Chapter 4 Natural Gas Utilization Industry

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4.1 LNG (Liquefied Natural Gas)

In the LNG technology, natural gas (mainly comprising methane and gaseous at normal temperature) is cooled to -162°C to produce LNG having a volume about 1/600th of that of gaseous status, thereby to enable long-distance mass transportation of natural gas via oceangoing tankers. Since the 1970's, increasing quantities of LNG have been exported to the markets in Japan and Northeast Asia that are situated away from large gas fields. LNG currently accounts for about one-third of the volume of the international natural gas trade. Although LPG can be produced when natural gas used as a feedstock which includes a large amount of propane and butane, natural gas produced in Tanzania has a high methane content of 98%, and it is considered difficult to produce LPG in a material quantity at a natural gas plant in Tanzania.

A schematic diagram of LNG production process is shown in Figure 4.1-1.

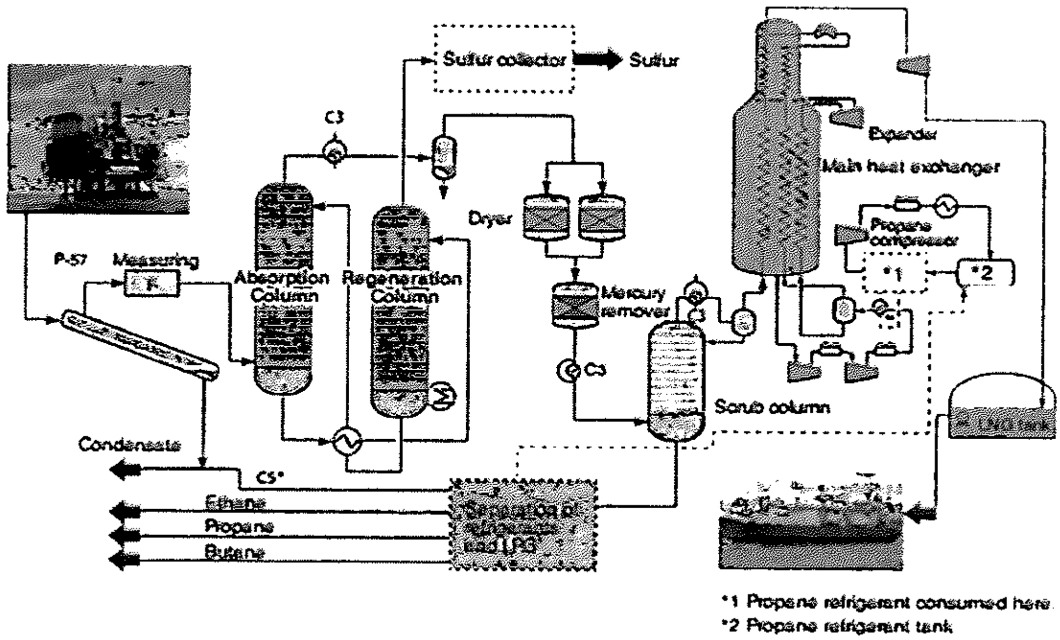


Figure 4.1-1 Schematic Diagram of LNG Production Process

Natural gas sent from gas fields is at first introduced into the Slug Catcher and separated into gas and condensate. Condensate is heavier hydrocarbon and sent to the storage tank after adjusting the vapor pressure. Separated gas is introduced into the Acid Gas Removal Unit, Dehydration Unit, and Mercury Removal Unit in order to remove CO_2, H_2S, Moisture and Mercury. CO_2 and Moisture shall be removed because of solidification in the low temperature.

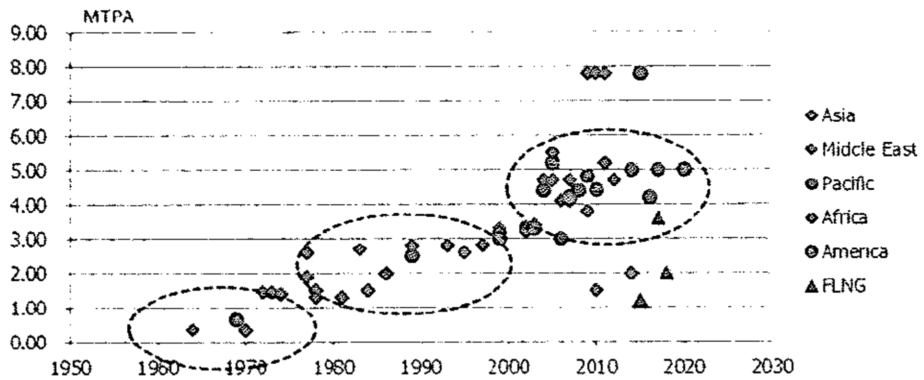
H_2S shall be removed because of environment requirement. Mercury shall be removed because of corrosion protection of downstream aluminum material at the main heat exchanger.

In the liquefaction section, the treated gas as above is introduced into the Scrub Column in order to separate heavy hydrocarbon because of solidification in the low temperature. After removal of heavy hydrocarbons, gas is introduced into the MCHE (Main Cryogenic Heat Exchanger) for liquefaction by heat exchange with the Refrigerant. After the MCHE, expander may be installed for the purpose of power recovery. LNG is run down into the storage after pressure is reduced to the atmospheric pressure.

LNG plant consist of the above mentioned process facility, utility facility and storage & loading facility.

Although the typical production capacity of LNG plants in the early days was about 500,000 tonnes/year (single train), plant sizes are growing larger and larger in recent years where mammoth LNG plants having a capacity of 7,800,000 tonnes/year have been built. Historical trend of LNG train capacity is shown in the Figure 4.1-2. The recent LNG plants typically have a capacity of 5,000,000 tonnes/year. Recent LNG project record is also shown in the Table 4.1.

A single train having a capacity of 5,000,000 tonnes/year uses natural gas as a feedstock in an amount of approximately 5.5 Tcf over 20 years, including about 10% consumed as fuel for captive use. Since a large amount of natural gas can be handled by two of such trains, i.e., 11 Tcf in total, it has become an important means for developing a gas field that is situated away from the gas market, and for which it is difficult to commercialize based on pipelines. The natural gas field discovered in Tanzania is situated at a water depth as deep as 1,150 to 2,500 meters, and it is considered that huge expenditures of several tens of billion dollars may be required for its development. An LNG project is a most important option as a means for providing a stable anchor demand for such a megaproject.



(Source) IEEJ

Figure 4.1-2 Historical trend of LNG train capacity

Recent trend of LNG industry are use of unconventional gas resources and floating LNG. Unconventional gas such as coal seam gas (coal bed methane) and shale gas are utilized in addition to the conventional gas. Coal seam gas liquefaction projects are on-going in Australia and shale gas liquefaction projects are on-going in North America and Canada. In the past, LNG plants were built on shore, but recently several floating LNG projects are being developed for remote offshore gas fields.

Table 4.1-1 Recent LNG project record

No.	Country	Project	Start Year	Number of Trains	Nameplate Capacity per Train (mmtpa)
1	Equatorial Guinia	EG LNG T1	2007	1	37
2	Norway	Snohvit LNG T1	2007	1	42
3	Qatar	RasGas II (T3)	2007	1	47
4	Australia	North West Shelf (T5)	2008	1	44
5	Nigeria	NLNG (T6)	2008	1	41
6	Indonesia	Tangguh LNG	2009	2	38
7	Qatar	Qatargas II	2009	2	78
8	Qatar	RasGas III	2009	2	78
9	Russia	Sakhalin 2	2009	2	48
10	Yemen	Yemen LNG (T1)	2009	1	335
11	Peru	Peru LNG	2010	1	445
12	Qatar	Qatargas III	2010	1	78
13	Yemen	Yemen LNG (T2)	2010	1	335
14	Qatar	Qatargas IV	2011	1	78
15	Australia	Pluto LNG (T1)	2012	1	43
16	Algeria	Skikda - GL1K Rebuild	2013	1	45
17	Angola	Angola LNG (T1)	2013	1	52

(Source) IGU World LNG Report - 2014 Edition

In order to secure a robust facility and sustainable operation for long term LNG supply, which is also associated with a significant capital investment, an LNG project is normally developed in a phase-wise manner until the final investment decision (FID) is made: namely, proceeding through various decision-making gates based on technical, commercial and institutional studies as well as designs.

Firstly, conceptual and feasibility studies will be conducted leading to general but serious consideration being given to the project. These studies may indicate a level of positivity about furthering definitions, and then key project basis as well as other important factors (project cost, schedule, etc.) will be studied in the pre-FEED phase. If the pre-FEED studies prove favorable in clearing the gates to proceeding with the front-end-engineering-design (FEED), further time and effort will be allocated to establishing the defined basis of the EPC activities.

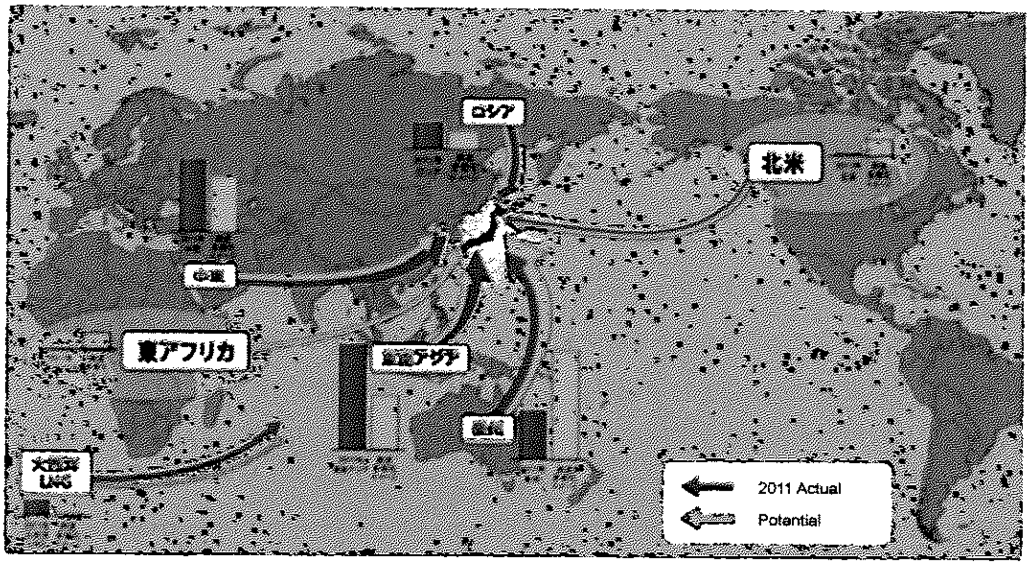
Based on such FEED outcome, the definitive cost estimate and schedule planning are developed by contractors in a competitive situation, as a typical approach. (Dual or triple FEED competitions are often adopted in recent times for the selection of EPC contractor). In parallel, Project owners will need to discuss and negotiate with the relevant parties and institutes to ensure that other important matters are in place for FID, such as an environmental impact report and construction permits, natural gas supply agreements, LNG supply agreements with buyers and off-takers, as well as financial arrangements.

Industry experience tells us that 4 - 6 months is required for the conceptual and feasibility studies, 6 - 12 months for the pre-FEED phase, another 12 months for FEED, and 4 - 6 months for the definitive cost and schedule estimate, for a typical green field stick-built project in a remote location. Depending on the applicable contracting strategy, these periods may be optimized. However, under circumstances where the selection of a contractor for each phase is necessary, additional periods may be considered for tendering and for the related approvals.

In an economic analysis study to be conducted in the initial project phase, cost factors, such as natural gas price, LNG plant construction and operation and transportation, will be estimated based on professional assumptions and available information. This analysis is to evaluate would-be profit margins of the project and/or possible alternatives for securing a certain expected level of profit. A high level plant cost estimate will be one of the key efforts in building an economic model.

As described earlier, a green field LNG plant comprises full facilities for pre-treatment, liquefaction, utility and storage and offloading, as well as administration buildings and residential areas. These elements will be considered in the estimate. Corresponding to the uniqueness of the natural gas characteristics, the bathymetric, metocean and soil conditions, the probable overall project cost may increase due to consideration to additional pre-treatment facilities, longer offloading jetties and extensive marine facilities for berthing of LNG carriers, excessive piling and foundation, as well as other logistical requirements. The availability of relevant information will result in a practicable evaluation in the economic analysis.

After the turn of the century, large LNG projects have been carried out one after another in countries such as Qatar and Australia, encouraging the international LNG trade to be increasingly active. In addition to China and India which have started to import LNG, a well-known fact is that Japan has rapidly increased its LNG imports after the Fukushima nuclear accident in 2011. From around 2010, Thailand, Indonesia, and other countries have started to use LNG as well, and LNG demand is expected to grow in the future and mainly in Asia.



(Source) JOGMEC

Figure 4.1-3 Diversified LNG Supply Sources for Japan

In 2014, some 240 MTPA LNG have been produced and traded worldwide. A total of 130 MTPA LNG will be added in the period between 2015 and 2018 from projects including those in Australia and the US which are already sanctioned and currently under construction. Moreover, similar volumes of LNG are planned to be supplemented, targeting 2019 and onwards from those projects now at a stage close to FID and in the advanced stage of design and planning. If we consider projects in the very early stage of planning and somewhat speculative, this will amount to a total of over 700 MTPA.

Not all of the projects under planning would be materialized and some may face delays in their plans. However, it is also true that there will still remain many projects where the planning targets start-up in the early 2020's such as our Tanzania LNG project, which may reach FID in the late 2010's, while at the same time it appears that competition for survival among projects will become increasingly severer.

Potential LNG buyers will choose from the many projects that are planned, in line with their purchasing strategy for selecting those that have the positive fundamentals of a robust and reliable LNG facility and sustainable operation capability for long term stable supply of LNG. Selection criteria must be expended to confidence in the competitiveness of LNG prices from a project to be delivered in a competitive design manner on the basis of execution by a proven and reputable contractor. Under these circumstances, it is important to recognize that the most urgent key factor for making progress is, among others, to take action for securing committed and bound LNG buyers and off-takers by showing and proving the abilities of the project owners.

4.2 Ammonia and Fertilizer

4.2.1 Fertilizer - Necessary for Plant Growth

Plants take up water and inorganic substances through their roots, and take carbon dioxide from the air through their leaves as nutrients. Fertilizers are substances that supply plant nutrients which are not always enough available in the soil. Nitrogen (N), phosphorus (P) and potassium (K) are the most important elements in plant nutrition, called three fertilizer elements. Besides them, plants cannot grow well without other fertilizers that supply calcium (Ca), magnesium (Mg) and micronutrients that are also not always enough in the soil.

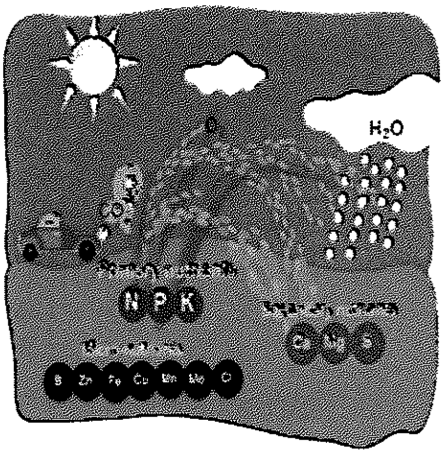


Figure 4.2-1 Nutrients Necessary for Plant Growth

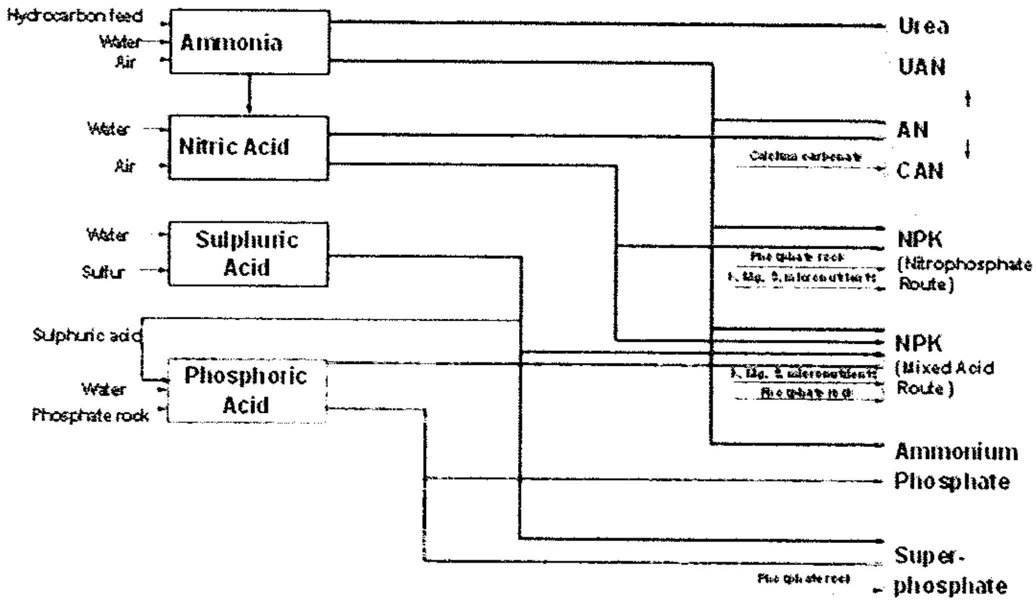


Figure 4.2-2 Fertilizer Value Chain

4.2.2 Ammonia, Urea, and Their Production Process

Urea is a typical nitrogen-based chemical fertilizer, and accounts for about 40% of chemical fertilizers comprising nitrogen-, phosphorus-, and potassium-based products combined. Ammonia, which is a starting material for urea, is produced by reacting hydrogen (H_2) included in natural gas with nitrogen (N_2) in air. Urea is produced from ammonia (NH_3) using carbon dioxide (CO_2) produced as a by-product in the above process.

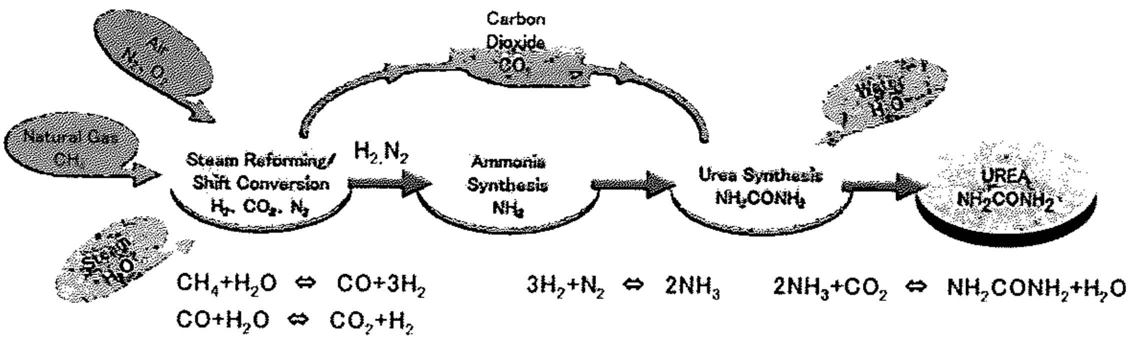
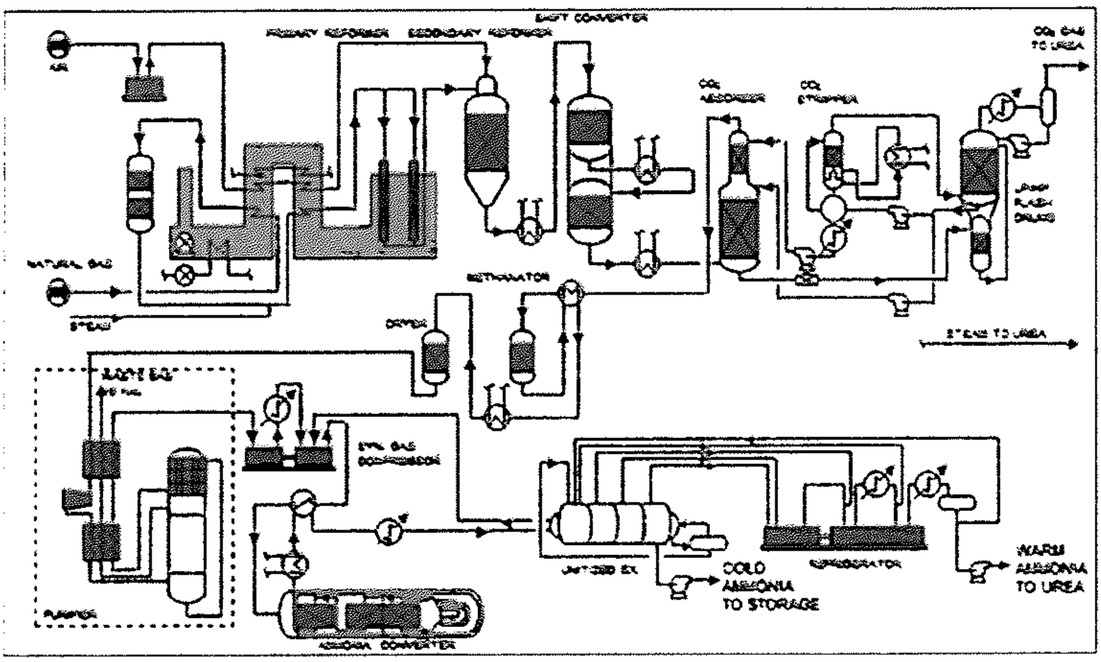


Figure 4.2-3 Process for Ammonia and Urea Production

Ammonia is also used as a raw material for other nitrogen-based fertilizers including ammonium nitrate and ammonium sulfate as well as chemicals such as synthetic fibers, whereas urea is also used as a raw material for plywood adhesives and melamine. Therefore, a chemical industry group can be formed by combining these products. In recent years, ammonia and urea plants have grown in scale with reduced unit energy consumption, where their capacity has reached a level of 3,000 to 4,000 tonnes/day. The typical natural gas consumption is about 80 MMSCFD or 0.5 to 0.6 Tcf over 20 years, on the basis of a combination of a 2,300 tonnes/day ammonia plant and a 4,000 tonnes/day urea plant. The natural gas consumption in a typical combination plant is about 1/10th of that of LNG plants.

