calorie and Volume Basis of Domestic Gas Demand (Tentative)

Year	Calorie Basis per calendar year (million GJ/year)	Volume Basis per calendar day* (MMcfd)
2018	10	25
2019	19	47
2020	129	321
2021	214	532
2022	214	532
2023	214	532
2024	226	562
2025	237	589

Note*: Converted assuming gross heating value is 1,045 BTU/cf and using the conversion factor (1GJ =947.83x10^3 BTU)
Source: JICA Study Team based on Gas Master Plan

4.2.2 Condition for Preliminary Study to Develop Large-Scale Projects

(1) Priority Large-Scale Projects

The Gas Master Plan sets the order of descending priority for large-scale projects as follows: LNG,

power station, fertilizer and GTL. The scenario for the development of large-scale projects was formulated in the Gas Master Plan and demand was estimated. It is assumed that the gas from Rovuma Basin will be utilized for LNG, power stations, fertilizer, GTL and methanol.

(2) Location of Large-Scale Projects

The Government of Mozambique supports the development of some large-scale projects in Palma. In particular, preference will be given to the development of a power station in Palma consistent with the plan of EDM, and the development of GTL or a fertilizer plant.

If private gas holders wish to invest in a chemical industry utilizing natural gas, such as producing fertilizer, methanol and/or GTL, they would tend to locate their factory at Palma where cost for pipeline construction is not necessary. However, the Government seeks to avoid a concentration of large-scale projects in Palma that would not benefit other communities in Cabo Delgado Province and Nampula Province.

4.2.3 Gas Utilization by Large-Scale Projects

(1) Electricity Generation

The need for gas for electricity generation is determined by local and regional demand, the transmission network and by competitors (hydro-electric, wind, coal, renewable, energy efficient). It is necessary for the Government to formulate the Electricity Master Plan to solve those issues.

According to the Gas Master Plan scenario, it is likely that two 150 MW power plants will be set up in the short term, and they will be expanded to 300-500 MW combined cycle power plants in the medium term in northern Mozambique.

In the preliminary study, it is assumed that two 150 MW power plants should be built in Cabo Delgado and Nampla Provinces and they should be expanded to 300-500 MW combined cycle power plants in the medium term.

(2) Fertilizer (Urea)

Urea is suited for local production for local consumption. As Table 4.2 shows a total demand for urea in Mozambique and its neighbouring countries including Zambia and Malawi is larger than the economic scale of ammonia and the urea plant. The production capacity of the urea plan is assumed to be 500 thousand ton per year, which is the same as the Gas Master Plan scenario.

Taking account of access to markets in Mozambique, Zambia, Malawi and large markets in Asia, Nacala is a more suitable place than Palma to locate such plant because transportation infrastructure in Nacala such as railway, port and roads is better than those in Palma.

However, as recognized through the analysis in Chapter 3, the amount of gas available for domestic use will be very limited if only using royalty gas and profit gas. Therefore, the Government of Mozambique needs to use gas provided by private gas holders for electricity generation and chemical industry projects. In such case, it is necessary to consider which private gas holders to participate in electricity generation and chemical industry projects using gas extracted by those gas holders. If private investors are to participate in natural gas related industries, it is preferred to locate the ammonium and urea manufacturing factories in Palma rather than Nacala. This is because a long pipeline between Palma and Nacala will not be necessary in this occasion.

Vale (Brazilian company) has proposed a phosphate plant in Nacala, Nampula Province, with a capacity for producing two million ton per year. Phosphate rock will be supplied from a mine in Monapo District, Nampula Province, and product will be exported to Mozambique and its neighbouring countries from Nacala via railway, and to foreign countries from Nacala Port by sea[13]. If urea and phosphate are produced in the same area, it is expected to give a synergistic effect in production of combined fertilizer, so called NPK fertilizer. Vale is, however, going to review the project, since analysis of samples revealed that the phosphate rock from Monapo contained a great deal of chlorine according to information obtained in September 2013.[14]

Table 4.2 Demand for Urea in Mozambique, Zambia and Malawi

Unit: Ton

Year	Mozambique	Zambia	Malawi	Total
2007	28,000	180,000	270,000	478,000
2008	32,000	192,600	283,500	508,300
2009	33,000	206,100	297,700	540,800
2010	51,400	220,500	312,600	575,700
2011	50,000	235,900	328,200	613,100
2012	53,900	247,700	338,000	639,600
2013	59,300	260,000	348,200	667,500
2014	62,200	273,000	358,600	693,800
2015	71,700	286,700	369,400	727,800
2016	78,900	301,000	380,500	760,400
2017	86,800	316,000	391,900	794,700

Source: The Future of Natural Gas in Mozambique: Towards a Gas Master Plan (December, 2012) by ICF, Page 5-64
(Based on Mozambican Ministry of Agriculture document "Comparison of Current Consumption and Forecast for Fertilizer between SADC Countries (2007-2011 and 2011-2017)")

(3) GTL

The world demand for GTL is dictated by the demand for crude oil and petroleum products and their prices. The current demand is even greater in Europe, where the GTL can replace the more expensive diesel, gasoline and aviation fuel. The big uncertainties for GTL are the future global prices of oil, the growth of global demand for diesel, and the expansion plans for GTL in Qatar, South Africa and Canada.

GTL plants tend to be large-scale and capital intensive, although Sasol has indicated that smaller GTL plants can be operated profitably in Mozambique. According to ICF, a 50,000 barrel per day plant would cost around US$8.1 billion. GTL may have a greater risk of cost overrun, since it is a relatively new technology.

The production of GTL in Mozambique could replace current imports and open up regional African fuel markets to Mozambique. The market for GTL is expected to be for domestic usage and exports to the neighbouring countries and Europe. Therefore, it is recommended that the GTL plant, which consumes a large amount of gas, should be located in Palma so that the cost for a pipeline is

[13] http://www.macauhub.com.mo/en/2012/07/20/vale-mocambique-expects-soon-to-finish-feasibility-study-for-ph
[14] If phosphate rock contains a lot of chlorine, construction costs of the phosphorous fertilizer plant are increased due to requiring anticorrosive equipment and materials. This results in lowering the profitability of the project

avoided. It is also assumed that transporting GTL by tanker from Palma would be cheaper than constructing a pipeline.

(4) Methanol

Investment in methanol is based on the world market trend of various chemical goods' raw material. There are some Japanese companies which are considering investing in methanol manufacturing in Mozambique. Furthermore, it is possible to target the Chinese market from the location of northern Mozambique because Palma, Pemba and Nacala are all suitable for this purpose.