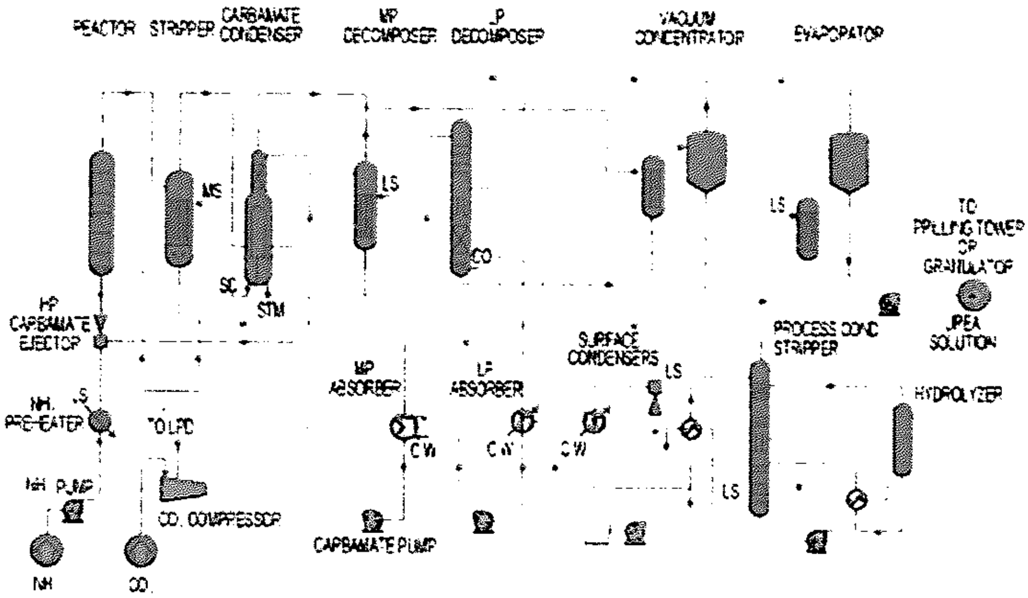
(Source) Toyo Engineering Corporation (P.T. Pupuk Kalimantan Timur)

Figure 4.2-4 Ammonia & Urea Plant in Indonesia



(Source) Toyo Engineering Corporation

Figure 4.2-5 Process Flow Diagram of Ammonia Production Process (KBR Process)



(Source) Toyo Engineering Corporation

Figure 4.2-6 Process Flow Diagram of Urea Production Process (Toyo Engineering Process)

Subsections 4.2.1 and 4.2.2 briefly reviewed the outline of fertilizers and the ammonia/urea production processes. The following subsections describe information and data related to fertilizer in Tanzania and neighboring countries from the view point of consumptions, government policies and demand forecasts as a reference in planning fertilizer projects in Tanzania.

4.2.3 Situation of Fertilizer Use in Tanzania

Current situation of fertilizer use in Tanzania has been surveyed based on the reports by research institutes.

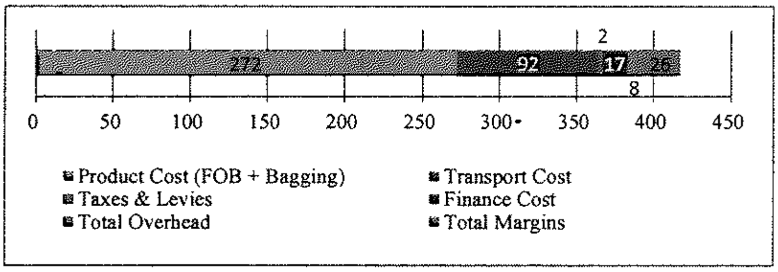
According to International Fertilizer Development Center (IFDC), the annual consumption of fertilizers in Tanzania was 263,000 tonnes in 2010, which was less than a half of the government target of 528,000 tonnes by 2015. Additionally, in the same year, the average fertilizer use per unit cultivated land in Tanzania was still 7kgs/ha, far less than the minimum Sub-Saharan countries' target of 50kgs/ha declared in Abuja Declaration of Africa Fertilizer Summit 2006. As described above, agriculture in Tanzania is in absolute shortage of fertilization, symbolized by the extremely low fertilizer use. Increase of fertilizer use is anyhow needed in Tanzania, at least to achieve the government target immediately, and to subsequently achieve the target of Abuja Declaration. JICA study team estimates that 2 million tonnes of fertilizer use is required annually in order to meet the 50kg/ha target of Abuja Declaration, which is seven times greater than the263 thousand tonnes, the actual consumption in 2010.

Under such circumstances, the Government of Tanzania is promoting fertilizer use in order to enhance agricultural productivity. A typical measure is National Agricultural Input Voucher Scheme (NAIVS), implemented with financial support by the World Bank.

On the other hand, since there are no fertilizer plants in Tanzania except for a small scale Phosphate (P2O5) based one, Tanzania relies on imports for most of fertilizers including urea.

4.2.4 Fertilizer Price

This subsection describes survey results of fertilizer price and relevant data available in public by research institutes. According to IFDC, average price of fertilizer imported from abroad and delivered to in-land market in Tanzania was 419 USD/tonne in 2006, consisting of FOB price 65%, transportation cost 22% and importers/traders' margins 6.1%.



(Source) IFDC (2009)

Figure 4.2-7 Components of Average Price of Fertilizer Delivered to In-land Market in Tanzania (2006)

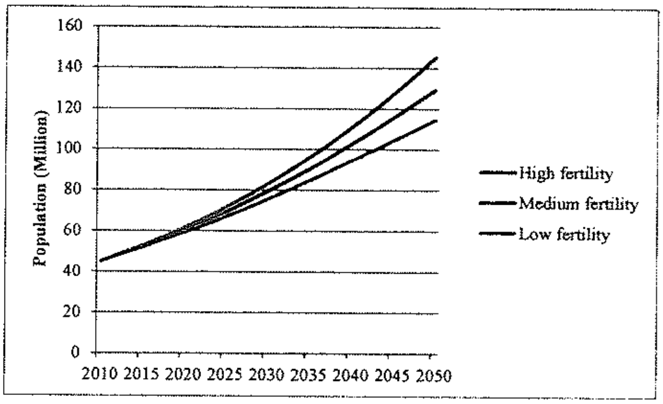
According to the International Food Policy Research Institute, while average urea local retail price in Tanzania was 592 USD/tonnes in the period from August 2010 to January 2011, the average price of FOB Middle East was 381 USD/tonne which was 64.3% of the retail price, indicating that the ratio of retail price to FOB price is kept almost constant regardless of the prices.

Fertilizer is an internationally traded commodity, and its price changes depending on supply-demand balance, feedstock price, etc. For example, the urea price of FOB Middle East in July 2014 ranged from 305 to 318 USD/tonne.

4.2.5 Fertilizer Demand Forecast

1) Fertilizer Demand Forecast in Tanzania

Population of Tanzania of 49.25 million (2013, World Bank) is forecasted to expand to 115.69 million in 2045 according to the United Nations Population Division (moderate projection). In order to meet an increase in food consumption along with the population expansion, needless to say, the first priority should be given to increase in food production; and thus, enhancing agricultural productivity would become significantly important. In addition to the efforts for towards the target of Abuja Declaration, further demand for fertilizers is foreseen because of the future population growth.



(Source) World Population Prospects (United Nations)

Figure 4.2-8 Population Prospects in Tanzania

2) Fertilizer Demand Forecast in Countries Neighboring Tanzania

Similar to Tanzania, the promotion of fertilizer use is a key issue in agriculture in neighboring countries. According to IFDC in Ethiopia, while government's target of annual fertilizer use is 1,200 thousand tonnes in 2015, consumption in 2010 was 427 thousand tonnes, and in Kenya, while government's target of annual fertilizer use is 910 thousand tonnes in 2015, consumption in 2010 was 447 thousand tonnes. Consumptions of fertilizers in both countries fall well below the targets.

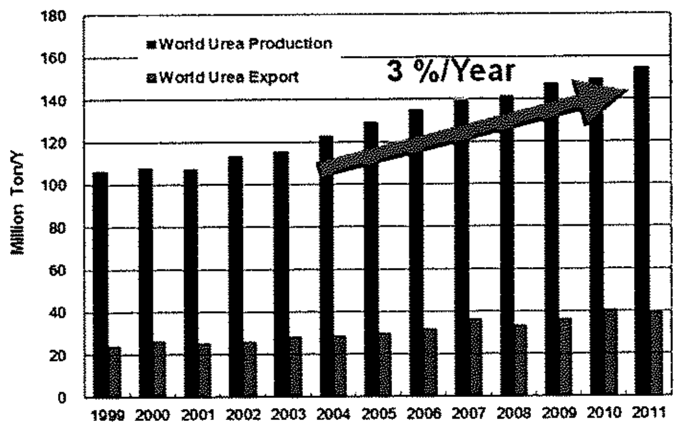
According to the International Fertilizer Society, the average fertilizer use per hectare in Sub-Saharan countries was 8kg/ha in 2010 which was one sixth of Abuja Declaration target of 50kg/ha. Besides, while the population of Ethiopia and Kenya are 94,100 thousand and 44,350 thousand respectively (2013, World Bank), the World Population Prospects estimates that the population of Ethiopia will be reaching 175,890 thousand and that of Kenya reaching 90,810 thousand (moderate projection) respectively by 2045; which are almost the double of present populations. In those neighboring countries, in order to meet an increase in consumption of food along with the population expansion, in addition to the efforts towards government and Abuja Declaration targets, further increase in fertilizer use would be required.

In order to achieve at least the present target of 50kg/ha fertilizer use declared in Abuja Declaration, JICA study team estimates that more than 8 million tonnes of fertilizer per annum, 9 times greater than the fertilizer consumption in 2010, would be required in neighboring countries such as Uganda, Rwanda, Burundi, Zambia, Malawi, Mozambique, Ethiopia and Kenya.

In addition, such neighboring countries have no full-scale fertilizer plants such as those for ammonia and urea except for small-scale chemical fertilizer plants; therefore, those countries also rely on imports for most of fertilizers.

3) World Urea Demand

As shown in Figure 4.2-9, the global urea fertilizer consumption has been increasing by 3 percent each year since 2001. This growth rate of annual urea fertilizer consumption corresponds to new annual installation of 3 to 5 urea plants and the growth is expected to further continue in the long run.



(Source) International Fertilizer Industry Association (IFA)

Figure 4.2-9 World Urea Production

4) Summary of Fertilizer Demand Forecast

Since the increase in fertilizer use is a key issue in developing agriculture in Tanzania and its neighboring countries, the first priority should be given to achieving government and Abuja Declaration targets. Additionally, in order to meet an increase in food demand along with the population expansion, fertilizer use should be further enhanced as one of the measures in improving agricultural productivity.

In addition, Tanzania and its neighboring countries rely on imports for fertilizers. In such circumstances, fertilizer production including urea from low cost natural gas produced in Tanzania would contribute to self-sufficiency of fertilizers in Tanzania and improving agricultural productivity, as well as meeting fertilizer demands in neighboring countries. Furthermore, urea can be exported to an international market as a commodity.

On February 3rd 2015, a German company Ferrostaal issued a press release that announced a consortium led by Ferrostaal with Haldor Topsoe in Denmark and Fauji Fertilizer Company Ltd. in Pakistan, launching a project to develop an ammonia/urea plant in Tanzania. The plant will be producing 1.3 million tonnes annually, for both local consumption and international export, which would be operational in 2019-2020.

However, in view of the fertilizer demand forecast in Tanzania and neighboring countries reviewed as above, JICA study team believes that Tanzania deserves further fertilizer projects to meet the future demand.

4.3 Methanol

4.3.1 Methanol Production Process

Methanol plants produce highly-purified methanol from hydrocarbon sources such as natural gas as a raw material via syngas and methanol synthesis through catalysis and distillation. A typical syngas preparation process is a steam reforming process in which the feedstock hydrocarbon reacts with steam as reforming agent in the presence of catalyst at high temperature.

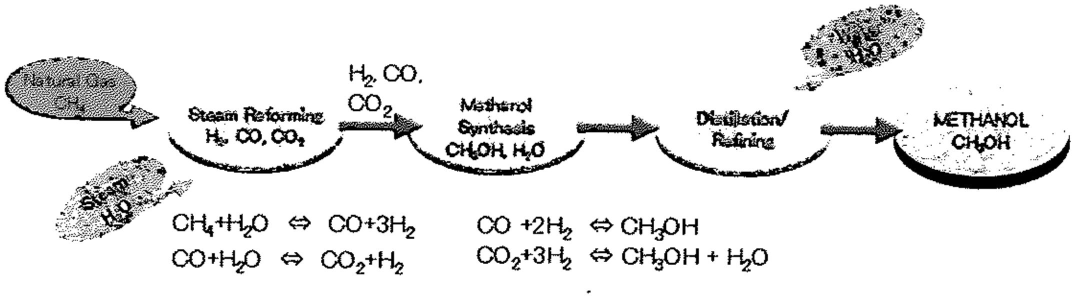
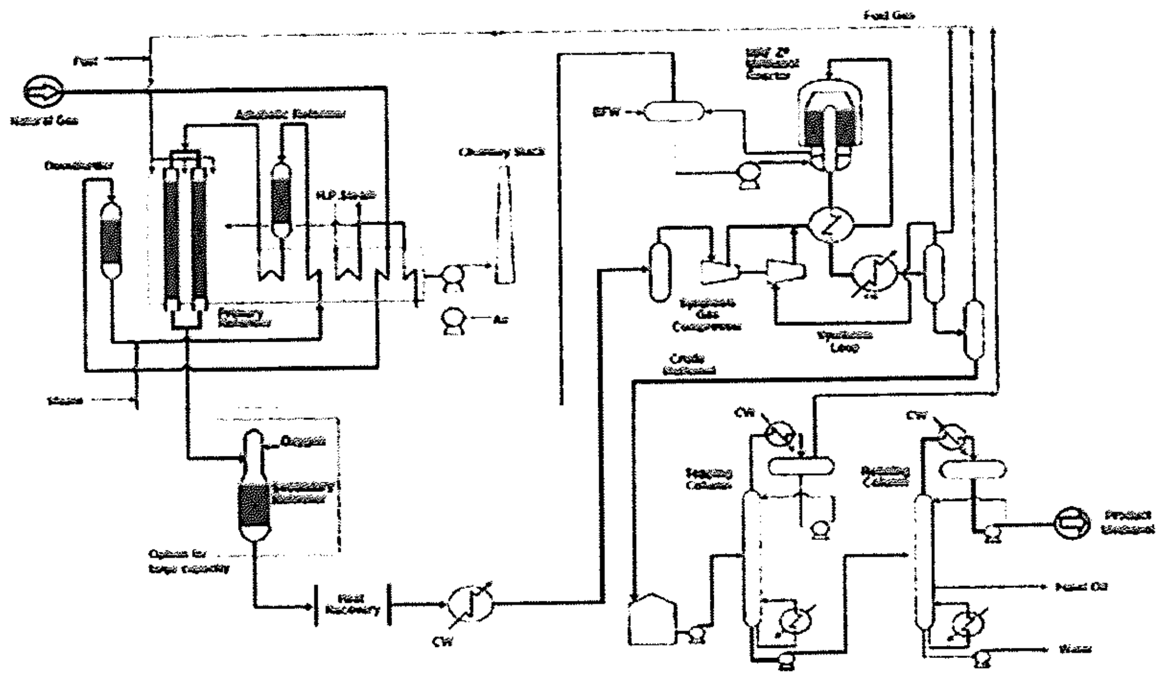


Figure 4.3-1 Methanol Production Process



(Source) Toyo Engineering Corporation

Figure 4.3-2 Process Flow Diagram of Methanol Production (Toyo Engineering Process)

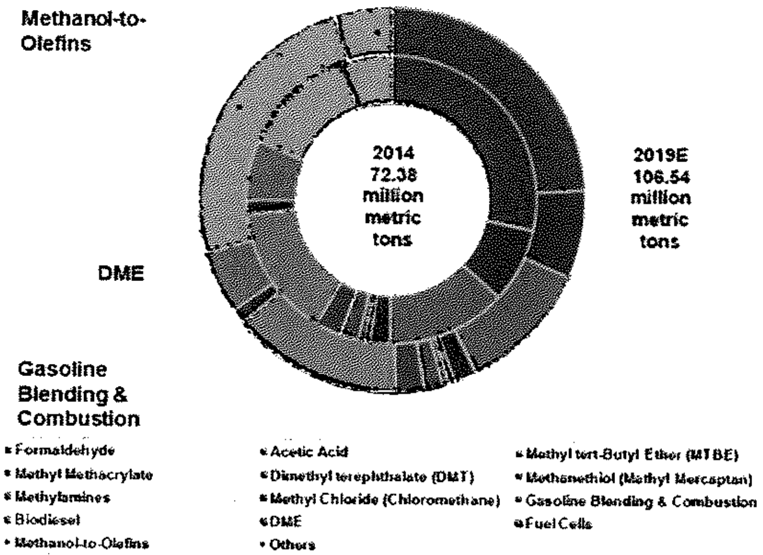
The scale of methanol plants has been increasing significantly, and their capacity has reached 3,000 to 5,000 tonnes/day (1.0 to 1.7 million tonnes/year) per single train. The consumption of natural gas in producing 3,000 tonnes/day of methanol is approximately 100 MMSCFD (about 0.7 Tcf over 20 years), which is comparable to that of ammonia - urea plants.

(Source) Toyo Engineering Corporation (Oman Methanol Company L.L.C.)

Figure 4.3-3 Methanol Plant in Oman

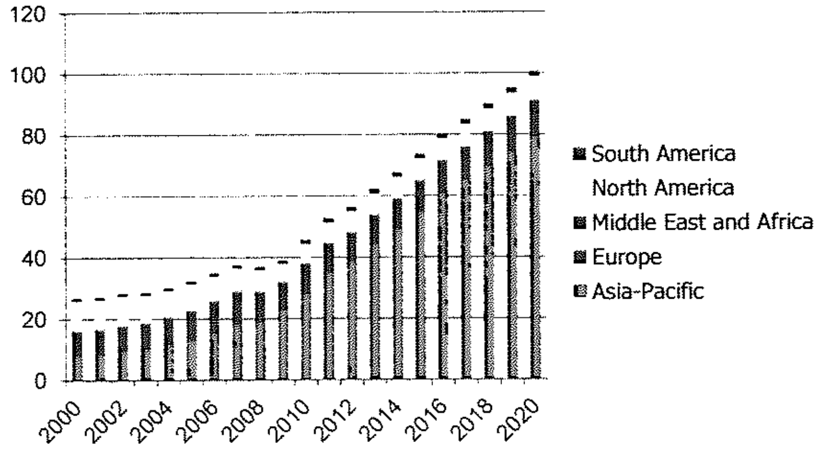
4.3.2 Applications and Demand Forecast of Methanol

Methanol is mainly consumed in advanced countries and China. It is distributed from gas producing regions such as The Middle East, CIS, South America, and Southeast Asia to consuming regions such as Europe, North America, Far East, and China. The global methanol market was about 72 million tonnes in 2014, of which approximately half being traded internationally, and is predicted to reach approximately 107 million tonnes in 2019. Approximately 70 to 80% of methanol is used for chemical applications as a basic raw material, whereas 20 to 30% is for fuel. It is expected that the demand for methanol will increase steadily. In chemical applications, methanol is used to produce formalin, acetic acid, synthetic fibers, agrichemicals, adhesives, etc. Furthermore, methanol is attracting attention as a feedstock of olefins such as ethylene and propylene for an alternative production method called MTO (Methanol to Olefin) instead of the conventional feedstock such as naphtha and ethane. Moreover, in fuel applications, methanol is used both for direct blending to gasoline, or to produce a gasoline by means of MTG (Methanol to Gasoline), DME (described in 3.5), etc.



(Source) Courtesy of MMSA Pte Ltd. Feb 2015

Figure 4.3-4 Global Methanol Use by Derivative



(Source) Global Data (19 Jan. 2015)

Figure 4.3-5 World Methanol Demand

4.3.3 Possibility of Methanol and Its Downstream Industries in Tanzania

Tanzania has no methanol plants and imports only about 50 tonnes of methanol annually. The neighboring countries also have no methanol plants and import low amounts of methanol.

As one of the natural gas utilization industries, methanol produced in Tanzania can be exported to other countries, and at the same time consumed domestically. In case that methanol is produced at a low cost from natural gas in Tanzania, it could be exported to neighboring countries and further to the global market, and could potentially develop chemical industries starting from methanol as a feedstock.

As Tanzania produces neither crude oil nor petroleum and petrochemical products, development of new industries, such as production of basic chemicals (MTO), gasoline (MTG) and DME, etc., starting from methanol as a feedstock, should be considered.

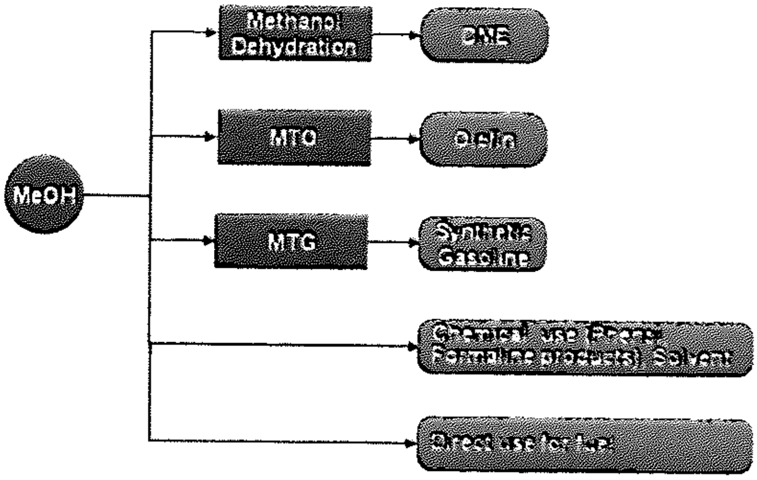


Figure 4.3-6 Methanol Value Chain

MTO is a process which converts methanol to olefins. In case that olefins are produced at a low cost from methanol, downstream chemical industries such as polymer plants could be developed as well. In general, 3,000 tonnes/day of methanol can be converted into 300,000 tonnes /year of olefins.

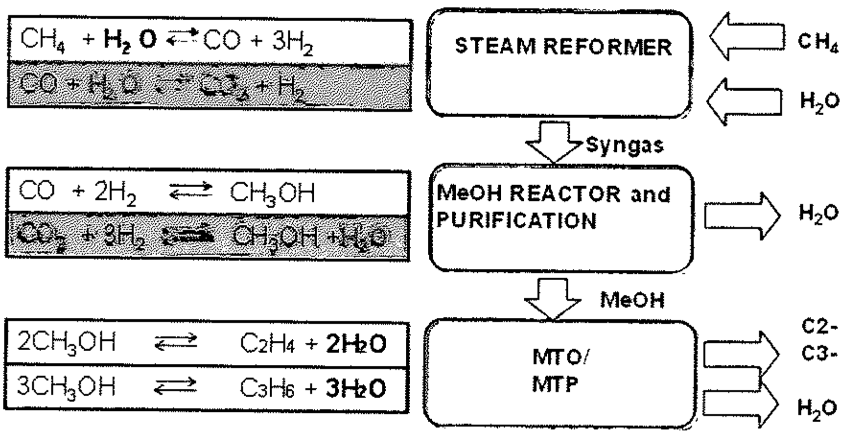
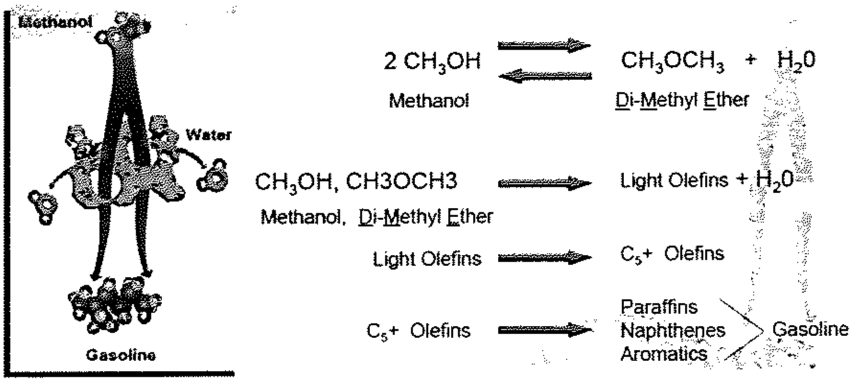


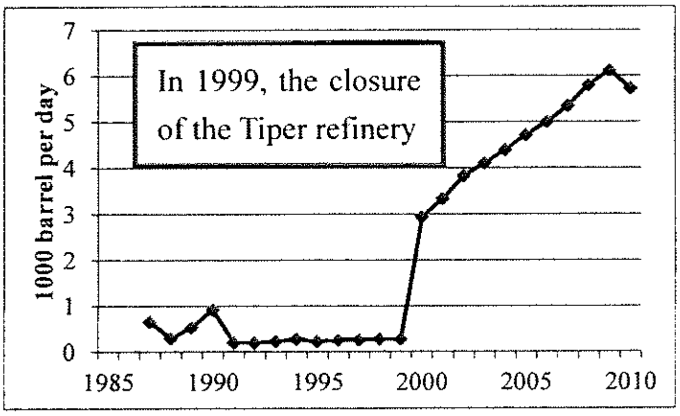
Figure 4.3-7 MTO Production Process

MTG refers to processes which converts methanol into gasoline. As shown in Figure 4.3-9, since the closure of the Tiper refinery in 1999, imports of gasoline have been increasing drastically in Tanzania, reaching 6,000 bpd in 2010. As can be seen by the slope in Figure 4.3-9, and given that motorization trend will be rising, demand for gasoline is expected to further grow in the future. In this context, gasoline production via MTG process from methanol in Tanzania could reduce the import of gasoline, and subsequently achieve self-sufficiency in gasoline. In general, 3,000 tonnes/day of methanol can be converted into 10,000 bpd of gasoline.



(Source) Courtesy of ExxonMobil Research & Engineering

Figure 4.3-8 MTG Production Process



(Source) Index Mundi

Figure 4.3-9 Imports of Gasoline in Tanzania

4.4 GTL

GTL (Gas to Liquid) process produces liquid petroleum products such as naphtha, kerosene and diesel oil, using natural gas as feedstock. It should be noted that petroleum products produced by GTL mainly contain paraffinic components. For emerging countries like Tanzania who possesses abundant natural gas resources, but at the same time imports oil products due to the shortage of oil resources, GTL would be one of the important options for gas utilization.

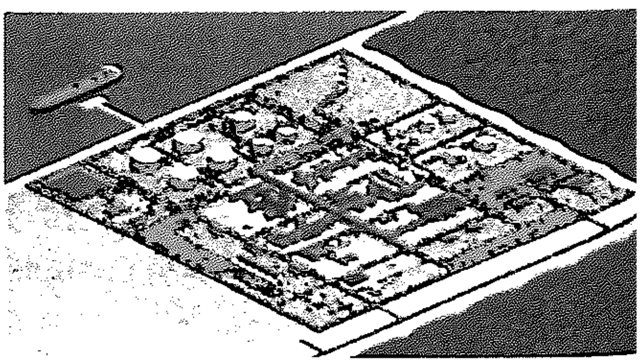


Figure 4.4-1 General Image of GTL Plant

GTL process consists of three sections; Syngas production, FT synthesis, and Upgrading sections as shown in Figure 4.4-2.

Natural gas is first fed to the *Syngas production section*. The feedstock is mainly methane accompanied with steam, O_2, or CO_2, and the output from this section is the mixture of H_2 and CO, which is called syngas. The syngas is then fed to the *Fischer Tropsch (FT) synthesis* section and transformed into FT oil, liquid hydrocarbon. FT oil is then fed to the *Upgrading section* and treated to be the final GTL oil.

The reactions carried out in each section are as follows:

The first section is Syngas Production. Here, methane (CH_4), a major component of natural gas, is chemically reacted with steam, oxygen and/or CO_2, and converted into syngas, a mixture of H_2 and CO. Several reactions are available to produce syngas such as partial oxidation, oxidation, steam reforming and CO_2 reforming. Commercialized processes of syngas production are usually combinations of these reactions in different ways.

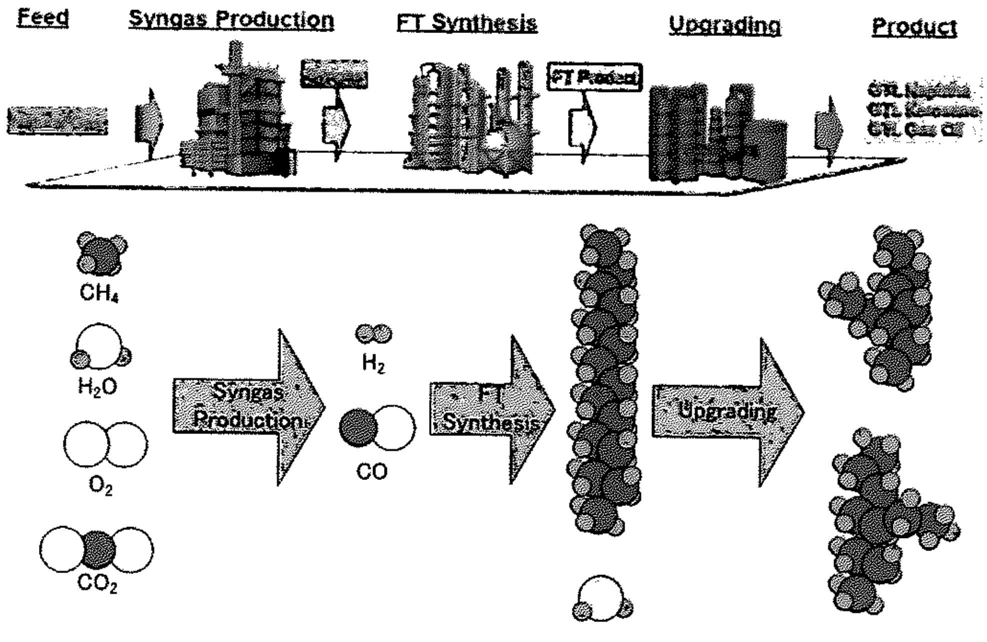


Figure 4.4-2 Constitution of GTL Process

The second section is FT Synthesis. Here, the mixture of CO and H_2 is transformed into long molecule of hydrocarbon by chain growth reaction. At the same time, a part of carbon is arrested by hydrogenation reaction to produce CH_4, C_2H_6, C_3H_8 and so forth. The hydrogenation terminates the chain growth. The ratio of carbon contained in the chain reaction to the total carbon input should be preferably more than 90% so as to improve the yield of product.

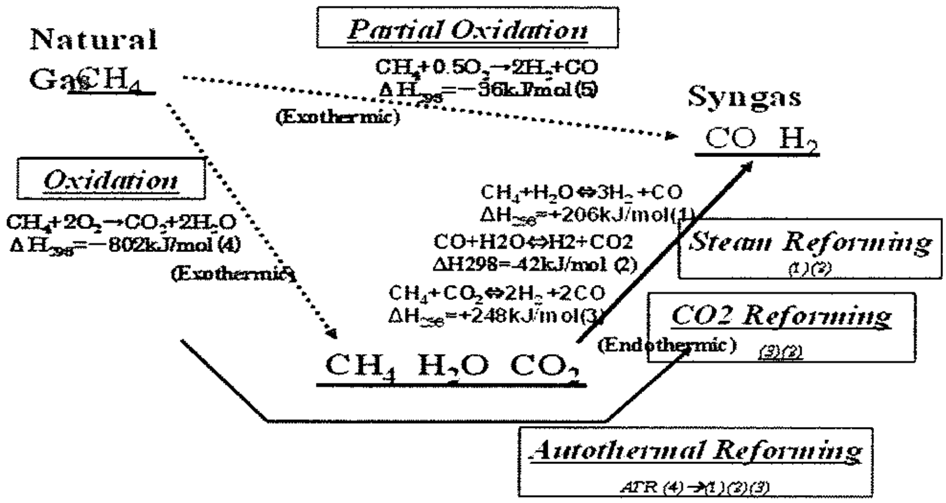


Figure 4.4-3 Syngas Production Section

The lighter products, CH_4, C_2H_6, C_3H_8 and so forth are recovered and used for heating or recycled in the feedstock. If LPG is needed as one of the GTL products, propane and butane can be separated as LPG.

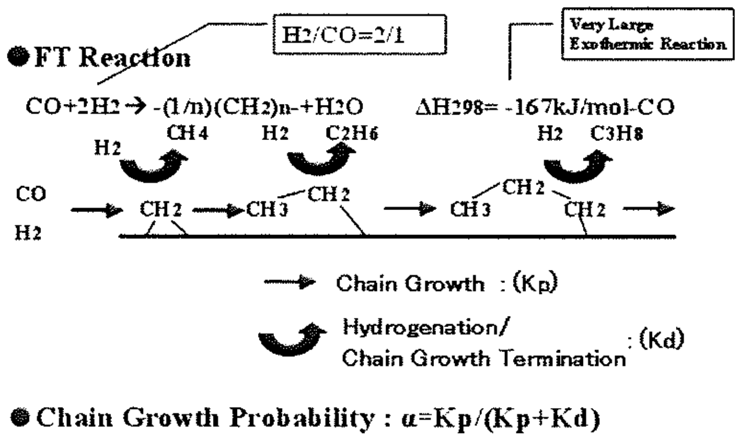


Figure 4.4-4 FT Synthesis Section

FT oil produced in the FT synthesis is not the final product because it still contains some undesirable components for fuel such as olefins and alcohols, and therefore the FT oil is fed to the last section for upgrading. There, the FT oil is treated by hydro-treating, isomerization, and hydrocracking to improve its properties as fuel, and finally the GTL oil of naphtha, kerosene, and diesel oil will be obtained.

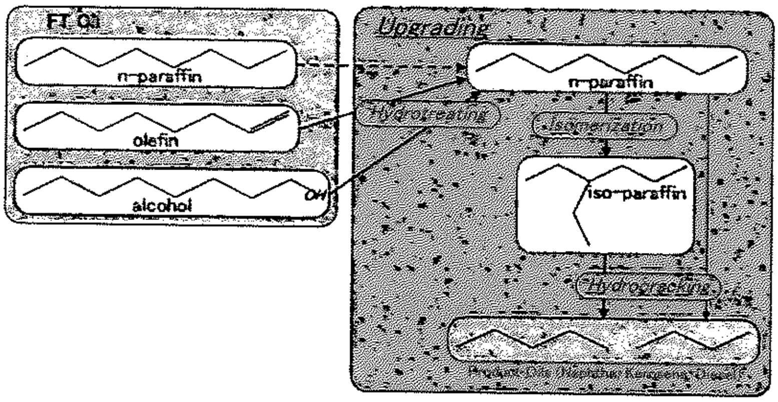


Figure 4.4-5 Upgrading Section

For a standard GTL plant, general process flow and plant layout are as shown below.

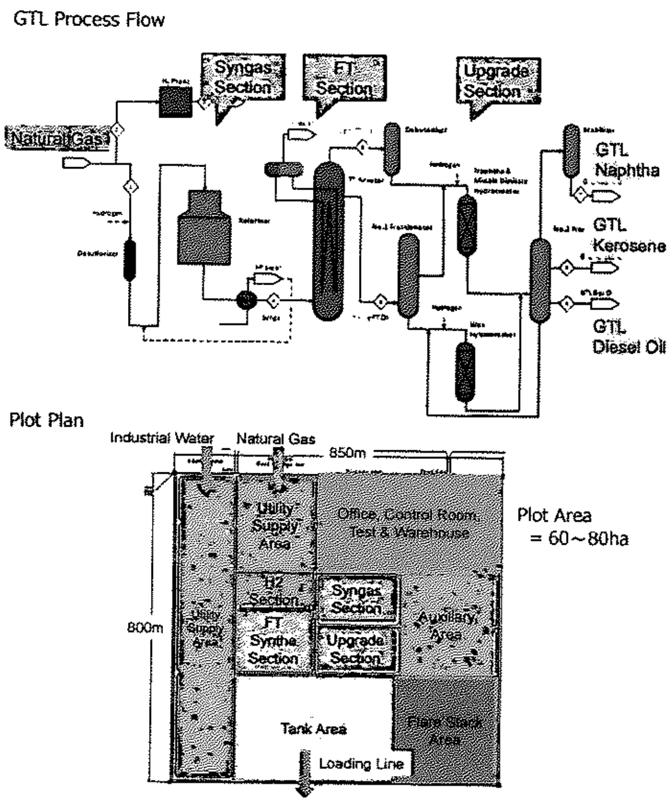


Figure 4.4-6 GTL Plant Process Flow and Plot Plan

Major GTL processes which are commercially available are shown below. Sasol, Shell, and Japan GTL consist of different combinations of syngas production, FT synthesis, and upgrading. Currently in the world, there are several operating GTL plants such as Mossel Bay in South Africa, Bintulu in Malaysia, Oryx and Pearl in Qatar. In addition, there are numerous plans of GTL project in various areas.

Table 4.4-1 Major GTL Technologies

	Syngas Profuction	FT Synthesis	Upgrading
Sasol	Topsoe (Autothermal Reforming)	Sasol (SBCR)	Chevron (Isomerization/ Hydrocracking)
Shell	Shell (Partial Oxydation)	Shell (Fixed Bed)	Shell (Hydrocracking)
Japan-GTL	Chiyoda (CO2/Steam Reforming)	NSENGI (SBCR)	JX-NOE (Isomerization/ Hydrocracking)

SBCR : Slurry Bubble Column Reactor

Chiyoda : Chiyoda Corporation
NSENGI : Nippon Steel & Sumikin Engineering CO., LTD.
JX-NOE : JX Nippon Oil & Energy Corporation

Among them, Japan-GTL Process has rather newly attained to the phase of commercialization, which is a unique cutting-edge technology made-in-Japan. As shown in Figure 4.4-7, Japan-GTL Process can utilize CO_2 directly 40% or less in feedstock gas and can eliminate the O_2 generation plant which is necessary for other conventional GTL processes.

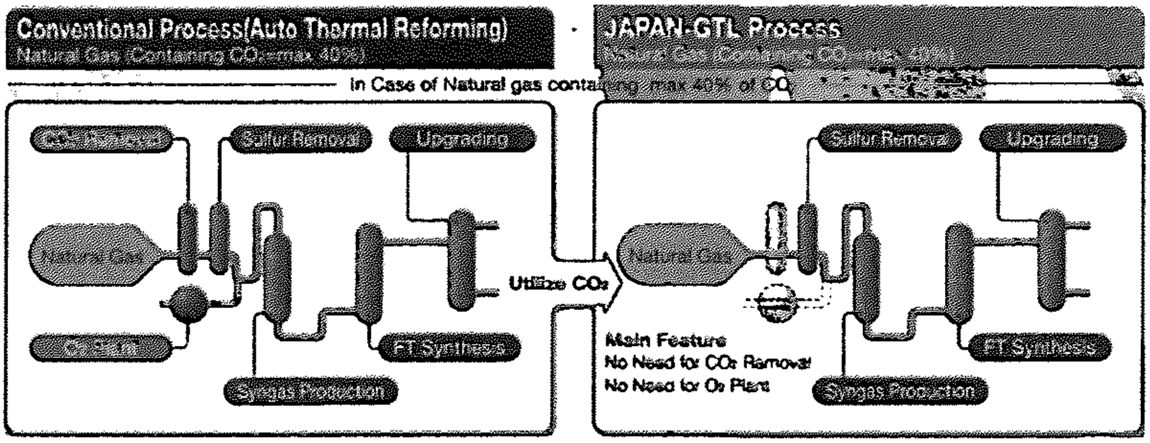


Figure 4.4-7 Feature of Japan-GTL Process

As GTL oil products, kerosene and diesel oil are superior fuel. GTL diesel oil, compared with conventional oil product, has superior characteristics for fuel because it has higher cetane number, no poly-aromatic, and no sulfur. This shows that GTL oil has higher cleanness and environmental friendliness than the conventional oil product. On the other hand, GTL naphtha is paraffinic and can be used as a superior petrochemical feedstock, but is not suitable for the direct use of gasoline.

The product of GTL plants is delivered to the various markets, such as fuel, mainly fuel for transportation, base oil for lubricant oil, and feedstock for petrochemical industries. In any case, the feasibility of GTL project depends on the value of products, the initial investment, and the cost of natural gas.

4.5 DME

DME (dimethyl ether) is not a natural product but a synthetic product that is produced either through the dehydration of methanol or a direct synthesis from syngas. Certain amounts of DME have been commercially produced as a propellant for spray cans because of its non-toxicity and suitable solubility and vapor pressure at room temperature. However, DME is now attracting great attention as an energy source for the 21th century, a hydrogen carrier and a feedstock for petrochemicals because of its multiple source, excellent physical and chemical properties and excellent storage properties.

Table 4.5-1 Properties of DME (Compared with other fuels)

	DME	Methane	Propane	Methanol	Diesel
Boiling Point (℃)	-25.1	-161.5	-42	64.6	180～360
Liquid Density (g/cm³@20℃)	0.67	-	0.49	0.79	0.84
Ignition Temp. (℃)	350	650	470	450	250
Cetane Number	55～60	-	5	5	40～55
Lower Heating Value (kcal/kg)	6,900	12,000	11,100	4,800	12,200

The boiling point of DME is -25degC, and DME is a gas at ambient temperature and air pressure. DME can, however, be liquefied at 20 degree C and about 5 atmospheres, and it can be transported in a normal temperature pressurized container. When DME and LPG are compared, the vapor pressure of DME is approximately the average of those of propane and butane. Besides, the gas density and the molecular weight are slightly higher than those of propane, but approximately equivalent. LPG technology can be used for the storage and handling of DME. However, there are some discrepancies in the physical properties that originate in the chemical structure differences between DME and LPG. While LPG consists of hydrocarbon that contains only carbon and hydrogen, DME is an either including oxygen. It is therefore necessary to take into account the different physical properties of DME and LPG in the system design when LPG facilities are applied to DME. Table 4.5-1 summarizes properties of DME and other fuels.

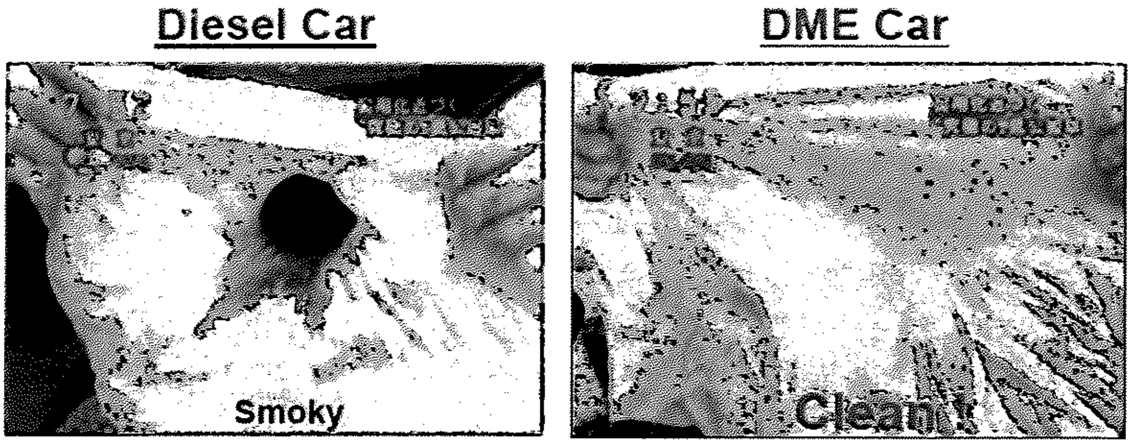


Figure 4.5-1 Comparison of Exhaust Gas (Diesel Car vs. DME Car)

DME burns cleanly without exhausting any black smoke during combustion like other gaseous fuels. It doesn't emit SOx and any particulate matters such as PM2.5. In addition, it helps to significantly reduce CO_2 emissions and minimize NOx emissions. Based on these characteristics, when it is used as fuel for diesel engine, DPF (Diesel Particulate Filter) will not be needed, drastically reducing the burden of aftertreatment for exhausts. As a result, the cost and man-hour of the maintenance will be saved significantly.

DME is produced via an indirect (dehydration) method that uses methanol as a raw material, or a direct method that uses synthesis gas as a raw material, and those reaction formulas are follows:

Indirect method: $2CH_3OH \rightarrow CH_3OCH_3+H_2O$ (1)

Direct method: $3H_2+3CO \rightarrow CH_3OCH_3+CO_2$ (2)

So far, only the indirect method has been used on a commercial scale, while the direct method remains only the bench scale verification.

At present, the global demand of DME for fuel applications is 2 to 3 million tonnes/year, and the global demand for DME in applications other than fuel is about 150,000 tonnes/year. It is expected that the global demand for DME as fuel for consumer and transportation applications will expand and DME produced in Tanzania can be consumed domestically as a new clean fuel, and also be exported to neighboring countries. Figure 4.5-2 shows capacity of the world's DME plants including planning stage.

The capacity of a typical DME production plant depends on the capacity of the methanol plant in the upstream. For example, if it is 5,000 tonnes/day and the output is fully used for production of DME, production of DME will be 2,000 tonnes/day. The amount of natural gas required for a DME production plant having a capacity of 2,000 tonnes/day is about 100

MMSCFD and 0.7 Tcf over 20 years. The optimal size of a methanol plant should be determined examining what amount of methanol would be used for production of DME

It is possible to use DME in various fields and DME has been experimentally confirmed practical for various utilization equipment.

(1)Household use fuel

DME can be used for cooking stove and home heating similar to the city gas and LPG. It is confirmed that equipment for LPG can be used with a mixture of DME and LPG of which the concentration of DME is maximum 20%. A cogeneration system using the diesel engine fueled with DME has been developed.