4.2.4 Gas Utilization by SME and Urban Transportation

(1) Gas Utilization by SME

If once the gas utilization infrastructure is developed and cheap gas is supplied through it, small and medium enterprises (SME) have potential of converting the currently used fuel to natural gas; creation of new industries are encouraged by use of natural gas or electricity generated by natural gas, for example, the Chlor-Alkali industry using salt produced around Nacala and electricity, and the Steel –Making industry by electric arc furnace using scrap steel.

In order to establish a climate favourable for gas utilization by SME, it is necessary to conduct studies concerning the situation of fuel usage by SME and development of the natural gas infrastructure.

In the preliminary study on the natural gas-derived value chain, demand for gas to be utilized by SME in northern Mozambique such as Nacala, Pemba, and Palma, is assumed at the level of 30% of the gas (from Pande-Temane gas field) that MGC is supplying to SME in southern Mozambique.

(2) CNG Supply for Urban Transportation

CNG buses and taxis would present a potential market for CNG because they have a limited required range and return to base every night for fuelling. Peromoc has begun developing CNG filling stations in Maputo and plans to develop stations in Beira and in between the two cities.

In the preliminary study on natural gas-derived value chain, it is assumed that filling stations will be developed to supply CNG to buses and taxis in northern Mozambique as well. CNG usage for buses and taxis could replace gasoline and diesel.

4.3 Locational Scenario of Natural Gas related Chemical Industries

Due to the possible ways that the natural gas will be used and their characteristics which are described in Section 4.2, production, such as LNG manufacturing and GTL manufacturing, may be fully exported after they are produced in Mozambique. Therefore, it is most likely that manufacturing companies will select Palma which is the closest to the natural gas extraction site as the location for those chemical industries.

On the other hand, the preferred location for methanol a manufacturing plant and ammonium / urea manufacturing plant may differ due to the chemical industry's cost and development benefit to the region.

In this section, based on the following understanding, locational scenarios for natural gas related electricity generation and chemical industries are proposed between actual potential locations in the Northern Region of Mozambique:

- Characteristics of each location for a gas power plant and chemical industries to utilize gas
- Utilization of private gas holders' gas for promoting gas related chemical industries
- Locational conditions of the coastal area in the Northern Region of Mozambique

4.3.1 Comparison of Potential Locations for Gas related Industries

The potential locations for a gas power plant and gas related chemical industries in the Nacala Corridor Region are Palma, Pemba and Nacala and areas surrounding these three cities. These three cities have been compared by locational conditions. (See Table 4.3)

Table 4.3 Comparison of Locational Conditions for Gas related Industries (Palma, Pemba and Nacala)

	Palma	Pemba	Nacala
Existing Port	• None	• Existing deep port • Site for expansion is limited to small area in the south	• Deepest natural port on the east coast of Africa • Existing plan for rehabilitation and upgrade
Industrial Port Development	• Possible • LNG plant site of 7000ha and other industrial site of 24,000ha are secured	• Possible • Some space for development available on the southern side of the existing port	• Highly possible • Space available for new port development at north east side of Nacala Bay
Procuring Industrial Site	• Highly possible	• Highly possible	• Highly possible
Current Urban Population (existing urban concentration and public facilities)	• Small urban population • Limited urban concentration and public facilities	• 170 thousand (2011)	• 290 thousand (2011)
Future Population Size (2035)	• 20 – 30 thousand	• 470 thousand	• 940 thousand (Nacala Bay Area)
Possible Natural Gas related Industries (mostly from the site procurement perspective)	• Methanol • Ammonia / Urea • GTL etc.	• Methanol • Ammonia / Urea • GTL etc.	• Methanol • Ammonia / Urea • GTL etc.
Large Demand for Energy (Power and Gas)	• None	• None	• Electricity consuming industries such as cement and aluminium manufacturers which will benefit from being located close to Nacala Port • Supplying city gas to urban residents
Gas Power Plant	• Possible due to the location close to offshore Palma sites (Area 1 and 4)	• If natural gas is discovered offshore of Pemba in the long-term future, possible by using that gas	• High necessity due to the location close to electricity consuming area
Necessary Gas Pipeline Length	• 5 km	• 250 km	• 426 km (20" diameter pipeline) • USD 391 million

Source: JICA Study Team

4.3.2 Locational Scenario for Gas related Industries

At present, natural gas reserves are only found in Area 1 and Area 4 located offshore of Palma which is at the northern end of Cabo Delgado Province. Therefore, an LNG manufacturing plant will be located in Palma which is the closest from the gas field. In addition to the LNG manufacturing plant, Palma will be the most favourable area for GTL which is expected to be exported to Europe and other international markets directly from the manufacturing plant.

On the other hand, methanol and ammonia / urea industries do not necessarily have to be located close to the gas field. Therefore, since Nacala already has various economic infrastructures and an urban environment, it may be more suitable for such industries to be located in Nacala.

Based on the comparative analysis in Table 4.3, in the short- to medium-term (as long as natural gas is available from only Area 1 and Area 4) either Palma or Nacala will be a more suitable location than Pemba for chemical industries.

Accordingly, Palma and Nacala were firstly compared for the possibility of locating chemical industries.

Scenario A: Concentration in Palma

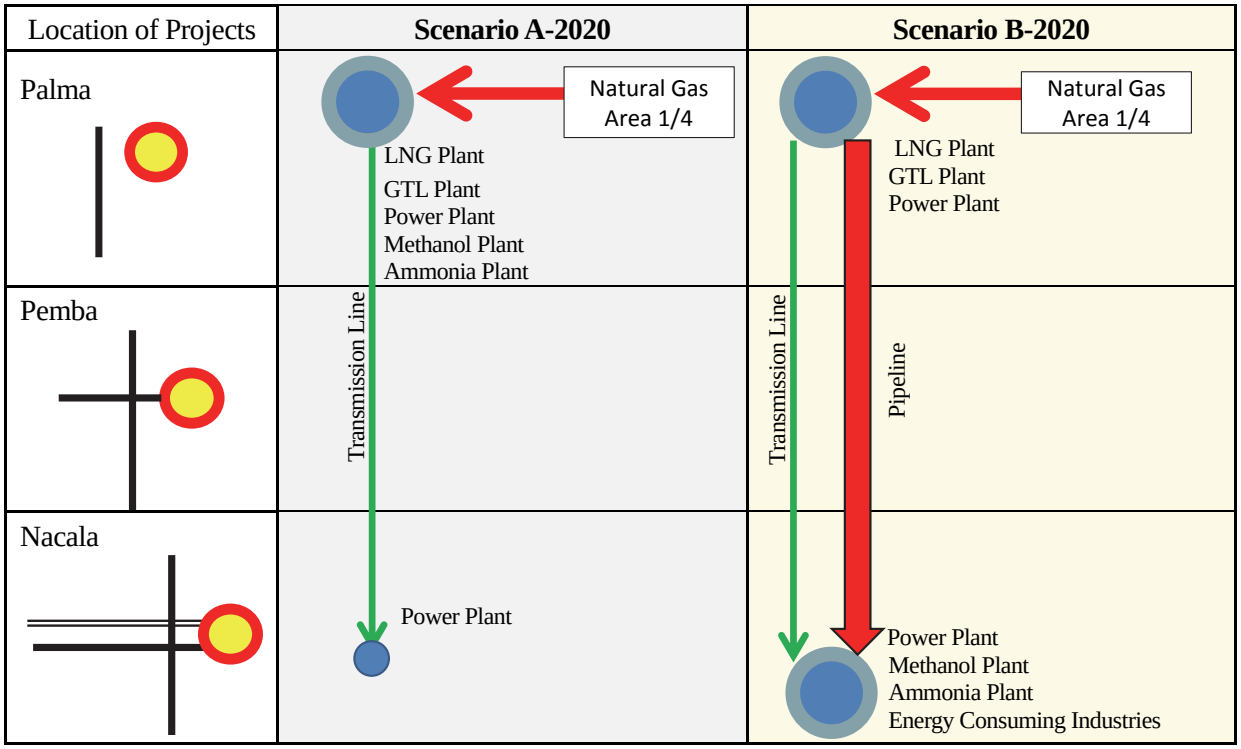
Gas power plants will be located in both Palma and Nacala Bay Area. However, the LNG plant and chemical industrial plant for GTL, methanol and ammonia / urea will all be concentrated in Palma. In such case a long distance pipeline is not necessary. Nonetheless, Palma will need to implement the necessary economic infrastructures and urban infrastructures for the chemical industries as well as labourers and supporting industries.