(2) Transportation fuel

As Cetane number of DME is as high as 55 to 60, DME can be used as a fuel for diesel engines. DME engine development and DME vehicle development have been completed, and the durability of DME vehicle has been confirmed by road running test for 100,000km or longer. Moreover, a technical development of DME filling equipment to DME vehicles has been completed, too.

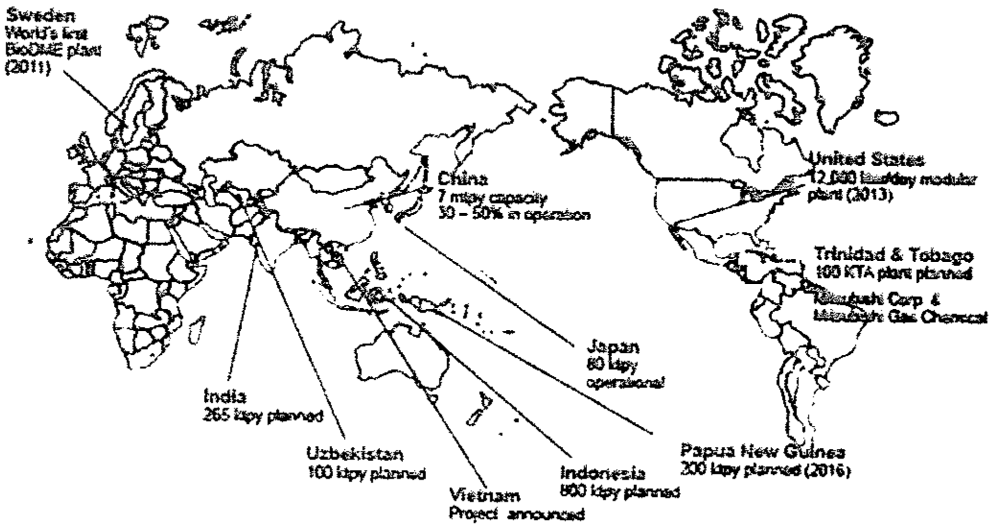


Figure 4.5-2 Capacity of the world's DME plants (including facilities in planning stage)

(3) Power generation fuel

DME can be used as boiler fuel as well as gas turbine fuel. It was confirmed by demonstration tests that a thermal efficiency and an environmental characteristic of existing equipment with DME are similar to those with the natural gas. A large-scale diesel engine test with DME for power generation has been tried. DME is reformed with steam at relatively lower temperature than natural gas and LPG, etc. and has some advantage on heat balance, therefore DME is a promising fuel for the fuel cell. Moreover, a compact reforming device has been developed for use by a fuel-cell car.

(4) Industrial fuel

DME is currently used for boilers at food processing companies.

(5) Chemical feedstock

A technology producing ethylene and propylene from DME has been developed. It is expected that the production cost will be reduced compared with producing them from petroleum naphtha, which is more expensive.

4.6 Methanol to Gasoline (MTG)

Gasoline is one of the major fuels used in Tanzania with a share of a quarter among the petroleum products consumption. Since good quality motor gasoline could not be produced by a GTL plant, we consider a Methanol to Gasoline (MTG) process to produce gasoline from natural gas via methanol as an option to produce liquid fuel from natural gas.

As explained earlier, there are two methods to produce liquid fuel from natural gas, namely, GTL (Gas to Liquid) process to mainly produce kerosene and gas oil, and MTG (Methanol to Gasoline) to produce gasoline. Naphtha produced via the GTL process has low octane number and hence not suitable to use as motor gasoline. As Tanzania relies its gasoline supply fully on import, we have added MTG process to produce gasoline domestically in the study. Production schemes of these synthetic liquid fuels are shown in Figure 4.6-1. Both of them are three-step processes using natural gas as feedstock. In this master plan study, MTG plant is a synthetic fuel plant positioned in the downstream of a methanol plant.

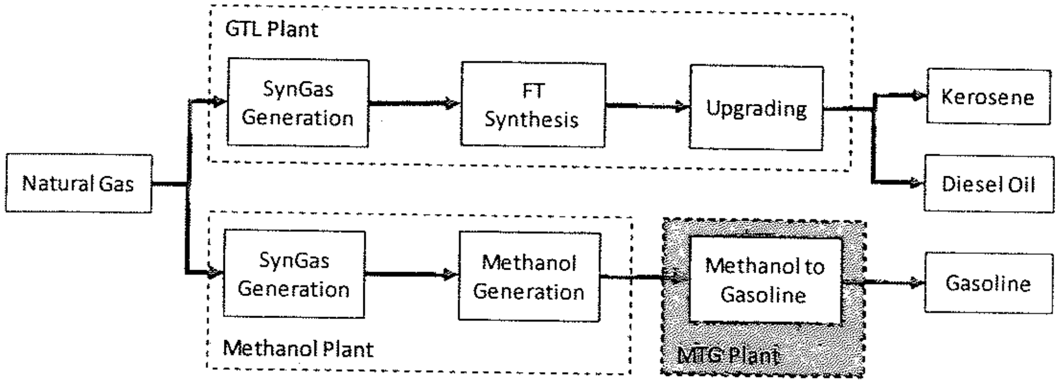


Figure 4.6-1 Production Scheme of Synthetic Transportation Fuel

Commercial MTG process was developed by Exxon/Mobil. The company constructed a commercial plant in 1986 in New Zealand which produces gasoline from natural gas via methanol, with an annual production capacity of 570,000 tonnes. In recent years, China has imported this process from Exxon/Mobil and trying to apply it to gasoline production from methanol originated from coal. A demonstration plant with a capacity of 100,000t/y is presently in operation and many plans to adopt this technology have been announced.

The process scheme of NTG plant is shown in Figure 4.6-2. Methanol, as a feedstock, is fed to MTG where crude gasoline is produced. The crude gasoline is sent to distillation process to be separated into light gasoline, heavy gasoline and LPG. Finally, finished gasoline is produced by blending process. Gasoline and LPG produced by the MTG plant can be directly delivered into the existing infrastructure of the petroleum supply chain.

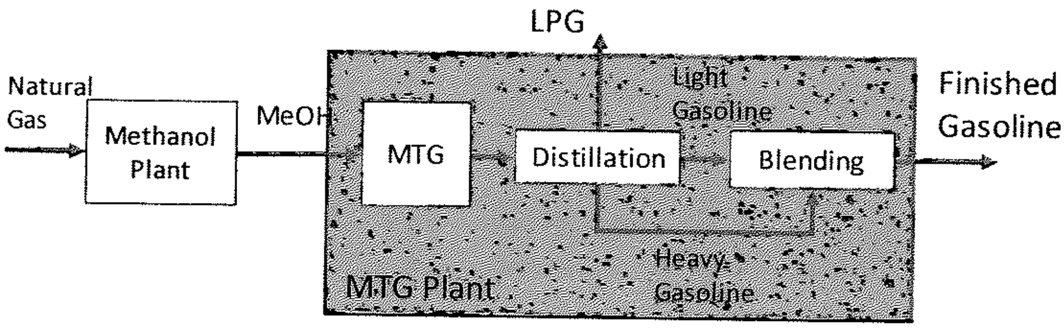


Figure 4.6-2 Process Scheme of MTG plant

4.7 CNG

4.7.1 Outline of CNG vehicle

CNG stands for compressed natural gas. Since the density of the natural gas is very low, we can transport and keep only relatively small amount per cubic volume of the gas in its normal gaseous state. Therefore, in addition to pipeline transport, natural gas is often converted to CNG by compressing it at a high pressure or to LNG by liquefying it at a temperature below -162°C, in particular for long haul transport.

In recent years, natural gas is widely used in many countries as clean fuel for vehicles. Compared to other fossil fuels, it produces lesser amount of CO_2 which is responsible for global warming, lesser amount of NOx and SOx which cause photochemical smog and acid rain, and no black smoke and PM (Particulate Matter) which damage health.

There are mainly two types of natural gas vehicles (NGVs); CNG vehicles and LNG vehicles. Presently, most of NGVs used worldwide are CNG vehicles. Fuels for CNG vehicles can be handled easily at ambient temperatures, and engine of common vehicle can be converted easily for CNG use. On the other hand, LNG vehicles are introduced quite recently in the United States for long haul heavy freighters, while LNG needs more sophisticated supply system but is powerful for heavy duty engines.

CNG vehicles are classified into four kinds according to their engine type.

1) Dedicated type

Because the delicated type CNG vehicle can combust only CNG as a fuel, this type of vehcile carries CNG cylinder, instead of fuel tank. This type of vehilcle has higher combustion efficiency than other types because the engine is optimized sorely for CNG. However, this type of vehicle can not be used in the region without CNG staions.

It is generally thought that this type of vehicle is suitable for use in urban areas. They are used for regular routine services in certain regions such as fixed-route buses, garbage trucks, delivery trucks, etc. Vehicle owners often operate their own CNG stations supplied by municipal gas system.

2) Bi-fuel type

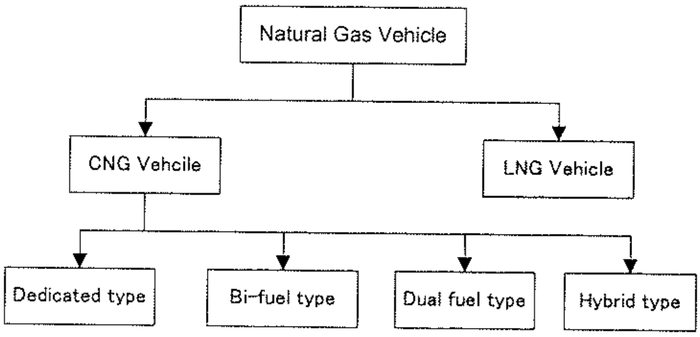
Bi-fuel type vehicle can run on either CNG or gasoline. Thus, it is possible to use even in the region where the CNG station is not installed. This type of vehicle normally uses CNG as fuel and switchs to gasoline once it runs out of CNG.

3) Dual-fuel type

Dual-fuel type vehicle is a vehcile which uses natural gas as a part of inhalated air and diesel oil as an ignition source, using the strucuture of diesel engine. This type of engine has a high energy efficiency similar to regular diesel engines, and can reduce the amount of CO_2 emissions about 10–20% when natural gas makes up 60–85% of the used fuel compared with the case using only diesel oil as fuel. Moreover, it is possible to run a dual-fuel type vehicles only on diesel oil, and thus they can be used even in a region without CNG stations.

4) Hybrid type

Hybrid type vehciles are equipped with both natural gas engine and electric motor. Hybrid vehicle generates electicity utilizing the additional power that are produced when engine is running effectively and also the energy produced during deceleration, and then this electricy can be used for the electric motor during the startup. Thus, a hybrid type vehcile realizes a better milage, while its price tends to be higher than that for a dedicated type CNG vehicle.



(Source) The Japan Gas Association

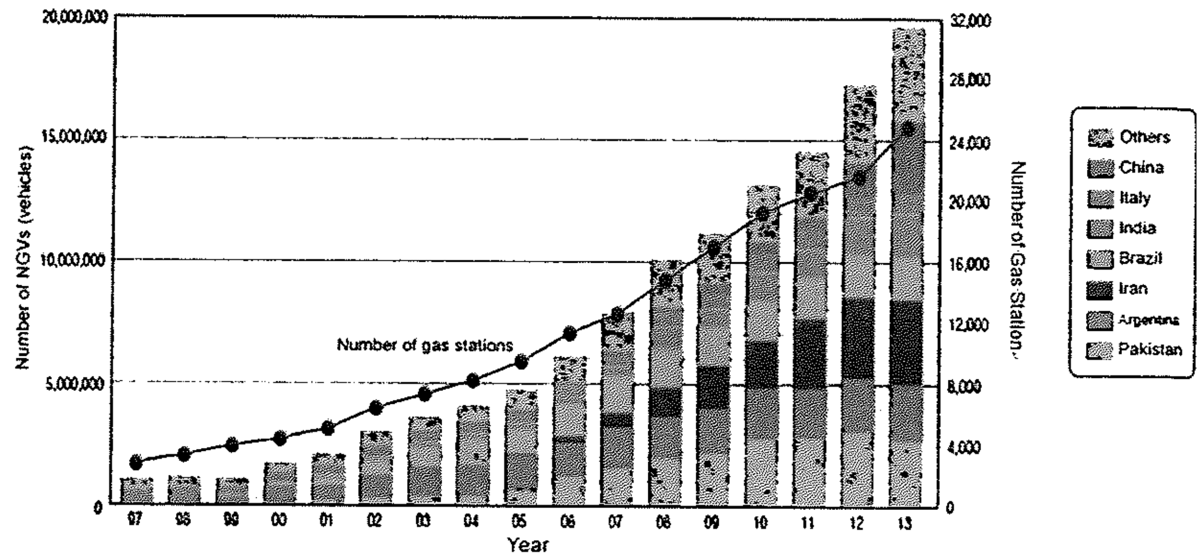
Figure 4.7-1 NGV Types

CNG vehicles were initially used mainly for public transportation such as buses and taxies because of shortage of CNG stations and shorter travel distances of these vehicles. In recent years, however, with technology improvement and expanding gas supply network, CNG vehicles have become an option of choice for environmentally friendly alternative-fuel vehicles worldwide in view of their practical as well as environmental performance.

4.7.2 Evolution of NGV in the world

Use of CNG vehicles has increased in Iran, China, Pakistan, Argentina, India, and other countries where domestic natural gas resources are available, and the number of NGV in the world reached almost 20 million units in 2013.

The situation in Tanzania, which solely relies it transport fuel on imported petroleum products, is similar to the above countries that are producing natural gas and promoting use of CNG vehicles. In view of the similar circumstance, Tanzania has started road tests; about 60 CNG vehicles are currently mobilized to examine possibilities of CNG vehicles to come into wide use. CNG is deemed as one of promising alternatives to petroleum in Dar es Salaam and some other locations where gas supply system is being developed.



(Source) Gas Vehicle Report

Figure 4.7-2 CNG Vehicles in the World

4.7.3 Current condition of CNG vehicle in Tanzania

1) Current Status

In Tanzania, introduction of CNG vehicles started in 2009 as part of a program to effectively use natural gas the country started to produce and currently 60 CNG vehicles are running in Dar es Salaam.

All of these CNG vehicles are bi-fuel type vehicles converted from gasoline-fueled passenger cars. A private enterprise (Tanzania Triangle Ltd.) under the supervision of the Dar es Salaam University is mainly working on conversion of engines. The conversion expense is about 1.6 million TZs (for four cylinders engine) and 2.0 million TZs (for eight cylinders engine) including the kit fee, and one day is necessary for engine conversion.

Owners of CNG vehicles are not only government and municipal offices but also include private companies. Among them, the CNG supplier PanAfrican Energy Tanzania Ltd. owns three CNG vehicles and is conducting experimental operation.

2) Economics of CNG Vehicles

Assuming that the mileage of a gasoline-powered passenger vehicle is 12km/liter, consumption of CNG by a gasoline-based CNG vehicle to run same distance is 0.73kg. Prices of gasoline and CNG are presently 2,300 TZs/liter and 1,210 TZs/kg, and thus fuel costs of gasoline vehicle and CNG vehicle are 191.7 TZs/km and 73.6 TZs/km, respectively. The fuel cost of gasoline-based CNG vehicle is only 38% of that of gasoline-powered vehicle. The amount of fuel cost saving per km is 118.1 TZs.

Similarly, assuming that the mileage of a diesel-powered passenger vehicle is 12km/liter, consumption of CNG by a diesel-based CNG vehicle to run same distance is 0.67kg. Prices of diesel and CNG are 2,200 TZs/liter and 1,210 TZs/kg, fuel costs of diesel vehicle and CNG vehicle are 188.3 TZs/km and 67.6 TZs/km, respectively. The fuel cost of diesel-based CNG vehicle is 36% of that of diesel-powered vehicle. The amount of the fuel cost saving per km is 120.7 TZs.

3) CNG Supply Station

There is one CNG station in Ubungo, jointly financed by TPDC, PanAfrican Energy Tanzania and others. Features of the present operation are as follows:

The construction cost of CNG station in Ubungo was about 1 million US$.

One big compressor and 3 dispensers, one of them for CNG trailer, are installed in the CNG station.

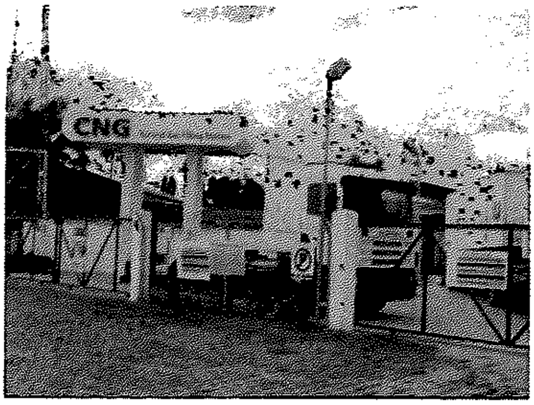
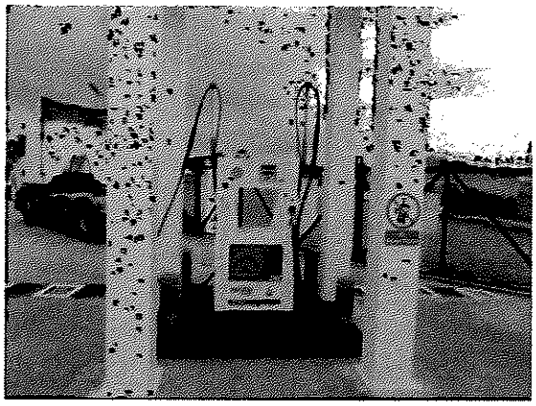
Filling time for a passenger vehicle is short; it takes one minute for a small car and a few minutes for a larger car.

Frequency of CNG vehicle visiting the station is low; 3 to 5 vehicles per day. The main reason is that CNG station is located in an inconvenient place·taking one hour or more to access from the Dar es Salaam business center due to road congestion.

In addition, the CNG trailer to carry CNG to the nearby Mikocheni light-industrial area uses the CNG station 2–3 times a day for refilling.

This CNG trailer carries 200 gas cylinders, and can transport about 4 tonnes of CNG at a time.

The price of CNG is 1,100 TZs/kg. CNG price for CNG vehicles and for the industrial area are same.



(Source) JICA Study team

Figure 4.7-3 Ubungo CNG Station

4.7.4 Future Natural Gas Supply Plan

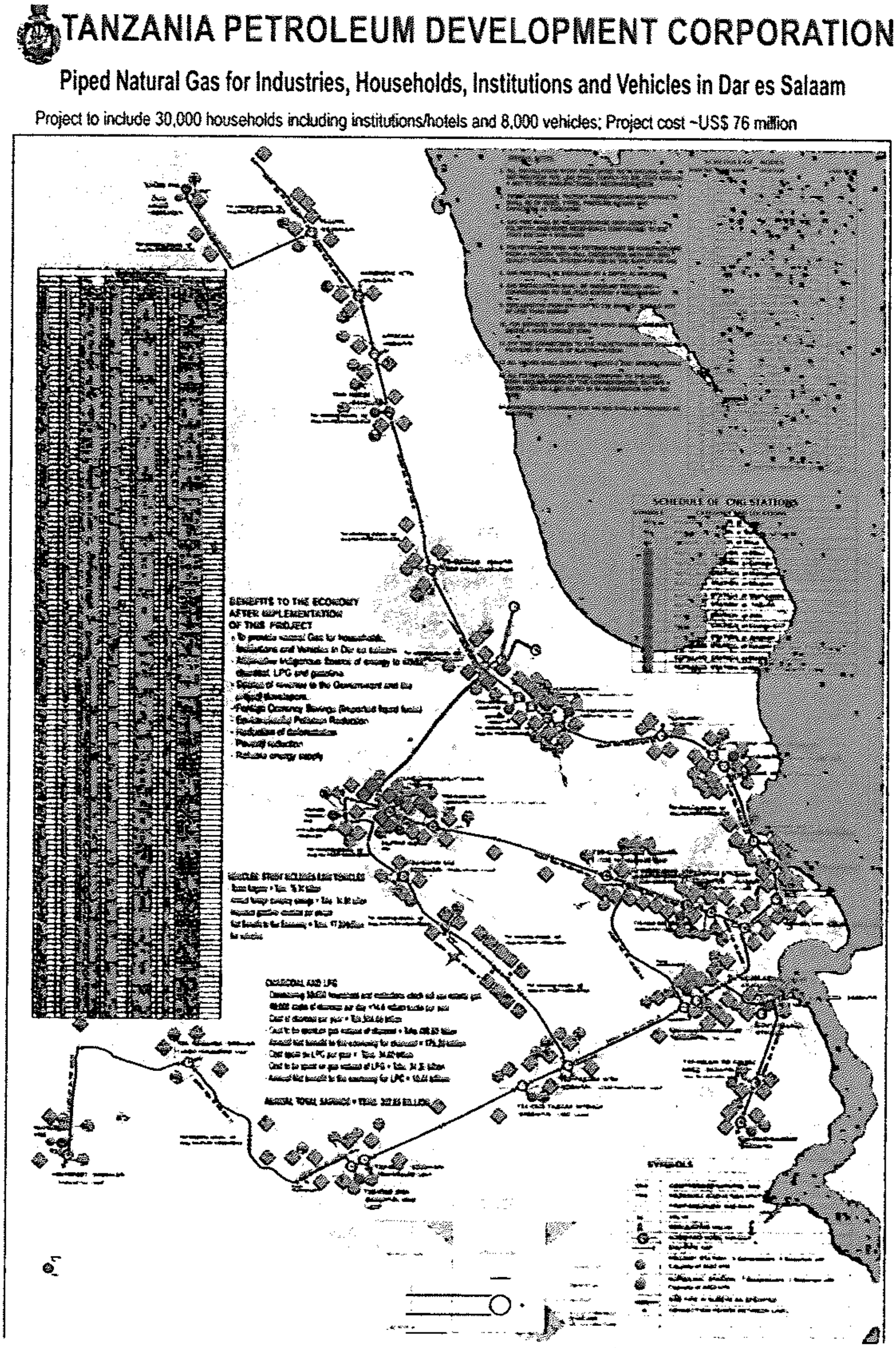
1) Summary of the Future Plan

This future plan is a pilot project, and it was made in 2013 by TPDC by engaging an external consultant. The purpose of this plan is to promote conversion from the existing energy sources such as gasoline, LPG, coal, and firewood to natural gas by supplying natural gas to 30,000 families including offices and hotels and running 8,000 CNG vehicles in Dar es Salaam. As a result, payment of foreign currency will be saved, and air pollution, deforestation and poverty will be reduced.

To realize these purposes, this plan proposes to construct a gas pipeline system, CNG stations at 15 locations, and gas terminal nodes for the bulk users at 38 points in the City.