Scenario B: Decentralization across Palma and Nacala Bay Area

The LNG plant as well as the gas power plant and GTL plant will be located in Palma. On the other hand, a gas power plant and industrial plants for methanol and ammonia / urea as well as other industries which use gas as energy will be located in the Nacala Bay Area. To supply gas to the Nacala Bay Area, a gas pipeline from Palma to Nacala will be necessary.

(1) Short-term Scenario until 2020

Two scenarios were prepared and compared. The first is Scenario A-2020 which is the case in which an LNG plant and other chemical industries will be located in Palma by 2020. The second is Scenario B-2020 which is the case in which Nacala will be promoted for chemical industries to be located.



Source: JICA Study Team

Figure 4.1 Comparison of Scenarios until 2020 for Gas related Industries

The biggest difference between these two scenarios is the share of direct cost that the private sector would need to invest. In Scenario A-2020, since no gas pipeline is necessary, private sector's direct cost will be smaller than Scenario B-2020. However, since urban concentration and infrastructure are underdeveloped, the share of cost for the public sector will be large. As a result, it can be said that the total cost which the private sector and public sector need to cover in Scenario A-2020 and B-2020 will not differ greatly.

Table 4.4 Preliminary Study of Cost by Scenario

Cost	Scenario A-2020 Concentration at Palma	Scenario B-2020 Decentralization across the Palma and Nacala Bay Area
Cost of Preparing Urban and Industrial Infrastructure at Palma	• Since there is very limited urban concentration and infrastructure or industrial infrastructure in Palma, the cost to prepare those infrastructures will be large.	• The cost to prepare necessary infrastructure at Palma will be saved. • Additionally, the urban and industrial infrastructure in Nacala Bay Area can be shared with other industries and urban functions.
Cost of Pipeline between Palma and Nacala	• Gas pipeline is not necessary	• Cost for Palma-Nacala gas pipeline (426km, 20 inch): USD 391 million
Cost of Preparing Transport Infrastructure for Products	• Road development is necessary • Railway development is not possible at the moment	• Both road development and railway development is undergoing
Total Cost	• The total direct cost which private sector would need to consider will be smaller than Scenario B-2020 • On the other hand, the total cost which the public sector would need to consider will be larger than Scenario B-2020	• If the private sector is to provide the full or part of the cost of the pipeline, the total direct cost which the private sector would need to consider will be larger than Scenario A-2020. • On the other hand, considering the cost which the public sector would need to provide for developing Palma, the total cost for Scenario A-2020 and B-2020 is likely to be similar.

Source: JICA Study Team

Next, Scenario A-2020 and B-2020 were compared from the perspective of beneficial impact to the region.

Scenario A: Concentration in Palma

- An LNG plant and chemical industry plant (GTL, methanol and ammonia) will all be located in Palma and the beneficial impact for regional development will be limited to a geographically small area.
- Urban infrastructure development is necessary for Palma to become an industrial city

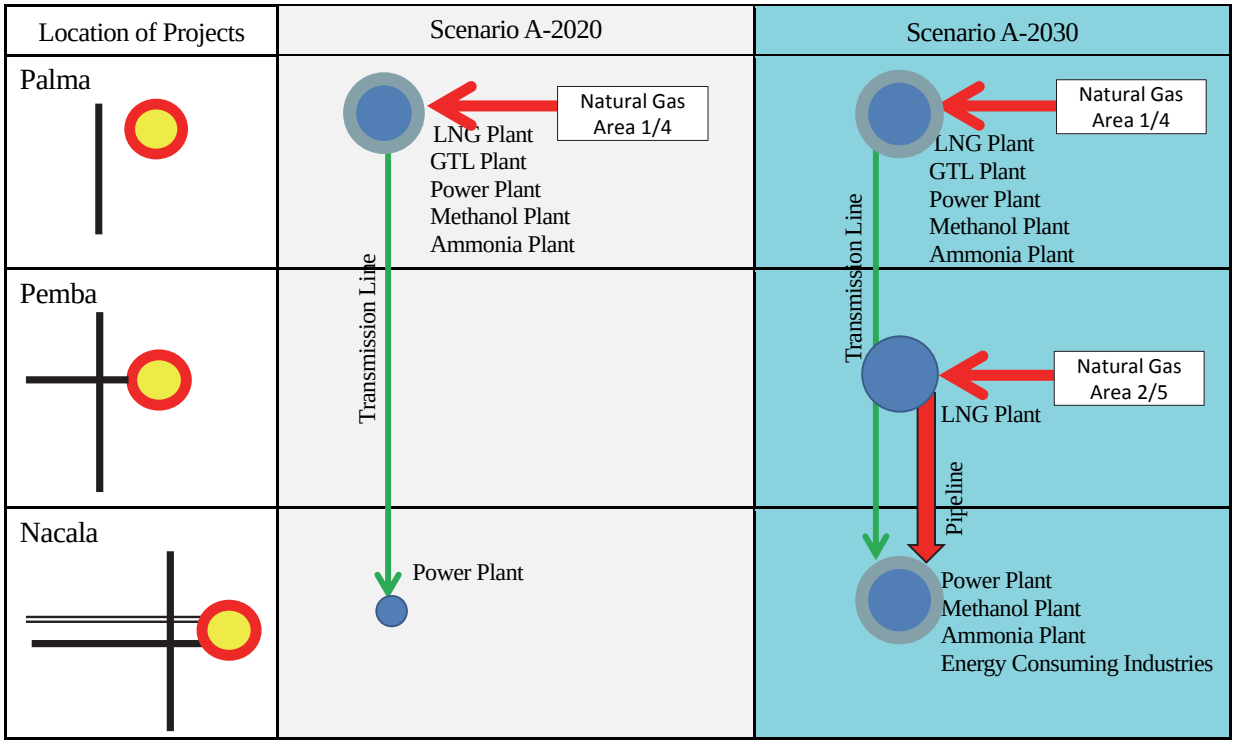
Scenario B: Deconcentrating across Palma and Nacala Bay Area