The target year of this plan is not decided specifically, and it depends on when donors would emerge to provide finance for the project.

The total project cost will be 76 million US$, and the annual total savings is estimated to be 202.8 billion TZs, consisting of the net benefit to the economy of 17.2 billion TZs from vehicles, 175.2 billion TZs from charcoal and LPG of 10.4 billion TZs from LPG. (See Figure 4.6-4)



(Source) TPDC

Figure 4.7-4 Project Map

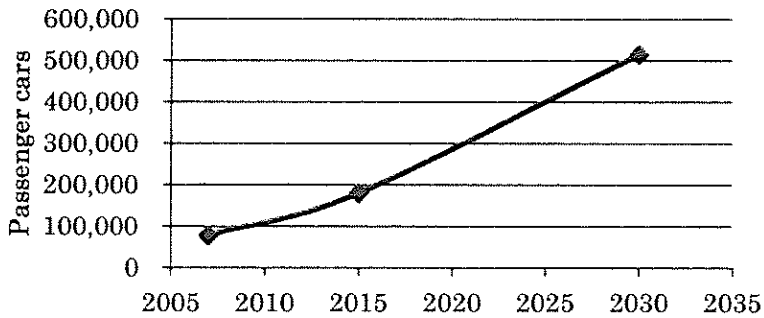
2) Summary of the promotion plan

This pilot project aims to construct CNG stations at 15 locations in Dar es Salaam City and run at least 8,000 CNG vehicles. As the users of 8,000 CNG vehicles, various entities are expected not only government institutions but also taxies, public bus companies and common private companies.

To run 8,000 CNG vehicles in the Dar es Salaam City is a tentative target for the pilot project, and is not the final target for the Dar es Salaam City. Therefore, the number of the CNG vehicles run in the Dar es Salaam City in the ultra-long term (2045) is set in this JICA Study separately.

3) Share of CNG vehicle

The total number of passenger cars including pick-ups owned by residents in Dar es Salaam City is estimated at 77,800 vehicles in 2007, and it is expected to increase to 180,000 in 2015 and 515,000 in 2030, according to the JICA "Dar es Salaam Transport Policy and System Development Master Plan" report prepared in 2008.



(Source) JICA Study Team, by using the JICA M/P report in 2008

Figure 4.7-5 Estimated number of passenger cars in Dar es Salaam

In 2025, 10 year from now, the number of personal passenger cars in Dar es Salaam is estimated to be about 400,000 units. If 8,000 vehicles are converted to CNG vehicles, the share of CNG vehicle will be only 2% of the total passenger cars, and this plan seems very modest. Thus, this plan may be considered fully feasible.

4) Challenges to realize the plan

In order to materialize the plan to run CNG vehicles, it is necessary to construct a necessary number of CNG stations at appropriate points, most likely under the leadership of the Tanzania Government. It may be necessary to set forth a target number of CNG vehicles to be introduced, presumably some proportion of public vehicles or large operators' vehicles that have to be converted.

Some preferential treatment may be also considered for CNG vehicles giving incentives for CNG vehicle users.

Typical incentives introduced in foregoing countries are as listed below. To promote CNG vehicles, governments are expected to

offer CNG at a price cheaper than that of gasoline and diesel;

subsidize the fee of conversion and/or exempt the tax payment in order to convert to CNG vehicle cheaply;

subsidize the part of the price difference between a CNG vehicle and a common vehicle;

promote and help local car mechanics to convert common vehicles into CNG vehicles;

exempt tax on CNG vehicles and/or impose tax corresponding to the amount of the CO_2 exhaust difference;

exempt the travel tax to enter the inner urban area, toll fee and so on for CNG vehicles;

permit to use the HOV[2] lane regardless of number of occupancies.

[2] HOV: High-occupancy vehicle

Chapter 5 Outlook of Domestic Natural Gas Demand in Tanzania

Chapter 5 Outlook of Domestic Natural Gas Demand in Tanzania

5.1 Model Structure and Assumptions

5.1.1 Structure of Energy Demand Model

Energy demand forecast presented in this section applies same approach and assumptions used for the ongoing another JICA/MEM study "The Project for Formulation of Power system Master Plan in Dar es Salaam and Review of Power System Master Plan 2012 ("PSMP Study")".

Energy demand is forecast by the model illustrated in Figure 5.1-1, which is structured based on the energy balance table concept and using the modeling software Simple.E developed by the Institute of Energy Economics, Japan (IEEJ). Firstly, the final energy consumption is estimated for individual sectors incorporating assumptions and projections on socio-economic factors such as population and GDP growth. Then, the final energy demand is estimated by energy source in consideration of availability, price, benefits/convenience, and other elements. Secondly, based on the final energy demand estimated as above, the primary energy supply is calculated applying conversion factors in the transformation sector such as power generation efficiency and refinery fuel use.

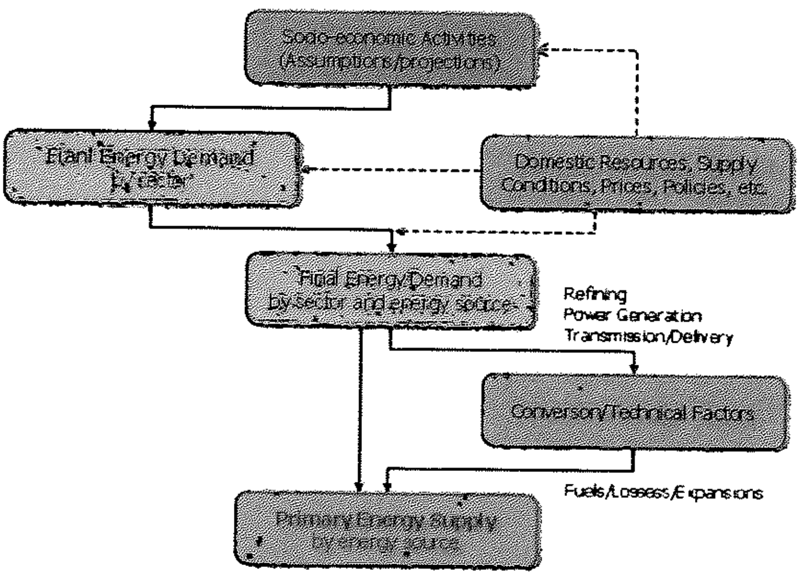


Figure 5.1-1 Flowchart: Energy Demand Model

The energy demand model comprises two main blocks, namely, the economic block and the energy demand block as shown in Figure 5.1-2. In the economic block, future levels of various elements that will impact energy demand are considered by assumption or internal projection, such as economic indicators, demographic features, energy prices, technical factors, etc., incorporating resource availability, development plans, policies, laws, regulations and so on. Then, these projections on key factors will be input into the energy demand block to calculate future energy demand. Major outputs produced by the model are illustrated in the right box of the Figure 5.1-2.

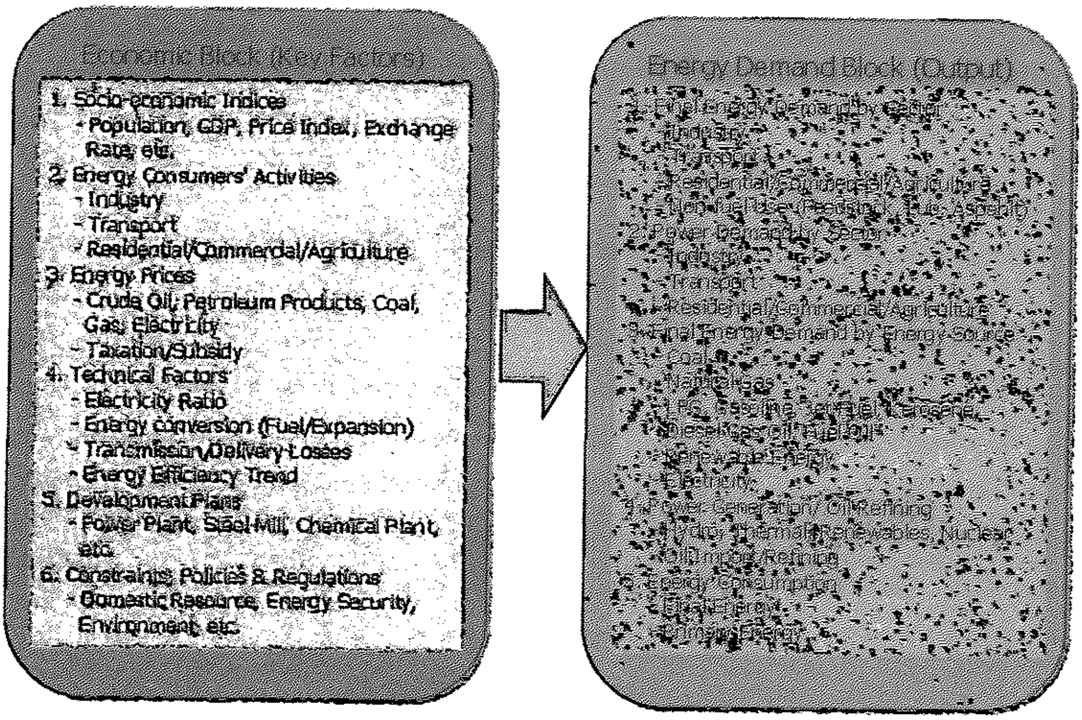


Figure 5.1-2 Key Elements and Output of the Energy Demand Model

The model is formulated incorporating various methods of approach such as econometric analyses on historical statistics, assessment on technical relationships, studies on efficiency improvement, resource availability, development plans, policies and regulations, etc. Relationships among various factors are numerically integrated by model equations and simulated to produce consistent outputs. The model should be from time to time updated and modified reflecting additional studies and observations.

5.1.2 Major Assumptions

(1) Population

The population of Tanzania is assumed to maintain a steady growth at 2.7% during the present decade and then gradually slow down the pace. The population will almost double in the coming three decades from 44.9 million in 2012 to 85 million in 2045.

Table 5.1-1 Assumption for Population Growth

		2000	2012	2025	2035	2045	12⇒45
Population	(million)	32.6	44.9	61.5	74.5	85.0	-
AAGR	(%)	-	2.71	2.45	1.92	1.34	1.95

(2) GDP

The real GDP[3] of Tanzania has recorded steady growth at an average 7% per annum from 2000 to 2013. According to "The Tanzania Development Vision (TDV) 2025" [4] set out in 1995 by the NEEC (National Economic Empowerment Council), the government aims at an economic growth rate more than 8% per annum through 2025 and become a middle income country with a high level of human development. To this end, the economy should achieve an annual per capita income of at least US$3,000 by 2025 through transformation from a low productivity agricultural economy to a semi-industrialized one. A solid foundation for a competitive and dynamic economy with high productivity should be laid with an adequate level of physical infrastructure. The government also expects the growth rate of 10% per annum in "The Tanzania Five Year Development Plan 2011/2012-2015/16" designed in 2011.

Considering these plans, three scenarios are set out in this study, namely, Base, High and Low cases. In the Base case, the real GDP growth rate will keep the present pace till 2025 and will start a slight decline thereafter mainly because of diminishing population growth rate; the overall average annual growth rate (AAGR) through 2045 will be 6.1%. In the High case, GDP will grow at 8% per annum through 2045 maintaining the level set out under the present Five Year Plan all the way through the projection period. In the Low case, the GDP growth rate is assumed to be 1% lower than the Base case.

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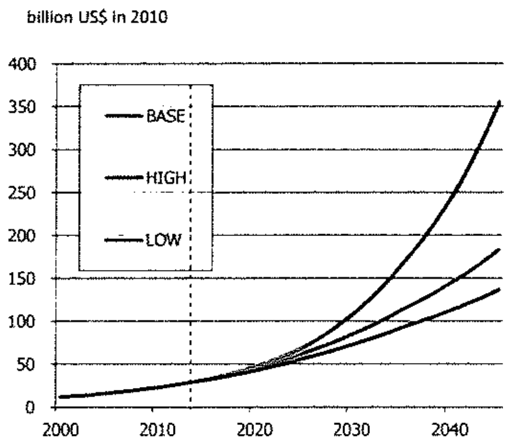
[3] The real GDP is expressed by purchasing power parity at 2010 US Dollar price. In this analysis, the exchange rate is assumed to be kept at the present level, Tzs 1,600/USD.

[4] Planning Commission, "The Tanzania Development Vision 2025", 1995



Growth Rates		00⇒12	12⇒25	25⇒35	35⇒45	12⇒45
Real GDP (A)		%	%	%	%	%
	Base	6.9	7.0	6.0	5.0	6.1
	High	6.9	7.8	9.0	8.0	8.2
	Low	6.9	6.2	5.0	4.0	5.1
Population(B)		2.71	2.45	1.92	1.34	1.95
Capital Formation + Total Factor Productivity (A-B)		%	%	%	%	%
	Base	4.2	4.6	4.1	3.7	4.1
	High	4.2	5.4	7.1	6.7	6.3
	Low	4.2	3.7	3.1	2.7	3.2

Figure 5.1-3 GDP Growth Rate per Different Scenarios

The table on the right of the Figure 5.1-3 illustrates how these scenarios can be interpreted. Applying the concept of the Cobb-Douglas production function for long term economic development, economic growth rate is a sum of growth rates of capital formation, work force and the total factor productivity.[5] In the Base case, the sum of the growth rates of capital formation and total factor productivity (that is, overall economic growth rate minus population growth rate) remains more or less at the present pace of annual 4%. This will be accelerated by more than 2% in the High case, while it declines by 1% in the Low case. The Base case seems a moderate projection for a developing country, where, under a backdrop of substantial development potential, healthy capital formation and human resource development will be maintained at a constant pace. Low case may be triggered by external elements like deterioration of world economy, while the High case looks ambitious but may be achievable provided that proactive development policy should lead to successful economic growth.

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[5] A Cobb-Douglas production function is usually used to define long term economic growth as

$Y=A(t)K^{\alpha}L^{\beta}$

Where $\boldsymbol{Y}$ = total output (GDP), $\boldsymbol{K}$ = capital input, $\boldsymbol{L}$ = labour input, $\boldsymbol{A(t)}$ = total factor productivity, $\boldsymbol{\alpha}$ = output elasticity of capital, $\boldsymbol{\beta}$ = output elasticity of labour, and, assuming a constant returns to scale, $\alpha+\beta=1$. Then, γ, the growth rate of A(t), represents the speed of improvement in the productivity. Thus, the GDP growth rate equals to $\alpha+\beta+\gamma$.

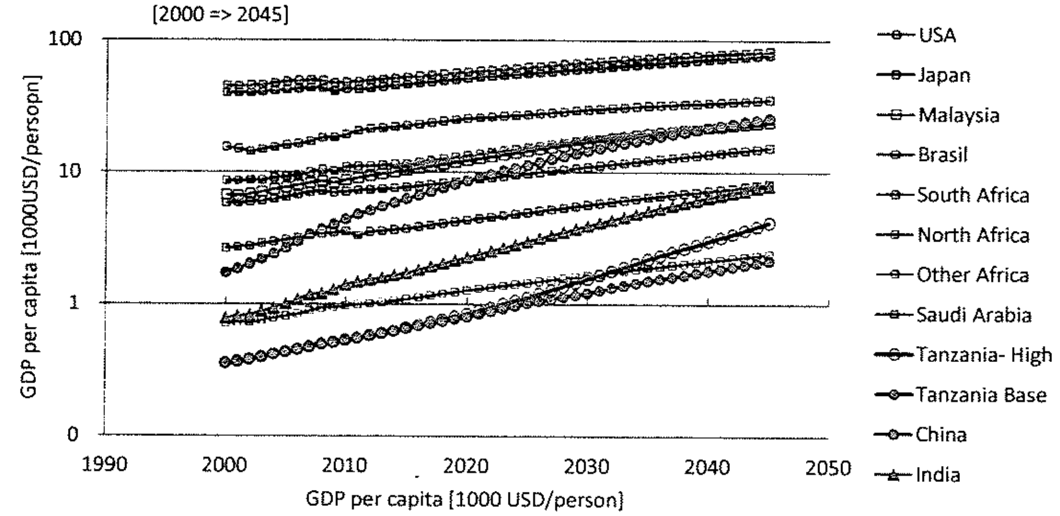
Table 5.1-2 GDP per Capita for Different Scenarios

		2000	2012	2025	2035	2045	00⇒12	12⇒25	25⇒35	35⇒45	12⇒45
Real GDP in 2010 US $		$ billion	$ billion	$ billion	$ billion	$ billion	%	%	%	%	%
	Base	11.7	26.1	62.9	112.6	183.4	6.9	7.0	6.0	5.0	6.1
	High	11.7	26.1	69.6	164.8	355.9	6.9	7.8	9.0	8.0	8.2
	Low	11.7	26.1	56.7	92.3	136.7	6.9	6.2	5.0	4.0	5.1
Real GDP per capita in 2010 US$		US$	US$	US$	US$	US$	%	%	%	%	%
	Base	359	581	1,021	1,512	2,157	4.1	4.4	4.0	3.6	4.1
	High	359	581	1,132	2,214	4,185	4.1	5.3	6.9	6.6	6.2
	Low	359	581	921	1,240	1,608	4.1	3.6	3.0	2.6	3.1
Nominal GDP per capita		US$	US$	US$	US$	US$	%	%	%	%	%
	Base	312	629	2,356	4,919	9,371	6.0	10.7	7.6	6.7	8.5
	High	312	629	2,610	7,203	18,187	6.0	11.6	10.7	9.7	10.7
	Low	312	629	2,125	4,035	6,985	6.0	9.8	6.6	5.6	7.6

Table 5.1-2 summarizes the outcome of the above assumption on the economic growth. Real GDP in 2010 US Dollar will grow from $26 billion US (2010 price) in 2012 to $183 billion US in 2045 for the Base case, and $137 billion US and $356 billion US in 2045, in Low case and High case, respectively. It should be noted that the merely 2% difference in AAGR between the Base case and the High case will yield a substantial difference in the absolute amount after three decades. The High case GDP will be almost double that for the Base case.

The real GDP per capita will reach $2,200US in 2045 for the Base case, and$1,600US, $4,200US, in Low case and High case, respectively. The nominal GDP per capita will exceed $3,000 US in the late of the 2020s.

Figure 5.1-4 compares growth path of per capita GDP of Tanzania with other major economies. In the Base case, Tanzanian economy will reach the level of China in the early 2000s by 2045. In the High case, Tanzanian economy will overtake the present level of India around 2030 and catch up the present level of China by 2045. Substantial industrialization and urbanization is expected to occur, sooner or later, to bring about better quality of life.



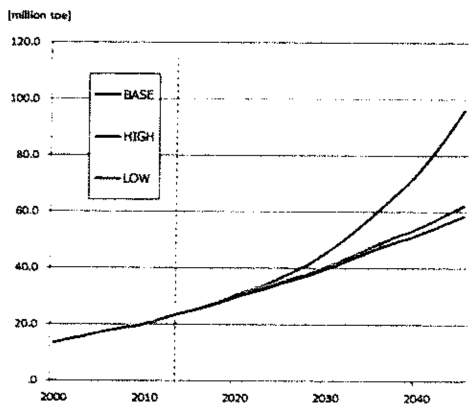
(Source) "Asia/World Energy Outlook 2014", IEEJ is referred for the countries other than Tanzania.

Figure 5.1-4 International Comparison of GDP per capita

5.2 Final Energy Demand

5.2.1 Total Energy Demand

Outlook of the final energy demand projected according to the above assumptions is shown in Figure 5.2-1.



Case	2000	2012	2025	2035	2045
	MM toe	MM toe	MM toe	MM toe	MM toe
Base	12.1	19.2	28.3	36.4	45.8
High	12.1	19.2	29.8	44.4	70.1
Low	12.1	19.2	28.0	35.4	43.2
	00⇒12	12⇒25	25-⇒35	35⇒45	12⇒45
(AAGR)	%	%	%	%	%
Base	3.9	3.1	2.5	2.3	2.7
High	3.9	3.5	4.1	4.7	4.0
Low	3.9	3.0	2.4	2.0	2.5

Figure 5.2-1 Final Energy Outlook

During the period between 2012 and 2045, energy consumption will increase from 19Mtoe in 2012 to 46Mtoe in 2045 for the Base case at an average annual growth rate of 2.7%, to 70Mtoe at 4.0% for the High case and to 43Mtoe at 2.5% for the Low case, respectively. At sight, the estimated demand growth looks slow. This is because a substantial transition from the traditional biomass to modern energies is expected to occur in the course of economic development, which will bring about significant improvement of energy efficiency. As shown in Table 5.2-1, consumption of modern energies excluding combustible renewables will grow at an average annual growth rate of 8.2% for the Base case; which is 10.0% for the High Case (Table 5.2-3) and 7.2% for the Low case.

Table 5.2-1 Final Demand Outlook by Energy Source: Base Case

	Final Energy Demand				Composition				AAGR			
	2012	2025	2035	2045	2012	2025	2035	2045	12=>25	25=>35	35=>45	12=>45
	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Coal	49	442	1,250	2,693	0.3	1.6	3.4	5.9	20.2	11.0	8.0	12.9
Oil	1,850	4,471	8,528	15,109	9.7	15.8	23.4	33.0	7.6	6.7	5.9	6.6
Natural Gas	130	985	2,936	6,628	0.7	3.5	8.1	14.5	18.4	11.5	8.5	12.7
Electricity	382	1,672	4,080	7,848	2.0	5.9	11.2	17.1	13.1	9.3	6.8	9.6
New Renewables	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible RE	16,742	20,773	19,629	13,558	87.4	73.3	53.9	29.6	1.8	-0.6	-3.6	-0.6
Total	19,153	28,342	36,424	45,837	100.0	100.0	100.0	100.0	3.3	2.5	2.3	2.7
Excluding RE	2,410	7,569	16,795	32,279	12.6	26.7	46.1	70.4	10.0	8.3	6.8	8.2

By energy source, increase in vehicle ownership boosts oil consumption at annual 6.6%. Natural gas demand grows significantly by 13% per annum driven mostly by the industrial sector. Domestic supply of natural gas will be welcomed by the industry sector over the imported diesel or fuel oil as natural gas is expected to be cheaper and its supply will be more stable. Electricity demand also rises considerably in every sector except for transport. The electricity demand will be explained more precisely in Section 5.3.