- Due to the Nacala Corridor Railway and major road development, by deconcentrating of natural gas industries across the Palma and Nacala Bay Area, the industrial development potential will be large in the Nacala Bay Area. However, infrastructure investment for power supply and water supply, which are not part of transport infrastructure, is urgently needed. If gas related chemical industries are located in Nacala Bay Area, it may become the driving force for the development of industrial infrastructure in the Nacala Bay Area.
- If the private sector needs to provide the full cost for gas pipeline construction, the prices of natural gas, which is the raw material for chemical industries, will be more expensive since the cost of pipeline construction needs to be covered. As a result, it will be difficult for gas related chemical industries to be located in the Nacala Bay Area. If the pipeline is constructed as a public pipeline, location of not only the chemical industries, but also the gas power plant and other industries which consume a large amount of energy will proceed in the future. Nacala Bay Area will become a possible destination for chemical industries if many actors share construction costs of the gas pipeline.
- Additionally, if the pipeline is constructed, the city gas supply and gas supply for industries can meet the energy demand of Nacala Bay Area.

(2) Medium- and Long-Term Scenario until 2030

If gas reserves are discovered offshore of Pemba in addition to Area 1 and Area 4 that are currently under development in Rovuma gas field, by constructing a gas pipeline between Pemba and Nacala, chemical industries can be located in Nacala Bay Area in both Scenario A-2020 and B-2020.

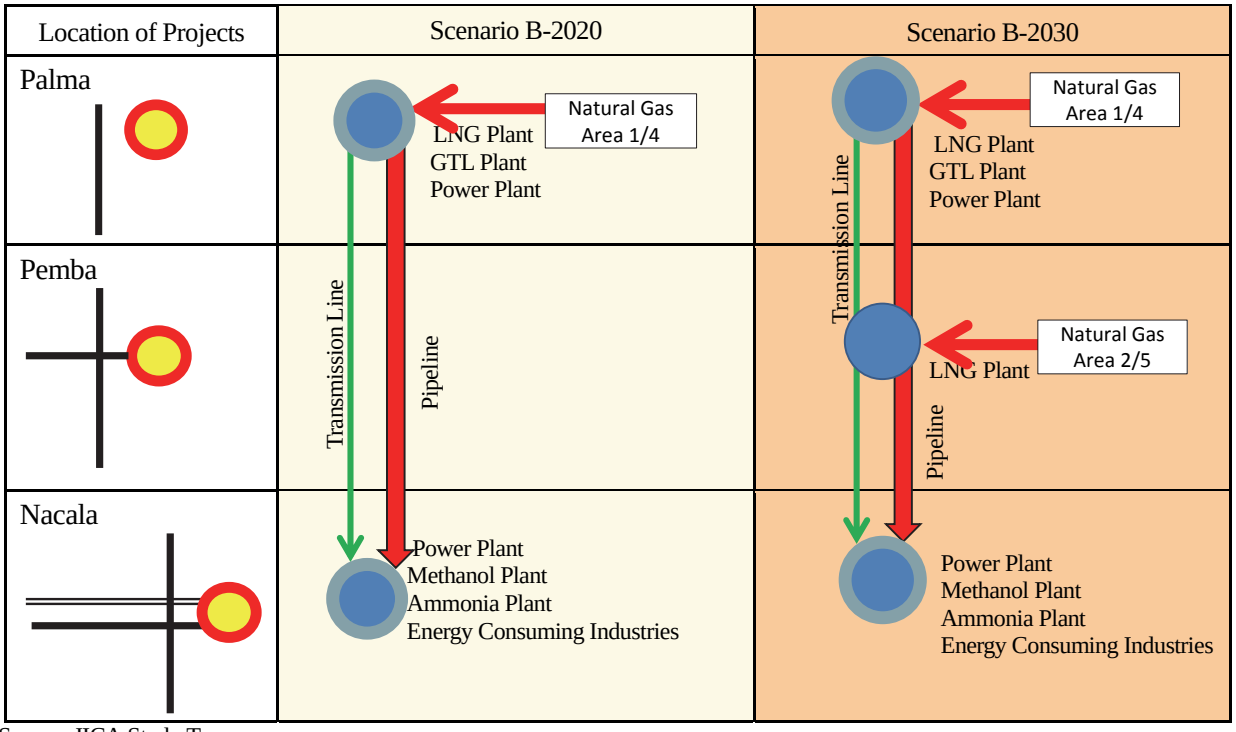
Figure 4.2 shows Scenario A-2020 and its future developed stage A-2030. Figure 4.3 shows Scenario B-2020 and its future developed state B-2030.



Source: JICA Study Team

Figure 4.2 Future Development of Scenario A

In Scenario A-2020, it would not be possible for Nacala Bay Area to become a destination for chemical industries. In Scenario A-2030, if gas reserves were found offshore of Pemba, since Pemba is closer to Nacala than Palma, gas related industries will not only be located in Pemba, but by constructing a short gas pipeline from Pemba to Nacala, it will also be possible for Nacala Bay Area to have chemical industries.



Source: JICA Study Team

Figure 4.3 Future Development of Scenario B

Furthermore, since a gas pipeline already exists from Palma in Scenario B, if natural gas will be extracted offshore of Pemba, it will be possible to transport gas to Nacala Bay Area using this existing pipeline as well as locate an LNG plant in Pemba.

As a result, if comparing Scenario A and B in the long-term, as long as gas reserves are found offshore of Pemba, all three cities have the chance to host gas related industries.

4.4 Forecast of Gas Demand in Palma and Nacala Bay Area

In Section 4.3, where the gas related industrial facilities should be located has been discussed. If it is concluded that such facilities should be located in Nacala Bay Area, it is necessary to construct a gas pipeline from Palma to Nacala Bay Area. This will be the case of Scenario B-2020 and B2030. Annual gas consumption on a stream day basis is estimated in Table 4.5 for the period between 2018 and 2025 for planning the pipeline, based on the preliminary study in Section 4.2 for gas utilization by large-scale projects, SME and urban transportation.

It is assumed that the following large-scale projects would have a potential market in Palma: a 150 MW simple cycle gas turbine power station, an expansion project by adding 250 MW gas combined cycle, and a GTL plant. Gas demand in Palma is forecast at 493 MMcfd on a calendar day basis or 555 MMcfd on a stream day basis in 2025.

The potential market for natural gas in Nacala is assumed as follows: a 150 MW simple cycle gas turbine power station, an expansion project by adding 250 MW gas combined cycle, a combination of ammonia and urea plants to produce 500,000 tons/year of urea, and users of SME and CNG. Gas demand in Nacala Bay Area is forecast at 105 MMcfd on a calendar basis or 125 MMcfd on a stream day basis in 2025.

Table 4.5 Forecast of Gas Demand in Palma and Nacala Bay Area (On a stream day basis)

User	Capacity	Av. Cons.	Capa. Factor	Flow Rate P/L	Gas Flow Rate for Pipeline Design (MMcfd)							
		MMcfd	%	MMcfd	2018	2019	2020	2021	2022	2023	2024	2025
In Palma												
Power St.	150MWGT	25	80	31	31	31	31	31	31	31	31	31
Power St.	250MWCC	32	80	40	-	-	-	-	-	-	40	40
GTL	50,000 b/d	436	90	484	-	-	484	484	484	484	484	484
Subtotal in Palma		493	-	555	31	31	515	515	515	515	555	555
In Nacala												
Power St.	150MWGT	25	80	31	-	-	31	31	31	31	31	31
Power St.	250MWCC	32	80	40	-	-	-	-	-	-	-	40
Am/Urea	500,000t/y	43	90	48	-	48	48	48	48	48	48	48
SME User	-	2	80	3	-	3	3	3	3	3	3	3
CNG	-	3	100	3	-	-	-	-	-	-	-	3
Subtotal in Nacala		105	-	125	-	51	82	82	82	82	82	125
Total Rovma Basin Gas		598	-	680	31	82	597	597	597	597	597	680

Source: JICA Study Team

4.5 Conditions regarding Palma-Nacala Gas Transmission Pipeline

In the case of Scenario B-2020, it is necessary to lay a high pressure gas transmission pipeline between Palma and Nacala to transport Rovuma Basin gas for use in Nacala. Table 4.6 shows the planning condition regarding the gas transmission pipeline.

Table 4.6 Conditions regarding the Palma-Nacala Gas Transmission Pipeline

Distance between Palma and Nacala	Approximately 400 km
Gas Flow Rate	125 MMcfd
Special Note	Pipeline project should be in harmony with the environment, in particular, Quirimbas National Park located between Palma and Nacala

Source: JICA Study Team

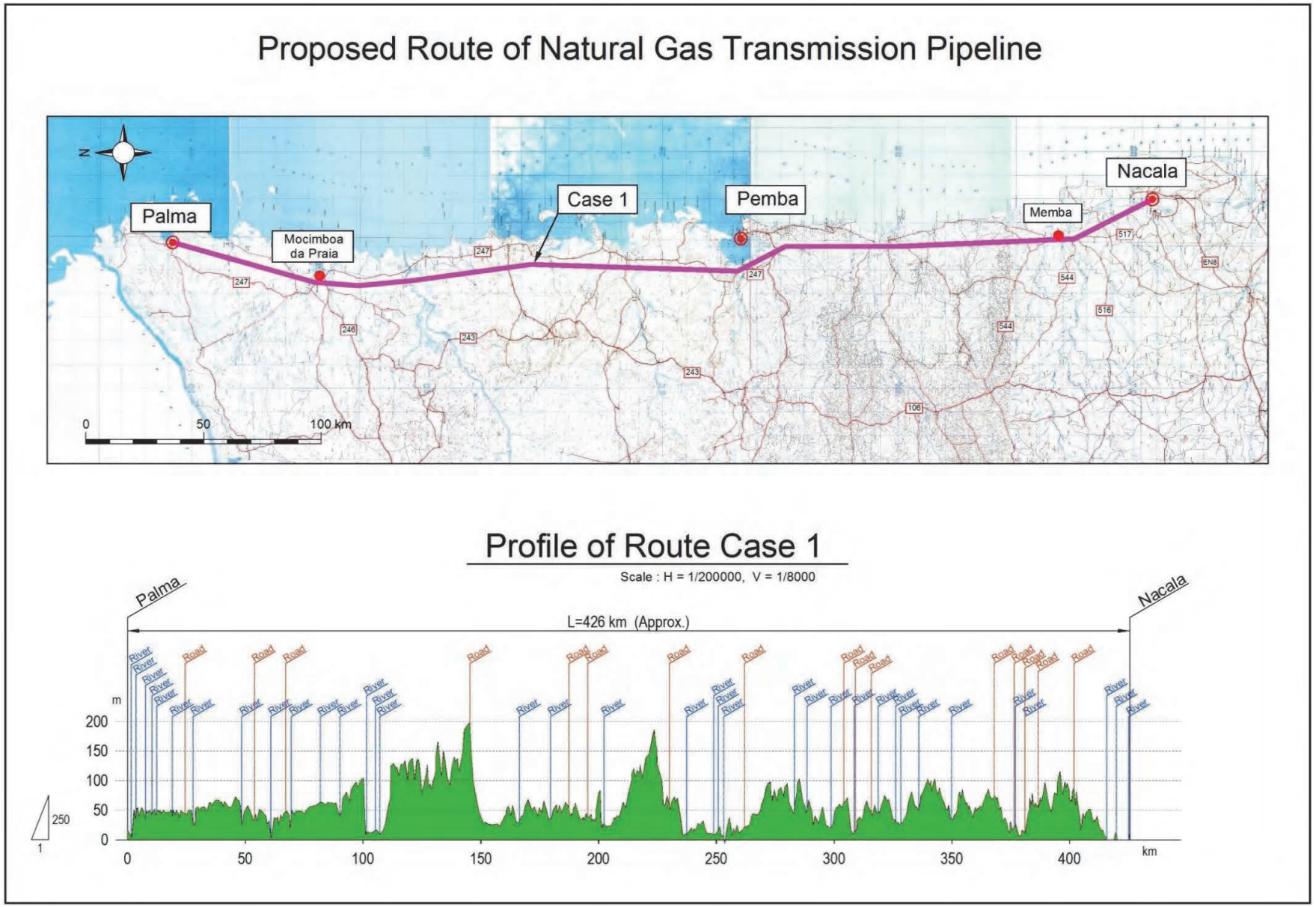
Pipeline route was selected to be along the road near the coast based on a 1/50,000 map with the length to be as short as possible. The following should also be considered in the future study:

- Imagination survey from Cessna was partially executed
- The width of the right of way will need to be a minimum of 20 m for construction
- During the feasibility study stage, a route for the pipeline should be selected to avoid swampy areas, rocky areas and housing areas as much as possible
- Soil investigations are necessary during the basic design stage
- Observing the cross sections, it seems that there are sudden changes in elevation from the 100km point to 150km point and from the 200km to 230km point. But pipeline construction work is not difficult.
- Since the pipeline route has to run through a national park area (Quirimbas National Park), coordination and approval process are necessary with the related authorities for environmental impact assessment.