Table 5.2-2 Final Energy Demand Outlook by Sector: Base Case

	Final Energy Demand				Composition				AAGR			
	2012	2025	2035	2045	2012	2025	2035	2045	12=>25	25=>35	35=>45	12=>45
	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Industry	2,715	6,474	11,920	19,675	14.2	22.8	32.7	42.9	7.5	6.3	5.1	6.2
Transport	1,593	2,985	4,840	7,848	8.3	10.5	13.3	17.1	5.4	5.0	5.0	5.0
Household	13,344	16,823	16,840	14,238	69.7	59.4	46.2	31.1	1.9	0.0	-1.7	0.2
Commercial	89	320	799	1,729	0.5	1.1	2.2	3.8	11.2	9.6	8.0	9.4
Agriculture & Others	1,411	1,740	2,025	2,347	7.4	6.1	5.6	5.1	1.8	1.5	1.5	1.6
Total	19,153	28,342	36,424	45,837	100.0	100.0	100.0	100.0	3.3	2.5	2.3	2.7

Among sectors, fast demand growth is expected in the commercial sector at 9.4% per annum, reflecting rapid expansion of the floor space area driven mainly by development of service industries and commercial buildings. Energy consumption by the industrial sector grows at 6.2% per annum, where new industries are expected to emerge and develop. Fuel demand for transport sector will also grow steadily driven by increase in the vehicle ownership. On the other hand, the demand growth rate in the household sector will remain at 0.2 % per annum, though its share is still large among sectors even in 2045. This is because use of traditional biomass with low energy efficiency will be replaced by commercial energy such as gas and electricity, which are more efficient, and thus the apparent growth rate of the total household energy consumption will be substantially slower.

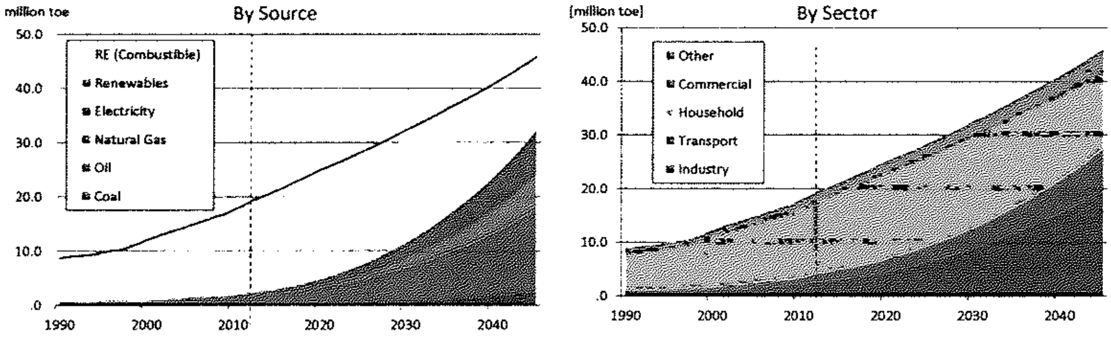


Figure 5.2-2 Final Energy Demand (Base case)

Compared with the Base case projection, the High case projection is significantly high as shown in Table 5.2-3. The total energy consumption in 2045 will be 53% higher than the projection for the Base case, and the fossil energy consumption will be75% higher as traditional biomass will be replaced with modern energies faster. Petroleum products will continue to dominate among fuel sources, reflecting faster growth in transport fuel consumption. It also includes LPG to be used at household and industry/commercial sectors located where piped natural gas supply is not available.

Table 5.2-3 Final Demand Outlook by Energy Source: High Case

	Final Energy Demand				Composition				AAGR			
	2012	2025	2035	2045	2012	2025	2035	2045	12⇒25	25⇒35	35⇒45	12⇒45
	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Coal	49	592	2,125	5,390	0.3	2.0	4.8	7.7	21.2	13.6	9.8	15.3
Oil	1,850	5,482	12,322	24,838	9.7	18.4	27.8	35.4	8.7	8.4	7.3	8.2
Natural Gas	130	1,368	5,107	13,218	0.7	4.6	11.5	18.9	19.9	14.1	10.0	15.0
Electricity	382	1,818	5,441	13,093	2.0	6.1	12.3	18.7	12.8	11.6	9.2	11.3
New Renewables	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	
Combustible RE	16,742	20,509	19,372	13,549	87.4	68.9	43.7	19.3	1.6	-0.6	-3.5	-0.6
Total	19,153	29,770	44,367	70,088	100.0	100.0	100.0	100.0	3.5	4.1	4.7	4.0
Excluding RE	2,410	9,261	24,995	56,539	12.6	31.1	56.3	80.7	10.9	10.4	8.5	10.0

In case high speed economic development is being achieved, an economy may be yielding more gains via contribution of modern high-tech industries and service industries that are less energy intensive. These aspects should be assessed carefully before we endorse the High case as a serious projection. Therefore, we will concentrate on the Base case projection in this Study.

Figure 5.2-3 shows the final energy demand outlook in each sector by energy source.

In the industry sector, rapid demand increase will be mainly supplied by domestic natural gas and imported oil products. Biomass, mainly charcoal and firewood, still maintains certain share in the energy mix as modern energy supply continue to be relatively expensive in the interior regions where long haul transport is necessary. Natural gas, where supply is available, and petroleum products, where piped natural gas supply is not available, will be dominant fuel in the industry sector. Coal will be gradually introduced in the resource rich interior regions, and will penetrate into fuel intensive industries such as steel and iron and cement production as domestic/import supply system develops.

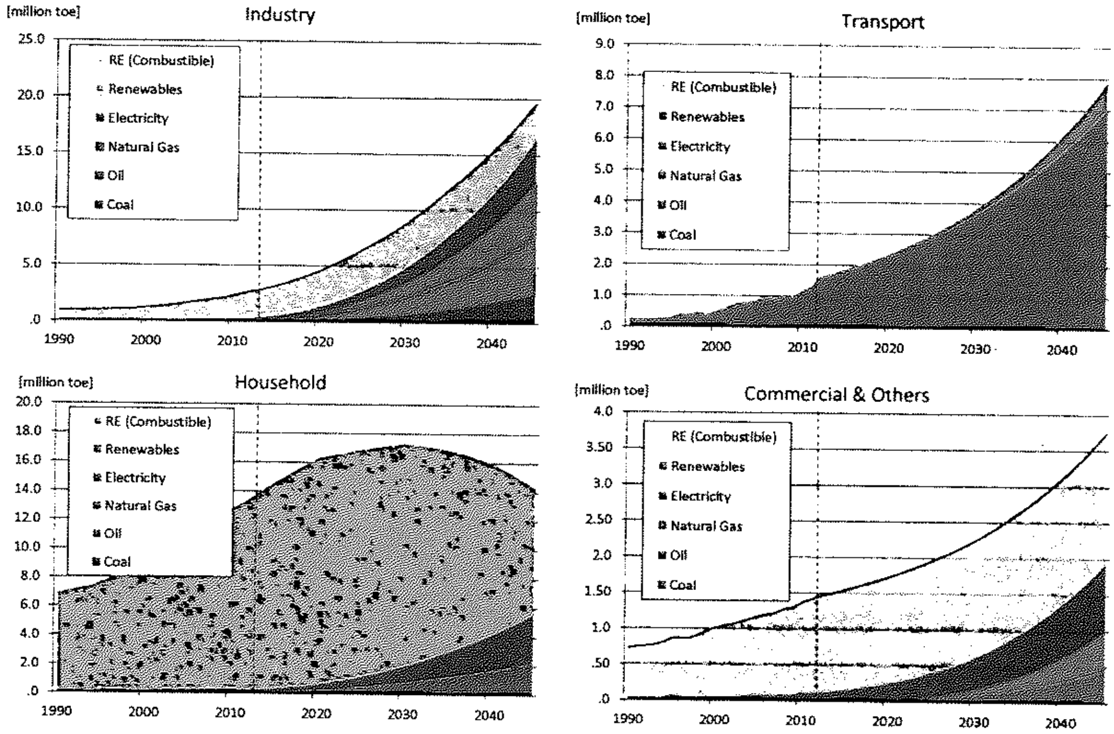


Figure 5.2-3 Final Energy Demand Outlook in each sector by energy source

Petroleum products will dominate in the transport sector; demand will increase significantly while supply must be sourced by import or GTL products. It is assumed for the Base case projection that, by 2045, about 10% of automobiles will be converted to use CNG, which means that about 320,000 units of CNG vehicles will be introduced among 3,200,000 vehicles. It is assumed at 20% or 640,000 units for the High case and 5% or 160,000 units for the Low case.

In the household sector, commercial energy will be introduced rapidly, while traditional biomass may peak in the early 2020s but still remain with a significant share. The total energy consumption may peak around 2030 reflecting the shift from the traditional biomass to more efficient commercial energies. In view of the spirit of the UN Millennium Development Goal, it is desirable to replace the traditional biomass for cooking and lighting with gas and electricity.

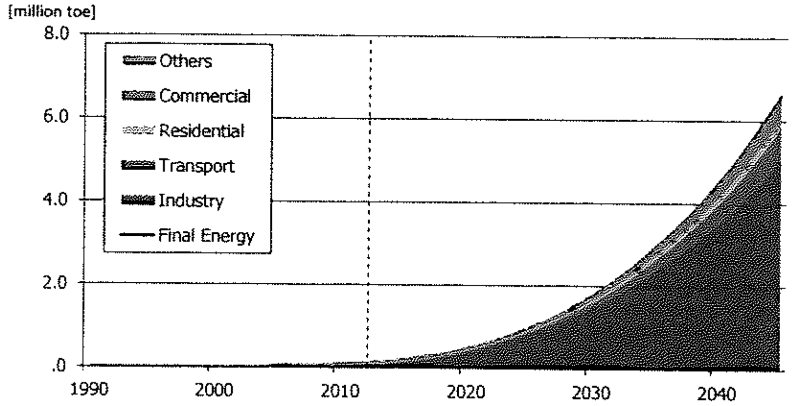
Such plan should be enhanced as fast as possible. However, construction of city gas delivery network is highly cost and time consuming. Thus, we assume for the Base case that, by 2045, about 5% of households in Tanzania will be enjoying city gas supply. This means that about four to five million people out of the 85 million populations or one million households will be using city gas; this compares to about 1/3 of the 12.5 million populations projected for Dar es Salaam. For the High case, we assume penetration of 10% or two million households and for the Low case 1% or 200,000 households.

In the commercial and public sector, same trend with the residential sector is observed. Although the commercial sector is still tiny in Tanzania, it is expected to grow fast and modern energy such as gas and electricity supply is essential for its development. Compared with the household sector, customers are larger in size and new large systems such as district cooling by CHP may be considered. Natural gas, if available, will be the fuel of choice in view of its clean and easy-to-use feature.

Potential demand in the residential and commercial sectors is high, while the question facing us is how to prepare a countrywide supply system of modern fuels for every potential user.

5.2.2 Natural Gas Demand

In the Base case projection, natural gas final demand is forecast to grow fast mainly in the industry sector. However, it depends upon development of piped gas supply network. In the backdrop of this, natural gas is the only domestic fossil fuel available in the developing center of Tanzania, and is expected to be supplied stably at a reasonable price compared with imported oil products such as diesel oil and heavy fuel oil. This estimation, however, is derived via macro intensity analysis only and may include the potential gas use by the future gas industries to be discussed in section 5.5. We need to take note that the gas demand forecast at present is a very preliminary one. Natural gas use will develop in the household and commercial sectors, but the absolute volume will remain small as developing city gas supply system is costly and time consuming.



	Final Energy Demand:Natural Gas				Composition				AAGR			
	2012	2025	2035	2045	2012	2025	2035	2045	12=>25	25=>35	35=>45	12⇒45
	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Industry	130	881	2,398	5,086	100.0	89.4	81.7	76.7	15.9	10.5	7.8	11.8
Transport	0	45	263	792	0.0	4.6	8.9	12.0	-	19.3	11.7	-
Household	0	27	89	185	0.0	2.8	3.0	2.8	-	12.5	7.6	-
Commercial	0	32	187	565	0.0	3.3	6.4	8.5	-	19.3	11.7	-
Agriculture & Others	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	-
Total	130	985	2,936	6,628	100.0	100.0	100.0	100.0	16.9	11.5	8.5	12.7

Figure 5.2-4 Natural Gas Demand in the Major Sectors (Base case)

The High case and Low case projections are summarized in Table 5.2-4. In the High case, natural gas demand in 2045 will be 99% higher than the Base case and in the Low case 38% lower. Major differences are seen in the industrial sector projection. Thus, if a robust economic growth is envisaged as assumed for the High case, energy supply should play a fundamental role to provide the platform to support it. A grand design of industry structure relating to a desirable composition of energy intensive industries such as steel & iron, cement and chemicals as well as a most suitable mix of energy sources must be examined carefully. In contrast, natural gas demand would grow only moderately in the Low case, and the domestic demand would be insufficient to support upstream gas field development.

Table 5.2-4 Natural Gas Demand: High Case and Low Case

	Final Energy Demand: Natural Gas				Composition				AAGR			
	2012	2025	2035	2045	2012	2025	2035	2045	12=>25	25=>35	35=>45	12⇒45
High Case	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Industry	130	1,160	4,033	10,147	100.0	84.8	79.0	76.8	18.3	13.3	9.7	14.1
Transport	0	113	659	1,986	0.0	8.2	12.9	15.0	-	19.3	11.7	-
Household	0	55	177	370	0.0	4.0	3.5	2.8	-	12.5	7.6	-
Commercial	0	41	237	715	0.0	3.0	4.6	5.4	-	19.3	11.7	-
Agriculture & Others	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	-
Total	130	1,368	5,107	13,218	100.0	100.0	100.0	100.0	19.9	14.1	10.0	15.0
Low Case	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Industry	130	687	1,675	3,273	100.0	93.2	85.8	80.0	13.7	9.3	6.9	10.3
Transport	0	18	105	318	0.0	2.4	5.4	7.8	-	19.3	11.7	-
Household	0	6	20	42	0.0	0.8	1.0	1.0	-	12.5	7.6	-
Commercial	0	26	152	458	0.0	3.5	7.8	11.2	-	19.3	11.7	-
Agriculture & Others	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	-
Total	130	737	1,953	4,091	100.0	100.0	100.0	100.0	14.3	10.2	7.7	11.0

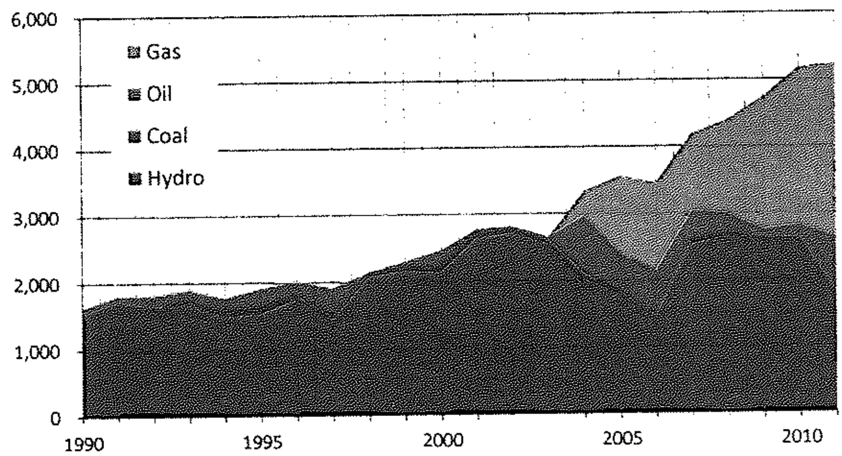
5.3 Natural Gas demand for Thermal Power Generation

Natural gas demand for thermal power generation is forecast based on the power demand forecast and the generation capacity expansion plan projected under the ongoing technical cooperation project assisted by JICA ; "The project for formulation of power system master plan in Dar es Salaam and coast region and review of power system master plan 2012". Outline of this study is cited in this section.

5.3.1 Current Composition of Power Plants in Tanzania

As of 2014, the total capacity of the power plants connected to the national grid in Tanzania is 1,583 MW, of which hydro accounts for 561 MW (35%) and thermal 1,022 MW (65%). Among the thermal plants, gas fired power plants account for 527MW and oil fired diesel power plants account for 495 MW; the latter are relatively small and costly.

Hydro used to be the major source of power supply before natural gas supply from the Songo Songo gas field started in 2004. In recent years, the share of gas fired power generation has reached around 50% in the power mix. Figure 5.3-1 shows historical changes in power generation by fuel type. After the severe drought experienced in 2010, hydro power generation has recovered to the original level. Incremental generation has come from gas-thermal since 2004, while oil consumption remains minimal. This trend will be maintained till coal thermal IPPs will be introduced around 2018-19.



(Source) International Energy Agency

Figure 5.3-1 Historical Trend of Electricity Generation Mix

5.3.2 Power Demand Forecast

With this backdrop, the dispatched power demand of Tanzania is forecast as shown in the following table. In the Base case, the power demand estimated to be 5,775 GWh in 2015 will grow to 19,440 GWh in 2025; to 3.4 times within 10 years from 2015. It will reach 47,445 GWh in 2035, to 8.2 times in 20 years from in 2015; and to 91,256 GWh in 2045, to 15.8 times in three decades from 2015. The average growth rates from 2015 to 2045 are 9.6 % for the Base case, 11.5 % for the High case and 9.0 % for the Low case.

Table 5.3-1 Electricity Consumption

Case	2012	2015	2020	2025	2030	2035	2040	2045	45/15
Final Electricity Consumption	GWh	GWh	GWh	GWh	GWh	GWh	GWh	GWh	%
Low	4,441	5,717	10,120	17,928	28,147	41,698	57,305	76,429	9.0
Base	4,441	5,775	10,663	19,440	31,258	47,445	66,722	91,256	9.6
High	4,441	5,834	11,240	21,136	37,649	63,269	98,906	152,240	11.5
Per capita Consumption	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	%
Low	99	118	181	291	409	560	715	899	7.0
Base	99	119	191	316	454	637	833	1,073	7.6
High	99	120	201	343	547	850	1,234	1,790	9.4

Per capita electricity consumption will grow 9 times during the coming three decades, while electrification progresses in every sector of the economy. Electric appliances will become popular among households, in particular in urban areas.

The peak electricity demand is forecasted as shown in the following table. As the peak demand for the Base case is estimated to be 1,116 MW in 2015, it will grow to 3,729 MW in 2025, to 3.3 times in 10 years, and to 9,259 MW in 2035, to 8.3 times in 20 years and to 17,811 MW in 2045, to 16.0 time in three decades.

Table 5.3-2 Dispatched Power and Peak Demand

Case	2012	2015	2020	2025	2030	2035	2040	2045	45/15
Dispatched Power	GWh	GWh	GWh	GWh	GWh	GWh	GWh	GWh	%
Low	5,484	7,055	12,215	21,227	32,746	48,513	66,669	88,915	8.8
Base	5,484	7,127	12,871	23,017	36,366	55,199	77,624	106,164	9.4
High	5,484	7,199	13,568	25,025	43,800	73,608	115,067	177,112	11.3
Peak Demand	MW	MW	MW	MW	MW	MW	MW	MW	%
Low	851	1,106	1,914	3,436	5,492	8,137	11,185	14,917	9.1
Base	851	1,116	2,017	3,729	6,101	9,259	13,022	17,811	9.7
High	851	1,128	2,125	4,052	7,347	12,348	19,304	29,711	11.5

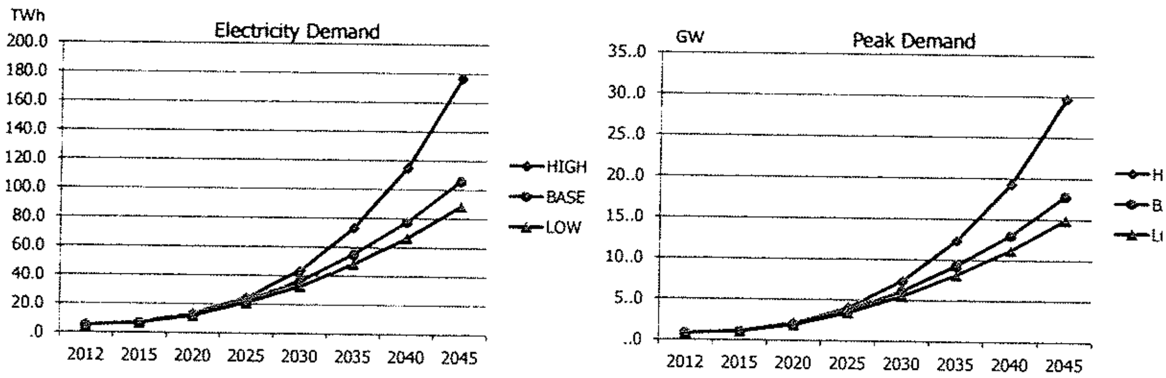


Figure 5.3-2 Power Demand Forecast

5.3.3 Power Development Plan

1) Method for compiling the least cost power development plan

In order to examine the least cost power development plan combining various types of power plants and development patterns, WASP (Wien Automatic System Planning Package, Version -IV), a power generation development planning software, is applied, which is developed by the International Atomic Energy Agency (IAEA). The WASP-IV can select the optimum power source development plan that satisfies constraints such as supply reliability (LOLP), reserve capacity, fuel limitation, and restriction on the amount of environmental pollutant emissions, etc. for the next 30 years. The optimum power source development plan refers to the plan in which the generation cost discounted to the present value becomes the minimum. The following paragraphs give an outline of the WASP calculation model.

Figure 5.3-4 shows the simplified flowchart of WASP-IV indicating the flow of information and data files between various WASP modules.

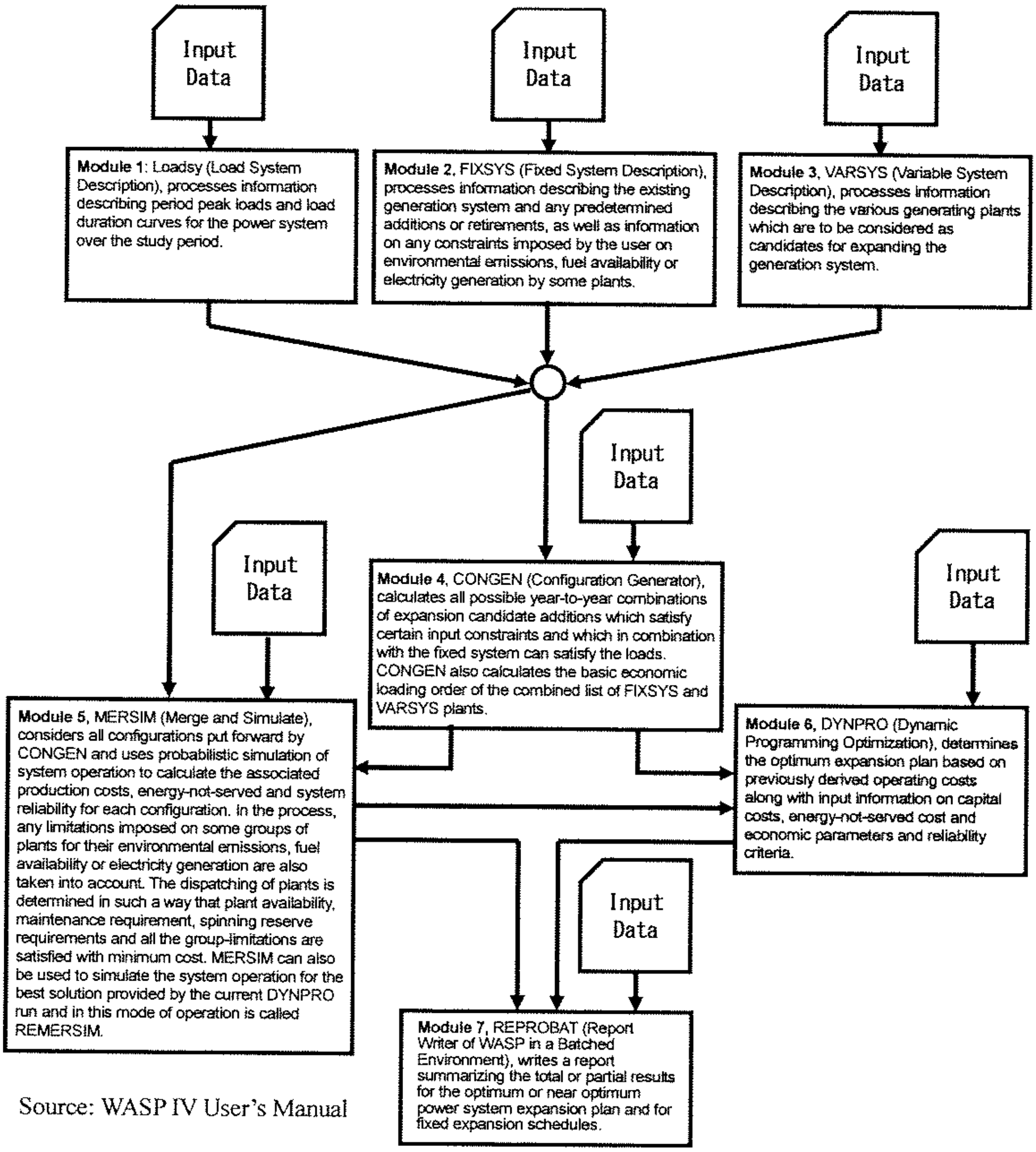


Figure 5.3-3 WASP-IV Flowchart

The combination of all power generation plants (power generation development plan) that satisfy constraints and are added to the power system is evaluated based on the objective function composed of the following items:

Depreciable investment cost: Equipment and installation cost (I)

Residual value of investment cost (S)

Non-depreciable investment cost: Fuel stock, replacement parts, etc. (L)

Fuel cost (F)

Non-fuel operation and maintenance cost (M)

Non-supplied power cost (O)

Here, the cost function evaluated in WASP is expressed by the following formula:

$$B_j = \sum_{t=1}^{T} [\ \bar{I}_{j,t} - \bar{S}_{j,t} + \bar{L}_{j,t} + \bar{F}_{j,t} + \bar{M}_{j,t} + \bar{O}_{j,t}\ ]$$

Where,

B_j : Cost function of the power source development plan j

t : Year of the power source development plan (1, 2, ... , T)

T : Term of the power source development plan (all years)

The bars above each symbol indicate prices that have been discounted at a discount rate *i* by the set time. The optimum power source development plan is the plan at which the cost function B_j in all development plan candidates *j* becomes the minimum.

2) Conditions of Analyses

a) Candidate power plants

<u>Thermal Power Plants</u>

Candidate power plants for thermal are derived from the planned and/or ongoing projects shown in Table 5.3-3 and the model plants shown in Table 5.3-4 as candidates for future power development.

Table 5.3-3 Thermal Plant Candidates (Planned and Ongoing)

Type	Name of plant	Capacity (MW)	Planned commissioning year PSMP2012	Earliest commissioning year PSMP Reiew
Gas	Kinyerezi I	150	2014	2015
	Kinyerezi II	240	2015	2017
	Kinyerezi III	600	2016	2019
	Kinyerezi IV	330	N/A	2019
	Sonamaga Fungu-1 (IPP)	210	2015	2017
	Somanaga Fungu-2 (IPP)	110	2015	2017
	Somanaga Fungu (TANESCO)*	8	2014	2017
	Mtwara (PPP)	400	2016	2019
	Zinga (IPP)	200	2015	2019
	Mkuranga (PPP)	250	2015	2020
	Mkuranga (NSSF)	300	N/A	2017
	Mtwara (TANESCO)*	18	N/A	2019
Coal	Mchuchuma-I	600	2018/20/22	2021~
	Kiwira-I	200	2016	2022
	Kiwira-II	200	2018	2025
	Ngaka-I	200	2017	2022
	Ngaka-II	200	2019	2025

(Note) PSMP 2012 : Power System Master Plan 2012, 25years long term power system developemt plan formulated by the Tanzanian side.
PSMP Review : Technical cooperation project conducted by JICA from May 2014 to March 2015 for review and update of PSMP2012.

Table 5.3-4 Model Plants for Variable Thermal Candidates

Type	Name	Capacity (MW)	Heat Rate (kcal/kWh)	Generation Efficiency	Construction Cost ($/kW)
Single Cycle Gas Turbine	SGT1	70	2,759	31.20%	900
	SGT2	120	2,845	30.20%	900
	SGT3	300	2,470	34.80%	900
Combined Cycle Gas Turbine	CGT1	110	1,773	48.50%	1,200
	CGT2	185	1,832	46.90%	900
	CGT3	470	1,616	53.20%	900
Coal	SBCL Conventional Sub-Critical	150	2,115	40.70%	2,000
	ASBC Advanced Sub-Critical	300	2,050	42.00%	2,000
	USCL Ultra Super Critical	700	2,040	42.20%	2,000

Hydro Power Plants

Hydro plant candidates are selected from the potential sites which are currently under construction, or those on which pre-feasibility or feasibility study is already carried out. Table 5.3-5 shows hydro power plant candidates.

Table 5.3-5 Hydro Power Plant Candidates

Site	Rated output (MW)	Planned commissioning year PSMP2012	Earliest commissioning year PSMP Review
Rusumo	30.0	2018	2019
Malagarasi Stage-III	44.7	2020	2024
Kakono	87.0	2019	2022
Songwe Manolo(Lower)	88.1	2028	2022
Songwe Sofre (Middle)	79.5	2026	2022
Mnyera – Ruaha	60.3	N/A	2020
Mnyera – Mnyera	137.4	N/A	2021
Mnyera – Kwanini	143.9	N/A	2021
Mnyera – Pumbwe	122.9	N/A	2021
Mnyera – Taveta	83.9	2029	2021
Mnyera - Kisingo	119.8	N/A	2021
Iringa – Ibosa	36.0	N/A	2020
Iringa – Nginayo	52.0	N/A	2020
Steiglers Gorge Phase 1	1048.0	2023~	2027
Rumakali	222.0	2025	2030
Ruhudji	358.0	2021	2023
Lower Kihansi Expansion	120.0	N/A	2022
Upper Kihansi	47.0	N/A	2025
Kikonge	300.0	N/A	2025
Mpanga	160.0	2022	2023
Masigira	118.0	2024	2023

b) Fuel Price

Fuel prices for the cost optimization calculation are assumed as shown in Table 5.3-6, which are derived assuming international prices observed in the middle of 2014 as below, despite that the present prices applied or under negotiation are much lower. In the long run, fuel prices are assumed to converge to the international levels.

The natural gas price at shore is calculated assuming that the international LNG price landed in Europe at \$12/MMBtu, and deducting freight cost at \$2/MMBtu and liquefaction cost of \$4/MMBtu. Coal price at the mine mouth in the interior regions is derived assuming the imported coal price at coastal regions at \$100/t and deducting transportation cost assumed at \$30/t. Both of them are hypothetical internationally competitive prices.

Table 5.3-6 Fuel Price Assumption used for Power Development Analysis

Fuel type	PSMP 2012	PSMP Review
Gas	Ubungo: US$ 0.64/MMBtu (US$0.68/GJ)	US$ 6.00/MMBtu
	Additional gas : US$3.01/MMBtu (US$ 3.18/GJ)	
	Mnazi Bay: US$4.49/MMBtu (US$ 4.74/GJ)	
Coal	Ngaka: US$2.37/MMBtu (US$2.5/GJ)	US$3.53/MMBtu
	Mchuchuma: US$ 2.46/MMBtu (US$2.6/GJ or US$55/tonne)	

c) Supply Reliability Standard

The LOLP (Loss Of Load Probability) is used as the indicator for evaluating the reliability of power supply. Then, the power source development plan withholding the necessary power reserve satisfying the target LOLP needs to be compiled. The LOLP is widely applied throughout the world as a standard to assess power supply reliability. NERC (North American Electric Reliability Corporation) adopts a LOLP of 1 day / 10 years, while PLN in Indonesia adopts 1 day / year, and CEB (Ceylon Electricity Board) adopts 3 days/year. In the PSMP 2012, the target LOLP is not stated, however, in the PSMP 2009 Update, the LOLE (Loss Of Load Expectation, used synonymously with LOLP) is set at 5 days / year. In this Project, it is intended to adopt LOLP 5 days / year as the target reliability standard.

d) Power Development Scenario

Power development plants are formulated running the WASP model in accordance with scenarios as defined in Table 5.3-7.

Table 5.3-7 Power Development Scenarios

Scenarios	Description
Scenario-0	■ No constraints imposed ■ Let WASP select the least cost generation configuration
Scenario-1	■ Energy generated from Gas and Coal is balanced
Scenario-2	■ Energy generated from Gas and Coal is balanced ■ Drought probability increased by 10% (twice in ten years or 20% occurrence) ■Reserve capacity is calculated based on available capacity of hydro during drought years
Scenario-3	■Energy generated from Gas and Coal is balanced ■ Drought probability is increased by 10% (twice in ten years or 20% occurrence) ■Reserve capacity is calculated based on available capacity of hydro during drought years ■ Estimated earliest commissioning year of hydro power candidates are delayed for 5 years

3) Results of Analyses

Optimum solutions for each development scenario obtained through simulations using WASP are calculated. Figure 5.3-4 shows optimized power generation mix under the respective scenario.

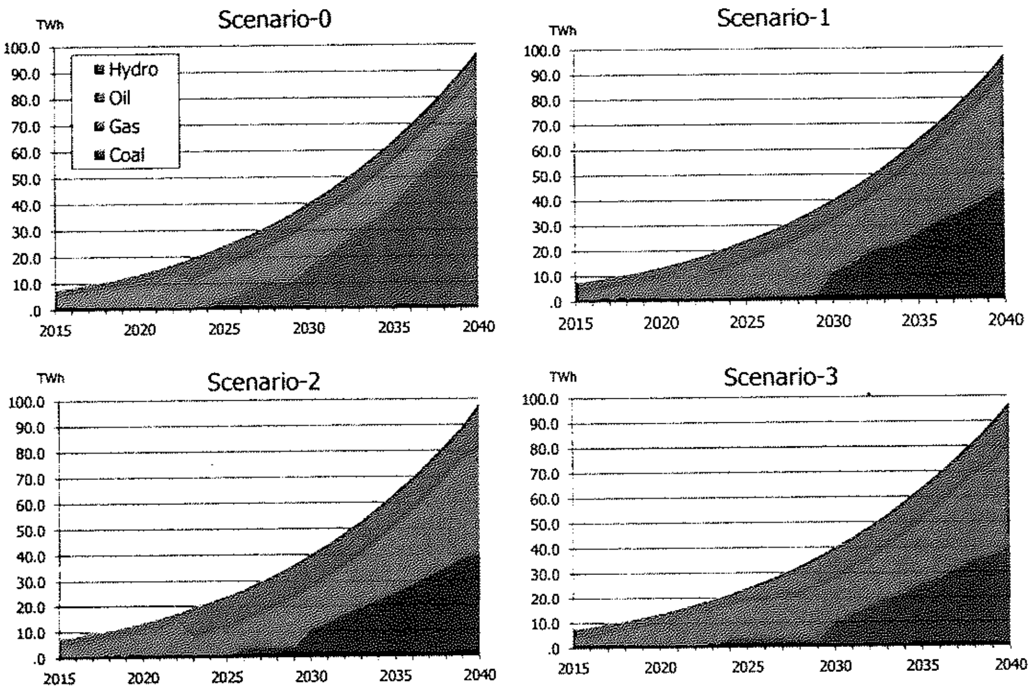


Figure 5.3-4 Transition of Energy Generated from Each Type of Fuel

The outcome is evaluated and scored as summarized in Table 5.3-8. The scenaio-3 is selected as most recommendable through this evaluation from the view point of total generation cost for 25years (from 2015 to 2040) , which includes capital cost, operation and maintenance cost and fuel cost, as well as energy balance and environmental consideration.

Table 5.3-8 Evaluation of Power Development Scenarios

Scenarios	**Features**	**Cost (million$)**	**Cost**	**Energy Balance**	**Environ ment**	**Order**
Scenario-0	■ Large share of coal generation (~70%)	48,798	Good	Poor	Poor	4th
Scenario-1	■ Energy generated from coal and gas is balanced (Hydro: 10%, Gas: 45%, Coal: 45%)	49,730	Fair	Good	Good	2nd
Scenario-2	■ Energy generated from Gas and Coal is balanced (Hydro: 20%, Gas: 40%, Coal: 40%) ■ Large share of hydro generation from 2023 to 2027 (more than 40%)	47,887	Excellent	Poor	Good	3rd
Scenario-3	■ Energy generated from Gas and Coal is balanced (Hydro: 20%, Gas:40%, Coal:40%) ■ The share of hydro generation is always 30% or less	48,811	Good	Excellent	Good	Best

5.3.4 Gas demand in Thermal Power Generation

Gas consumption for each power development scenario is shown in Figure 5.3-5. In the optimum scenario (Scenario-3) described as above, natural gas consumption for power generation will exceed 200 Bcf a year around 2030 and reach 350 Bcf in 2045; cumulative gas consumption for 25 years from 2015 to 2040 is approximately 5Tcf.

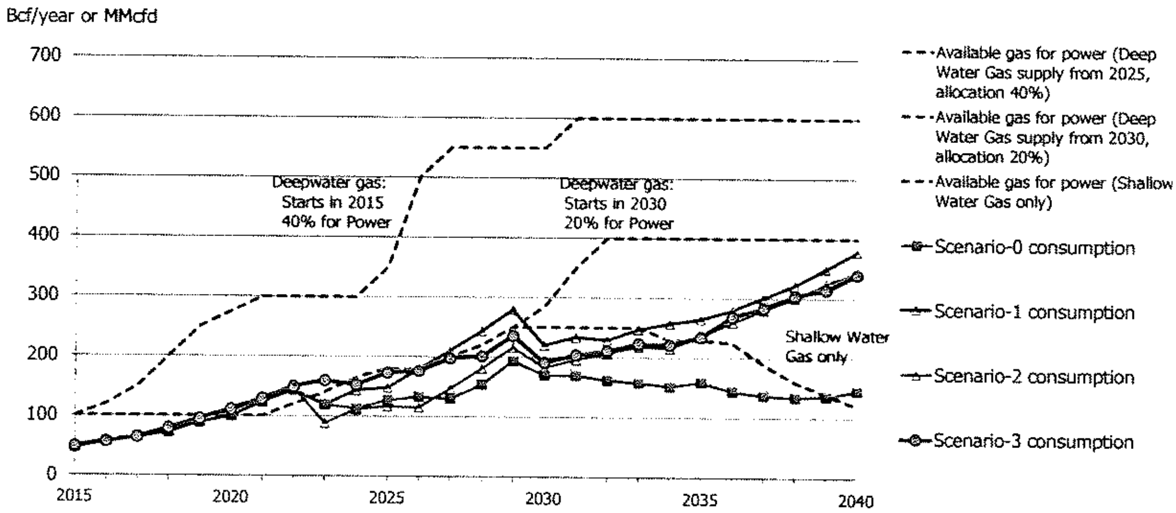
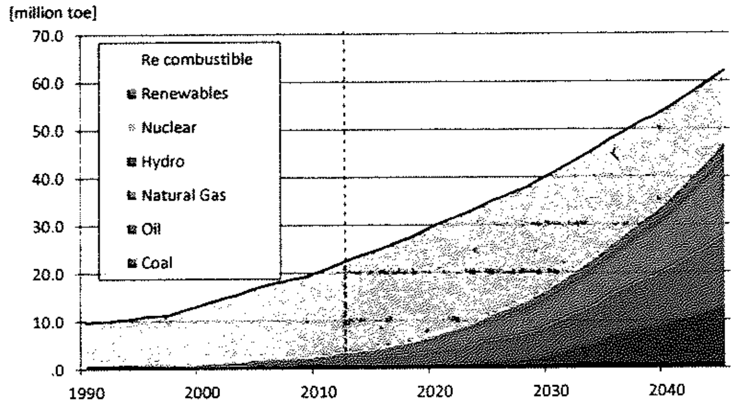


Figure 5.3-5 Gas Consumption by Power Development Scenarios

5.4 Primary Energy Supply

Figure 5.4-1 shows the primary energy supply estimated from the final energy demand and energy input to the transformation sector including power generation. The total primary energy supply will increase by 3.2% per annum from 22.2 Mtoe in 2012 to 62.2 Mtoe in 2045. The share of coal increases from 0% to 21%, oil from 10% to 24% and natural gas from 4% to 25%. Meanwhile, biomass decreases its share from 86% to25%, replaced by fossil fuels. Substitution from traditional biomass to modern energy sources brings about significant efficiency improvement, and thus the apparent growth rate of primary energy demand turns out slow. However, primary energy consumption excluding the traditional renewables is forecast to increase at an annual average growth rate of 8.4% between 2012 and 2045.

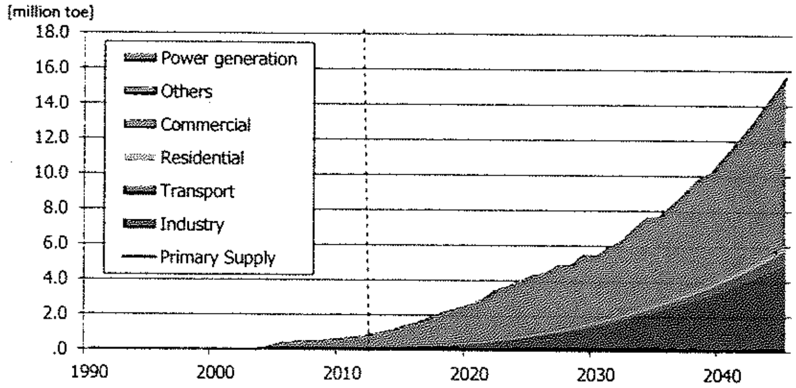


	Primary Energy Demand				Composition				AAGR			
	2012	2025	2035	2045	2012	2025	2035	2045	12⇒25	25⇒35	35⇒45	12⇒45
	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Coal	49	1,626	6,754	12,943	0.2	4.6	14.2	20.8	31.0	15.3	6.7	18.4
Oil	2,215	4,412	8,344	14,768	10.0	12.6	17.5	23.7	5.4	6.6	5.9	5.9
Natural Gas	812	4,278	7,619	15,612	3.7	12.2	16.0	25.1	13.6	5.9	7.4	9.4
Hydro	143	363	1,019	1,368	0.6	1.0	2.1	2.2	7.5	10.9	3.0	7.1
Nuclear	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	
New Renewables	15	550	1,348	2,150	0.1	1.6	2.8	3.5	32.2	9.4	4.8	16.3
Combustible RE	18,938	23,917	22,566	15,395	85.5	68.1	47.4	24.7	1.8	-0.6	-3.8	-0.6
Total	22,162	35,138	47,642	62,226	100.0	100.0	100.0	100.0	3.6	3.1	2.7	3.2
Excluding RE	3,224	11,221	25,076	46,831	14.5	31.9	52.6	75.3	10.1	8.4	6.4	8.4

Figure 5.4-1 Primary Energy Supply (Base case)

5.4.1 Domestic Natural Gas Demand

Outlook for the domestic natural gas demand including those for power generation is presented in Figure 5.4-2. The natural gas demand will increase from 0.8Mtoe in 2012 to 16.7 Mtoe in 2045. In addition to the industrial sector, residential and commercial sectors are expected to become gas consumers pending development of city gas supply network. In 2012, the power generation sector consumed about 80% of natural gas and the rest was mostly consumed in the industrial sector. The share will change significantly with emerging domestic demand by 2045; 50% for the power generation sector, 33% for the industry sector and 4% for the commercial sector. If we add the gas industries to be discussed in Section 5.5, gas consumption for industrial use as fuel and feedstock will gradually dominate in future in Tanzania.



	Natural Gas Demand				Composition				AAGR			
	2012	2025	2035	2045	2012	2025	2035	2045	12=>25	25=>35	35=>45	12⇒45
	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Industry	130	881	2,398	5,086	16.0	20.6	31.5	32.6	15.9	10.5	7.8	11.8
Transport	0	45	263	792	0.0	1.1	3.4	5.1	-	19.3	11.7	-
Household	0	27	89	185	0.0	0.6	1.2	1.2	-	12.5	7.6	-
Commercial	0	32	187	565	0.0	0.8	2.5	3.6	-	19.3	11.7	-
Agriculture & Others	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	-
Power Generation	682	3,293	4,682	8,984	84.0	77.0	61.5	57.5				8.1
Total	812	4,278	7,619	15,612	100.0	100.0	100.0	100.0	13.6	5.9	7.4	9.4

Figure 5.4-2 Domestic Natural Gas Demand (Base case)

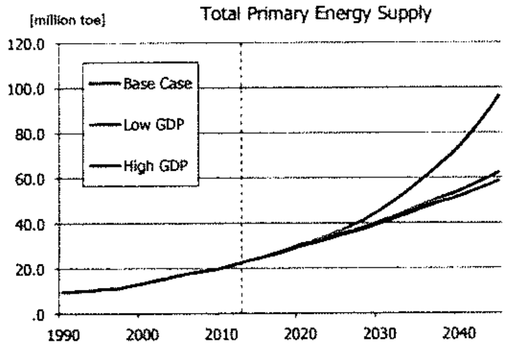
We should note that, however, potential demand will be high in the household and transport sector. If supply infrastructure development were accelerated, though costly and time consuming, gas demand in these sectors may grow significantly as projected for the High case.