The preliminarily selected route by the JICA Study Team is shown in Figure 4.5.

The approximate construction cost of the pipeline is US$ 391 million[15] excluding land acquisition and compensation.

[15] See PEDEC-Nacala Final Study Report Sector Document Chapter 5 for detailed construction cost.



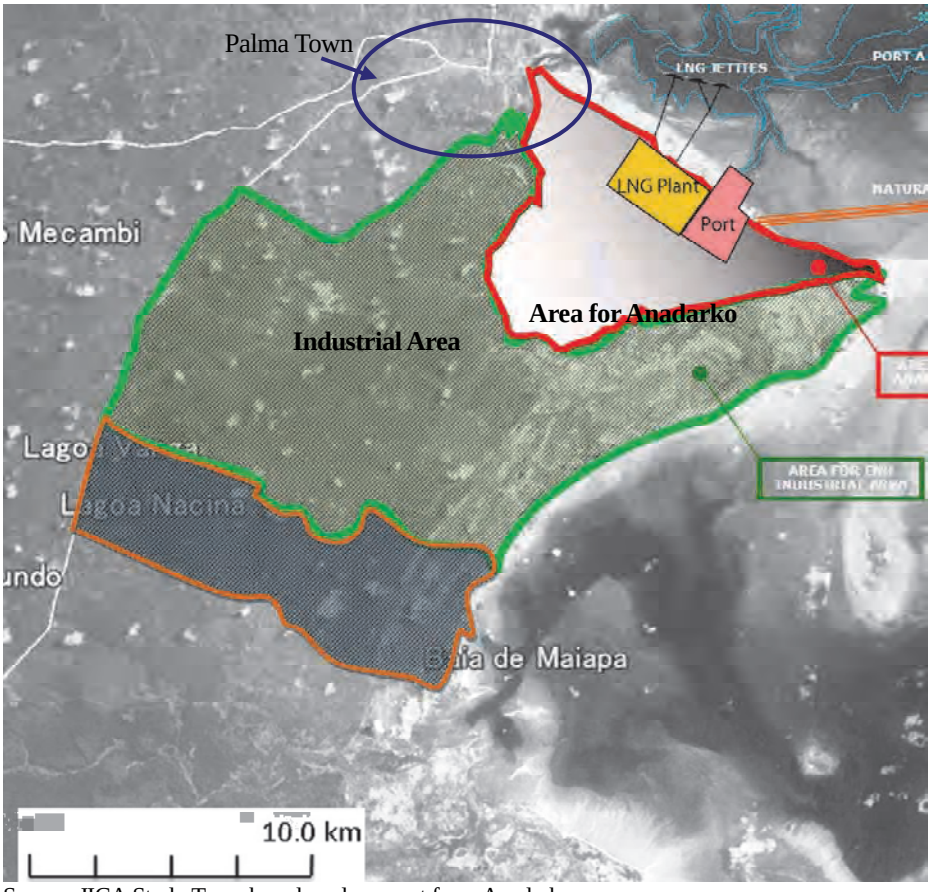
Source: JICA Study Team

Figure 4.4 Proposed Route for Palma-Nacala Pipeline

4.6 Preliminary Study for Development of a Public Port in Palma Town[16]

At present, there is no public port facility which enables normal cargo vessels to be docked at in Palma Town. Although offshore gas extraction will be mostly supported through sea from Pemba Town, there will be some support efforts from Palma Town too. In addition, provision of logistical and technical support to construction of LNG plants and chemical industrial plants will be required from Palma Town, as well as from Pemba Town. It will be necessary to develop not only urban infrastructure, but also residential areas for managers and workers in Palma Town. Furthermore, it will be necessary to develop urban function for nurturing and developing various services providers for natural gas extraction and chemical industrial operation in Palma Town.

However, the present layout plan for areas secured for LPG plants and their port facilities for Anadarko (shown in Figure 4.5) does not respond to any need for public port facilities.



Source: JICA Study Team based on document from Anadarko

Figure 4.5 Proposed Location for LNG Plants, Ports and Other Industries in Palma (Proposed by Anadarko)

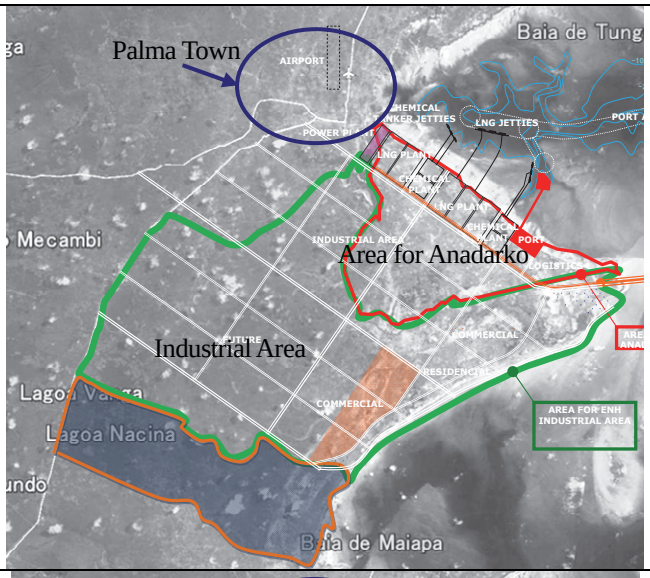
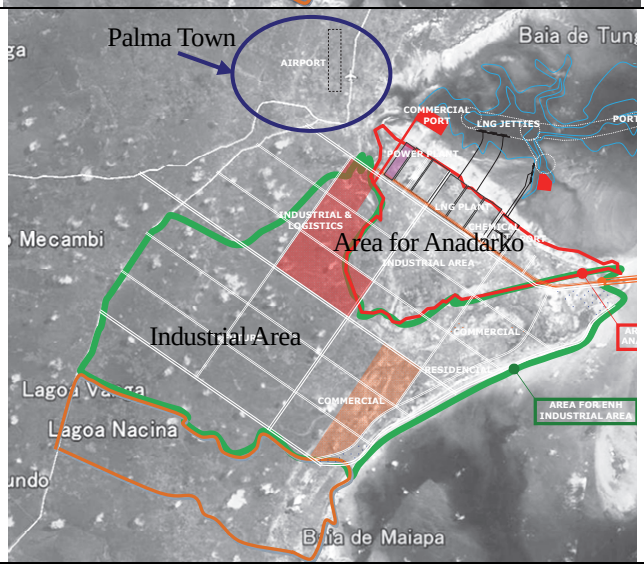
If the coastal development around Palma Town takes place following the proposal from Anadarko, Palma will not have any public port facilities during the stages of chemical industrial development and urban development when an onshore support base and gas related chemical industries are developed in Palma Town. There will be a risk for Palma Town to have a serious problem that

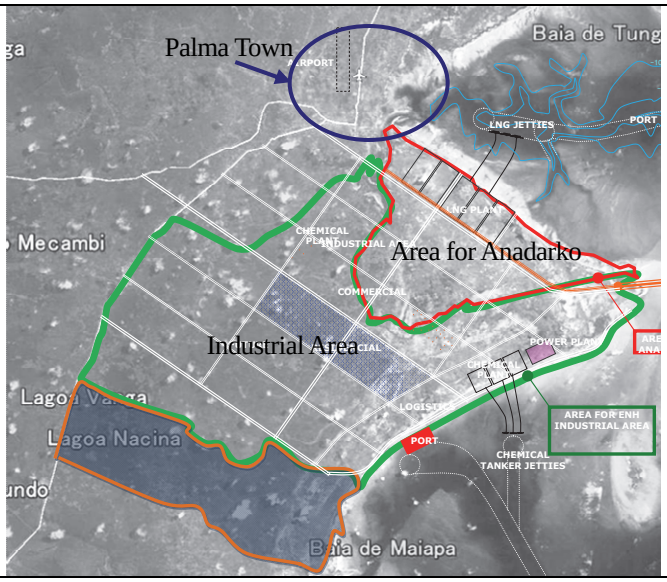
[16] See PEDEC-Nacala Final Report Main Text Section 5.3.4 for the present situation of Palma Port

urban and chemical industrial development cannot be promoted, because no public port facilities are available in Palma Town in the future.

In order to avoid such a problematic situation, it is necessary to prepare some ideas as counter measures. For this purpose, in this section, alternative locations of public port facilities will be considered and shown in Figure 4.6 in the context of Anadarko's layout plan shown in Figure 4.5. In order for the Northern Region of Mozambique to develop value chains for natural gas, a solution urgently needs to be found by creating a consensus regarding the location of a public port for Palma Town, among stakeholders including Anadarko.

Figure 4.6 Comparison of Alternative Locations for Public Port Facilities in Palma

Idea 1:Coexistence with Anadarko Area LNG plants, chemical industrial plants and a public port facility co-exist within Anadarko Area of the north-eastern shore.	
Idea 2: Partly Coexistence with Anadarko Area Only a public port facility and its access road are located within Anadarko Area of the north-eastern shore.	

<u>Idea 3: Separate Location from Anadarko Area</u> A public port and a port for chemical industries are located in the east-southern shore which is outside Anadarko Area. (Note: since this will need to be constructed on mangroves, environmental impact would be larger than other ideas.)	

Source: JICA Study Team

Chapter 5 Priority Projects related to Natural Gas

5.1 High Priority Projects of PEDEC-Nacala

A total of 93 projects selected as the priority projects to be implemented between now and 2035 in Chapter 19 of the Final Study Report were further reviewed in order to select the "High Priority Projects" to be initiated by 2017 and completed by 2025 in the short and medium terms. The following criteria were applied to identify those "High Priority Projects":

- Especially important projects in making the transport corridors effectively function as an initial driving force for development in the Nacala Corridor Region
- Especially effective projects in mitigating negative impacts on the natural and social environments of transport corridor upgrading and economic sector development
- Especially effective projects in promotion of economic sectors by taking advantage of development opportunities to arise due to the effectively upgraded transport corridors
- Especially important projects in starting up regional development so that other important development efforts could be implemented smoothly
- Higher level of maturity of projects whose necessity and methodology have been well understood by concerned agencies and stakeholders
- Projects whose negative environmental and social impacts could be mitigated with certainty by technologically established measures

As a result, a total of 48 projects were selected as the "Short- and Medium-Term High Priority Projects."

5.2 High Priority Projects related to Natural Gas Development

Out of the 47 high priority projects, the following five projects are selected as projects related to natural gas. As discussed in Chapter 4, with the only currently developable reserves in Rovuma Basin being Area 1 and Area 4, the locational pattern which will have facilities of natural gas related industries concentrated in Palma (Scenario A) will be most likely to be selected by the Government of Mozambique and private gas holders. In such case, high priority projects necessary to be implemented in the short- and medium-term are the following:

- Palma Port Project
- Palma Thermal Power Plant Project
- Palma-Pemba-Nacala Transmission Line Project
- Bridge Replacement Project for Pemba-Palma-Negomane Roads
- Palma Urban Water Supply Project
- Palma Urban Expansion Project

Chapter 6 Conclusions

6.1 Natural Gas Master Plan

The Natural Gas Master Plan was formulated by the Government of Mozambique and was approved by the cabinet in June 2014. The Natural Gas Master Plan sets a basic policy in which not only the export of LNG using the natural gas from Rovuma Basin should be exported, but also the domestic usage of natural gas should be emphasized as driving forces for industrialization in Mozambique.

Since the newly discovered gas in Rovuma Basin is located in the Northern Region of Mozambique, it is expected that the natural gas will contribute to the growth of the region which has been left behind in the development, as well as coordinate the development in the Nacala Corridor Region.

6.2 Conclusions: Value Chain for Natural Gas

The following are the possible uses of natural gas in the Northern Region of Mozambique

- Thermal power generation
- Manufacturing gas related products
  - LNG manufacturing
  - Ammonia / urea manufacturing
  - Methanol manufacturing
  - GTL Manufacturing

In order to achieve the above natural gas usage, development of a value chain is necessary.

Developing a value chain for natural gas means to create a value by connecting several activities like a chain starting from gas exploitation. The value chain for natural gas covers a wide range of activities as follows:

- Natural gas exploitation
- Transporting natural gas to a processing plant (via pipeline, CNG ship, truck etc.)
- Manufacturing products using natural gas (LNG, ammonium/urea, methanol and GTL)
- Transporting products made from natural gas to consumers (ship, train, truck, etc.)
- Thermal power generation using natural gas
- Electrical power transmission from gas-fired thermal power plants

The natural gas demand for the above mentioned activities in the Northern Region of Mozambique is estimated to be about 262 million GJ/year. It is understood that the amount of royalty gas and profit gas which belong to the Government is not adequate to satisfy this volume of natural gas demand. Based on this analysis, it is necessary to use the natural gas which belongs to private gas

holders for the purpose of satisfying the demand for Mozambique's domestic consumption of natural gas in addition to LNG manufacturing and exporting. In such a case, the locations of various domestic uses of natural gas should reflect private gas holders' business plans in terms of scale and location of chemical industrial plants and thermal power plants.