Table 5.4-1 Domestic Natural Gas Demand: High Case and Low Case

	Natural Gas Demand				Composition				AAGR			
	2012	2025	2035	2045	2012	2025	2035	2045	12=>25	25=>35	35=>45	12⇒45
High Case	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Industry	130	1,160	4,033	10,147	16.0	23.5	34.2	34.6	18.3	13.3	9.7	14.1
Transport	0	113	659	1,986	0.0	2.3	5.6	6.8	-	19.3	11.7	-
Household	0	55	177	370	0.0	1.1	1.5	1.3	-	12.5	7.6	-
Commercial	0	41	237	715	0.0	0.8	2.0	2.4	-	19.3	11.7	-
Agriculture & Others	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	-
Power Generation	682	3,571	6,687	16,130	84.0	72.3	56.7	55.0	13.6	6.5	9.2	10.1
Total	812	4,939	11,793	29,348	100.0	100.0	100.0	100.0	14.9	9.1	9.5	11.5
Low Case	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Industry	130	687	1,675	3,273	16.0	18.3	27.7	28.3	13.7	9.3	6.9	10.3
Transport	0	18	105	318	0.0	0.5	1.7	2.7	-	19.3	11.7	-
Household	0	6	20	42	0.0	0.2	0.3	0.4	-	12.5	7.6	-
Commercial	0	26	152	458	0.0	0.7	2.5	4.0	-	19.3	11.7	-
Agriculture & Others	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	-
Power Generation	682	3,026	4,093	7,481	84.0	80.4	67.7	64.6	0.0	0.0	0.0	7.5
Total	812	3,763	6,046	11,572	100.0	100.0	100.0	100.0	12.5	4.9	6.7	8.4

5.4.2 Sensitivity Analysis

The total primary energy supply and the domestic natural gas demand for three cases ("Low", "Base" and "High") are presented in Figure 5.4-3. In order to figure out the impact of the GDP growth to the energy demand and supply, the sensitivity of the total primary energy supply and the domestic natural gas demand to the real GDP that is analyzed based on the difference in growth rate among these three cases is shown in Table 5.4-1. The sensitivity of the domestic natural gas demand is 1.4, which is significantly larger than 0.45 of the total primary energy supply and 0.7 for the electricity demand. The apparent TPES growth will be slow reflecting the declining trend of the traditional biomass. Natural gas is expected to be the fuel of choice in the transition from the traditional biomass to modern energy in the course of industrialization.



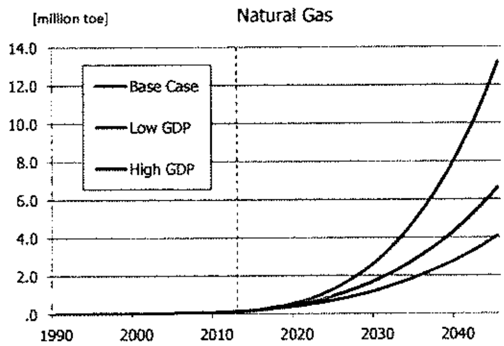


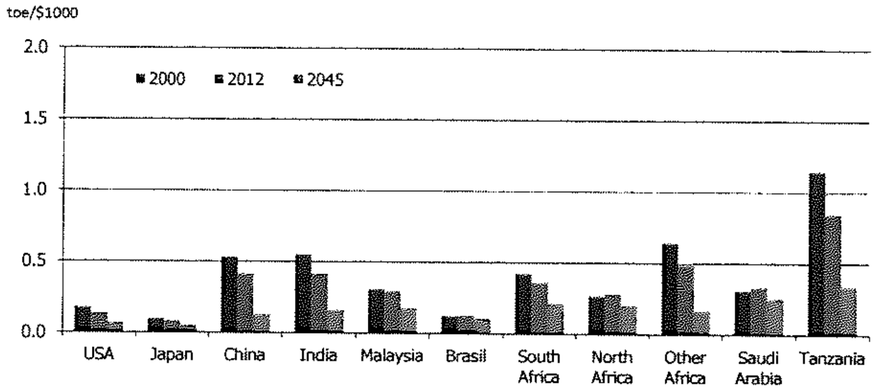
Figure 5.4-3 Total Primary Energy Supply and Domestic Natural Gas Demand by case

Table 5.4-2 Sensitivity Analysis

	Real GDP	TPES	Electricity	Natural Gas
Average Annual Growth Rate (2012-2045)				
Base Case	6.1%	3.2%	9.6%	12.7%
Low GDP	5.1%	3.0%	9.0%	11.0%
High GDP	8.2%	4.5%	11.3%	15.0%
Sensitivity		*0.45*	*0.72*	*1.38*

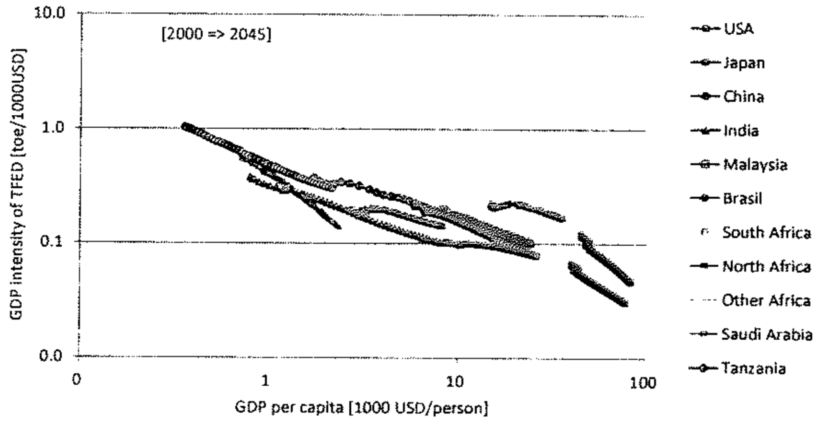
5.4.3 International Comparison

Figure 5.4-4 shows international comparison of energy intensity, the total primary energy supply divided by real GDP. The smaller energy intensity means higher energy efficiency of a whole country. In general, the energy intensity decreases as the economy grows. The energy intensity of the United States decreased from 0.18toe/1,000USD in 2000 to 0.14toe/1,000USD in 2012 and is expected to decrease to 0.07toe/1,000USD in 2045. In Japan, one of the most energy efficient nations, the energy efficiency has rapidly progressed by 1990 and its energy intensity decreased from 0.10toe/1,000USD in 2000 to 0.08toe/1,000USD in 2012 and is expected to improve to 0.05toe/1,000USD in 2045 according to the analysis by The Institute of energy Economics, Japan (IEEJ). The energy intensity of many developing countries that lay around 0.5toe/1,000USD in 2000 has fallen below 0.5toe/1,000USD in 2012 and is expected to be below 0.2toe/1,000USD in 2045. As Tanzania is in an early stage of economic development, its energy intensity still stays at a higher level; 1.12toe per 1,000USD in 2000 and 0.85toe per1,000 USD in 2012. However, according to the energy outlook analyzed in this study, it is expected to improve to 0.34toe per 1,000USD in 2045.



(Source) "Asia/World Energy Outlook 2014", IEEJ is referred for the countries other than Tanzania. Tanzania is included in Other Africa

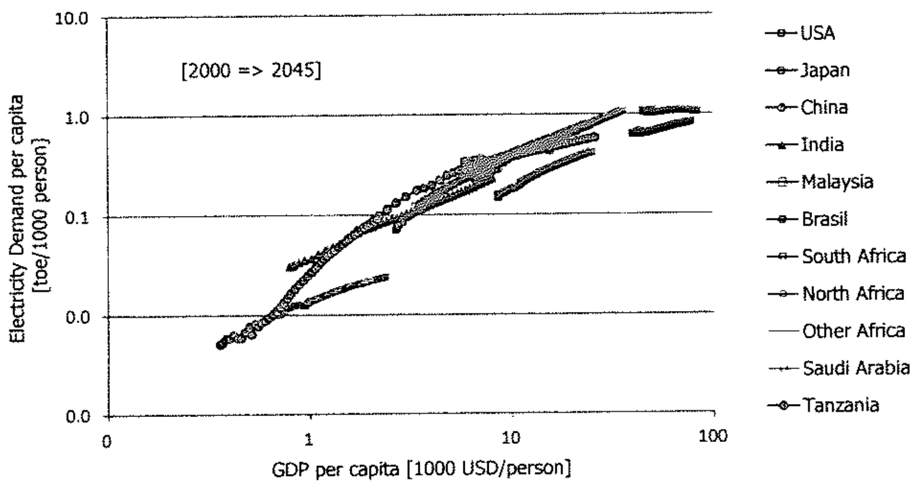
Figure 5.4-4 International Comparison of Energy Intensity



(Source) "Asia/World Energy Outlook 2014", IEEJ is referred for the countries other than Tanzania. Tanzania is included in Other Africa.

Figure 5.4-5 International Comparison of Energy Intensity and GDP per capita

In Figure 5.4-5, the time series relationship between GDP per capita and energy intensity is compared internationally. As economy grows, GDP per capita increases while energy intensity decreases. It is historically observed that many countries have followed the similar path. According to this international comparison, in terms of the relationship between GDP and energy consumption, Tanzania will reach by 2045 the level where China was in the early 2000s. Evolution of the relationship between GDP per capita and electricity demand per capita observed in various economies is presented in Figure 5.4-6. In general, per capita electricity consumption increases as per capita income increases. It is also observed that Tanzania will reach by 2045 the level of China in the early 2000s (about 1,400kWh per capita).



(Source) "Asia/World Energy Outlook 2014", IEEJ is referred for the countries other than Tanzania. Tanzania is included in Other Africa.

Figure 5.4-6 International Comparison of Electricity Demand and GDP per capita

The above graph covers very wide range of development stages. Development paths on the high side and low side will bring a substantial difference in the absolute volume of future energy consumption.

As shown in the graph, electricity consumption of Tanzania is projected to leap from the traditional lower tier to an upper tier of fast developing countries. A higher path represents industrialization with big-heavy industries and a lower path modernization with light industries and energy efficient service sectors. Thus, the above projection may be classified as substantially aggressive. However, Tanzania being a late comer, electrification once take off may progress faster than the foregoing developing countries even if the country would not aim at big-heavy type industrialization, as electric appliances and IT systems are getting more and more essential as a core element of the modern civilization. At the present pre-industrialization stage, it is difficult to define which path Tanzania would follow. This issue should be further delineated in the future energy plans incorporating various observations and the national will for development to define such direction.

5.5 Natural Gas Consumption by Optional Gas Industries

In this section, we will list up typical gas plant projects as candidates for gas industry development in Tanzania and examine potential of their natural gas requirements as feedstock.

5.5.1 Optional Gas Industries and Gas Consumption

Typical optional gas industries conceivable in Tanzania may be as follows:

1) Liquefied Natural Gas (LNG)

LNG is natural gas liquefied at -162℃ and its volume is compressed by liquefaction to 1/600 of the gaseous status, which enables long distance transport by LNG tankers.

Merit: To provide big anchor demand from the established global market.

2) Fertilizer/Ammonia

Natural gas is processed into ammonia, and then to fertilizer, while partly used as petrochemical feedstock.

Merit: To replace import and support promotion of modern agriculture

3) Methanol

Natural gas processed into methanol as chemical product as well as feedstock for petrochemical industry in further downstream such as MTO (methanol to olefin) and MTP (methanol to propylene).

Merit: To construct petrochemical industry, replace import and promote export.

4) Gas to Liquid (GTL)

Natural gas processed into petroleum products, such as petrol and diesel gas oil.

Merit: To replace import, save foreign currency and enhance security of supply.

5) Di-methyl Ether (DME)

Natural gas processed into DME, via methanol, characteristics of which are similar to LPG, for easy transport and handling.

Merit: To replace import and promote domestic gasification.

6) Methanol to Gasoline (MTG)

Natural gas processed into gasoline, via methanol.
Merit: To replace import and promote domestic gas industries.
(Technical information is deleted)

5.6 Summary on Natural Gas Demand Outlook

5.6.1 Base Case

The Base case natural gas outlook for the LNG 2-Trains case is summarized in Figure 5.6.1 and Table 5.6-1, which is compiled incorporating the domestic demand forecast, the gas requirement for power generation and the gas industry development scenario as explained above. Gas consumption for the first 20 years between 2015 and 2035 will be 11 Tcf, while that for the whole projection period between 2015 and 2045 will significantly increase to 23 Tcf, since, in the later stage, most of gas industries will be fully operating and domestic gas consumption will be increasing fast as the economy will be in much greater size then. Modernization of industry and human life with gas and electricity will be accelerated once development of energy infrastructure has established a reliable supply system in the country.

In terms of the gas requirement volume, LNG will provide about half of the gas demand followed by power generation and domestic fuel use. Industry comprises 77% of the domestic final energy demand in 2045. Domestic gas use will increase its share gradually as the economy develops. Gas to power increases to 2.7GW in 2035 and to 5.6 GW in 2045. In the early stage to launch the gas industry, however, LNG is the dominant gas outlet to provide the anchor demand for the gas field development, in particular for the deepwater gas fields that need to justify huge investment.

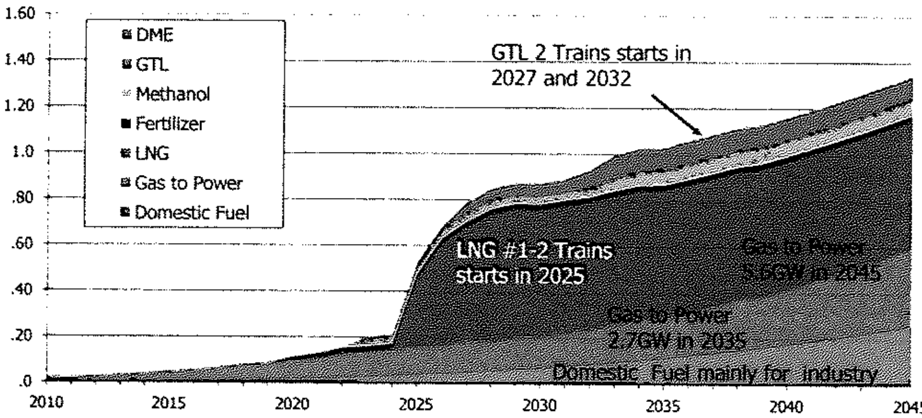


Figure 5.6-1 Gas Consumption Outlook: Base Case

5.6.2 High Demand Case

In the High case projection where highly ambitious economic growth of annual 8% is assumed throughout the projection period, domestic natural gas demand will expand substantially faster than in the Base case.

The natural gas demand for the whole projection period between 2015 and 2045 will increase to 27 Tcf, which is 4Tcf greater than the Base case.

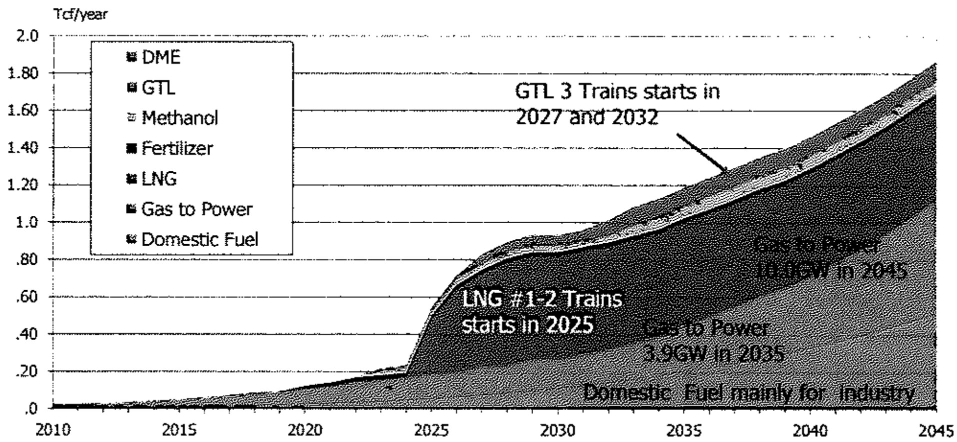


Figure 5.6-2 Gas Consumption Outlook: High Case

5.6.3 Low Case

In the Low case, we assume that domestic gas demand grows moderately and that only two trains will be built for GTL. Then, the share of LNG may remain above 50% during the projection period.

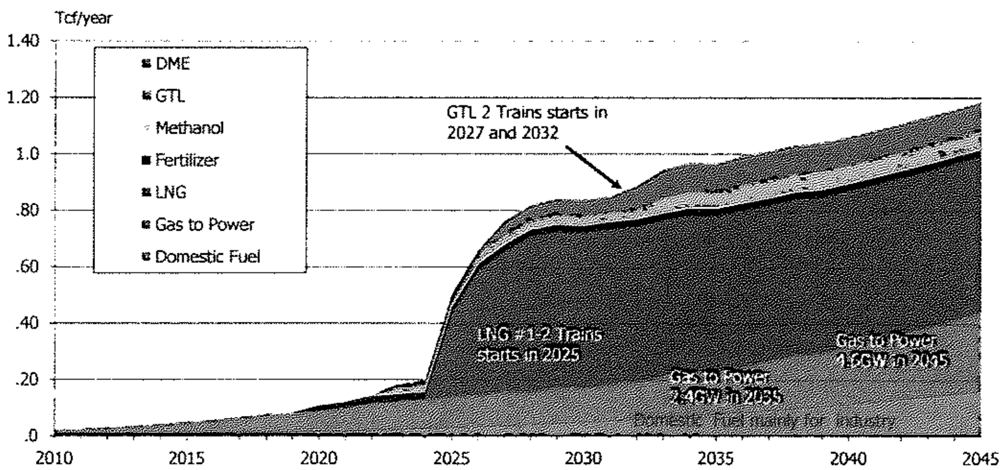


Figure 5.6-3 Gas Consumption Outlook: Low Case

5.6.4 Four Trains Case: Base Case

In view of the anxiety that only a half of the presently recognized gas reserves could be produced in the coming three decades, a case to construct additional two LNG trains may be considered.

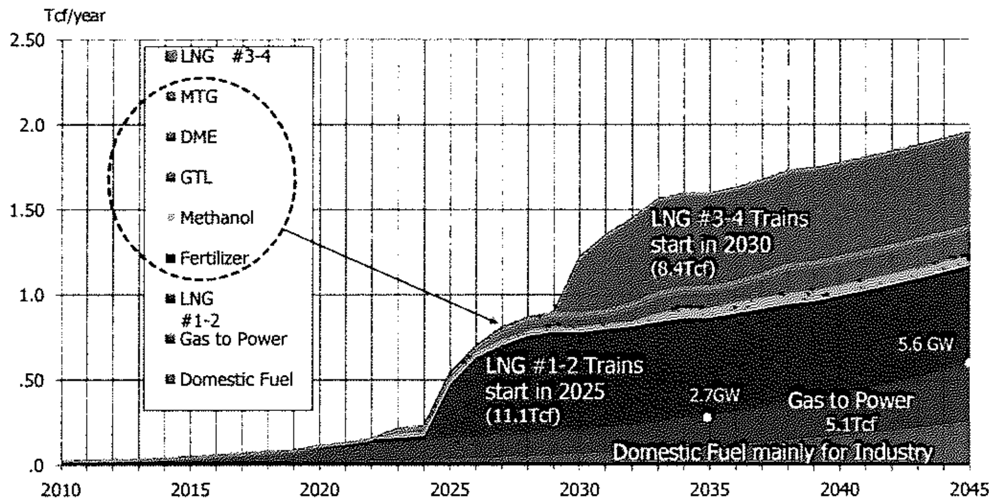


Figure 5.6-4 LNG 4 Trains-Case

5.6.5 Summary

The above projection illustrates patterns of future natural gas use where the presently discovered natural gas will last beyond 2050 for the cases of constructing 2 trains of LNG. Even in the LNG 4 trains- case, only 80% of the gas reserves will be consumed by 2045. In evaluating the above outcome, we should take note of the oil and gas industry business practice as below.

It is the customary of the oil and gas industry that discovered resources must be developed and produced in a timely manner to materialize their benefit. PSAs are formulated according to this business rule worldwide. To fulfill the depleting resources along with production, exploration efforts must be encouraged in due course as seen in many foregoing countries.

The presently confirmed reserves should be considered as if an inventory of resources at hand. If a huge inventory should be maintained without possibility of sale for decades, nobody would invest in further exploration to discover new resources. Such policy would dilute efforts for economic development significantly.

Based on the above principle, the result of the assessment for the LNG 2 trains cases may be summarized as follows.

The Base case projection consumes only 2/3 of the presently recognized reserves in the coming three decades. This would significantly depress oil and gas exploration in coming years.

The High case projection still cannot consume the present gas reserves by 2050, while the gas outlook for this case is really an ambitious projection aiming at big-heavy type industrialization with rapid increase in electricity consumption. If such high energy consumption is expected, more energy efficient equipment will be introduced on the user side, while more flexible choice of energy will be offered by suppliers. For example, though it is assumed in this projection that same quantity of coal and gas will be used for power generation in the long run, proactive development of coal thermal stations could cut back natural gas use for power generation. These aspects must be evaluated carefully.

Under the Low case projection, only a half of the presently recognized discoveries could be consumed in the next three decades. Such situation would awfully depress investment for oil and gas development, in particular deepwater gas fields, and threaten construction of a gas based energy supply platform in Tanzania.

From the above observation, construction of additional two LNG trains looks a healthy option, where 80% of the presently recognized gas reserves will be consumed by 2045. However, as discussed in Chapter 8, the present gas reserves cannot fully assure stable feed supply during the projection period. However, the depleting gas reserves must be filled up by new discoveries; it is the fundamental principle of the oil and gas industry. Once it is demonstrated that gas industries will start operation and provide robust outlet, as we have seen in many foregoing countries, oil industry will invest more in exploration to bring about additional gas discoveries. The economy begins rolling toward the goal. This is the first step we should take. Thereafter, to drive the economy properly, we should fine tune the energy plan from time to time when more affirmative information becomes available.

It is always a dilemma for energy planners if domestic resources would be sustainable in the long run. At this moment, however, we should not be intimidated worrying about this. It is more important to push forward economic development for better quality of life with natural gas at hand as the driver to materialize the goal of the Tanzanian Development Vision 2025.

Chapter 6 Site for Natural Gas Industries

Chapter 6 Site for Natural Gas Industries

(Since confidential information is included, the entire chapter is withheld.)

Chapter 7 Gas Industry Models and Economics

Chapter 7 Gas Industry Models and Economics

This chapter summarizes the outcome of the feasibility study on potential gas industry projects, namely LNG, ammonia/fertilizer, methanol, GTL, DME and MTG. This chapter contains strictly confidential information that should not be disclosed to any person other than the recipients designated by the Ministry of Energy and Minerals, the United Republic of Tanzania.

The analysis shows generally fair economics as discussed below, while the key points in addition to the amount of the required capital expenditure are how we should look at the future product prices and set out the revenue sharing between the upstream and downstream. In addition to economics observed by model analysis, socio-economic impacts of these projects should also be considered in the final project evaluation.

7.1 Method of Approach and Assumptions

7.1.1 Model for Feasibility Analysis

In this study, feasibility studies are run on