On the other hand, it turns out to be important and necessary to pay attention to and compare benefits to regional economy and society and monetary costs that public sectors should bear, for the purpose of selecting appropriate locational patterns. Alternative locations (other than Palma Town) for natural gas fired thermal power plants, a methanol manufacturing plant, an ammonia/urea manufacturing plant and heat utilization are considered and compared.

Scenario A: Concentration in Palma

Gas power plants will be located in both Palma and Nacala Bay Area. However, the LNG plant and chemical industrial plant for GTL, methanol and ammonia / urea will all be concentrated in Palma. In such case a long pipeline is not necessary. Nonetheless, Palma will need to implement necessary economic infrastructures and urban infrastructures for the chemical industries as well as labourers and supporting industries.

Scenario B: Deconcentrating across Palma and Nacala Bay Area

An LNG plant as well as a gas power plant and GTL plant will be located in Palma. On the other hand, a gas power plant and industrial plants for methanol and ammonia / urea as well as other industries which use gas as energy will be located in the Nacala Bay Area. To supply gas to Nacala Bay Area, a gas pipeline from Palma to Nacala will be needed.

Result of Comparing Alternative Options: Scenario B (Economic Choice)

The result of comparing the two alternative scenarios, Scenario A and B, is described below:

In Scenario A, in which the chemical industries are concentrated in Palma Town, a new chemical industrial city will emerge in Palma Town at the northern end of Mozambique.

Since chemical industries based on natural gas are capital intensive, social impact of such development to local areas would be very limited. On the other, medium and long-term public investments would be necessary for Palma's social infrastructure and urban infrastructure development.

On the other hand, in the case of Scenario B, in which chemical industries and other domestic gas users are located in both Palma Town and Nacala Bay Area, those gas-related industries and economic sectors located in Nacala Bay Area could take advantage of prospective economic and social infrastructures (roads, railways, and electricity and water supply) to be developed in Nacala Bay Area, as well as existing infrastructures in Nacala Bay Area.

Moreover, natural gas to be transported by pipeline could be utilized for energy and heat by various manufacturing industries to be developed in Nacala Bay Area.

By having chemical industries using natural gas in Nacala Bay Area, the possibility of regional development would rise strongly in Nacala Bay Area. In Scenario B, infrastructures can be utilized more efficiently. From these viewpoints, it can be evaluated that the deconcentrated spatial pattern across Palma and Nacala Bay Area is preferable.

Practical Selection: Scenario A (Most likely selection)

Since natural gas reserves have only been found in Area 1 and Area 4 to date, and the Government of Mozambique also only has a limited budget, it is most likely that the preferable scenario for the private gas holders will be Scenario A due to the smaller direct cost burden for the private sector.

High Priority Projects

The high priority projects necessary for achieving Scenario A are the following projects brought up in Chapter 5.

- Palma Port Project
- Palma Thermal Power Plant Project
- Palma-Pemba-Nacala Transmission Line Project
- Bridge Replacement Project for Pemba-Palma-Negomane Roads
- Palma Urban Water Supply Project
- Palma Urban Expansion Project

6.3 Issues

6.3.1 Issues for Scenario A (Concentration in Palma)

First of all, in the short- and medium-term, the manufacturing of LNG, GTL, methanol and ammonia will take place in Palma using the gas already found at Area 1 and Area 4 offshore of Palma.

The LNG plants of Anadarko and ENI will be allocated on the 7,000 ha land on the southern side of Tungue Bay which already has DUAT (land rights). Other gas utilizing chemical industries and supporting industries will be allocated the land already prepared at the rear of the LNG plants.

In such case, it may be difficult to locate the public port facilities to be used by the other chemical industries and their supporting industries as well as any other industries necessary in Palma and its residents. Therefore, MTC, CFM and PCD in charge of port facilities need to discuss with Anadarko and ENI about alternative locations for public port facilities. Based on this discussion they will need to determine the implementing policy for public port facilities and urgently pursue implementation.

6.3.2 Issue for Scenario B (Deconcentrating across Palma and Nacala Bay Area): Palma-Nacala Gas Pipeline

Construction, Operation and Maintenance of Gas Pipeline

In Scenario B, in which chemical industries will be deconcentrated across Palma and Nacala Bay Area, the construction of a gas pipeline between Palma and Nacala Bay Area will be necessary. There are the following three options for construction, operation and maintenance of the gas pipeline:

1) Mozambique National Hydrocarbon Company (ENH) is to construct, operate and maintain the gas pipeline under the guidance of the Government.

2) By utilizing the initiative of the private sector, ENH and private companies (such as the developers of large-scale projects) are to establish a joint company for the purpose of the pipeline project, and this joint company will construct, operate and maintain the gas pipeline.

3) A single private company or joint private companies (e.g., developers for large-scale projects) will establish a company for the purpose of the gas pipeline project, and this company will construct, operate and maintain the pipeline.

The Natural Gas Master Plan of Mozambique recommends that developers should propose options 2) or 3). However, since adequate incentives might not been given to developers, there is a concern about whether developers could actually propose towards the gas pipeline project.

In order to actually proceed with Scenario B, a further study will be necessary for the gas pipeline project in addition to a study on chemical industrial locations.

Route for Palma-Nacala Gas Pipeline

The proposed route for the Palma-Nacala pipeline, as shown in Figure 4.4, would go through the Quirimbas National Park. Therefore, it is necessary to carefully conduct environmental impact assessment at the stages of feasibility study and engineering design.

6.3.3 Natural Gas Reserves in Southern Areas of Rovuma Basin

If more gas fields are discovered in the Rovuma Basin, this will impact the domestic natural gas usage greatly. Continuous effort to understand the exploration situation are necessary and if there are any new gas fields found, the above locational scenarios for chemical industries need to be revised.

If gas reserves are found offshore of Pemba, it will be possible for a gas power plant and chemical industries using natural gas to be located in Nacala Bay Area and Pemba City.

The possibility for LNG plants and a gas power plant to be located in Pemba City will also become more likely. In addition to that, constructing a gas pipeline between Pemba and Nacala will increase the potential to locate a gas power plant and chemical industries (such as methanol and ammonia) in the Nacala Bay Area and opportunities for private businesses will emerge.

APPENDICES

Appendix Table of Contents of Final Study Report for PEDEC-Nacala

The Final Study Report of PEDEC-Nacala is composed of the following volumes.

- Summary
- Main Text: Volume 1
- Main Text: Volume 2
- GIS Atlas
- Sector Supporting Document

The Main Text of the Final Study Report is composed of 7 parts with 21 chapters and 5 appendices. The table of contents of the Main Report is as follows: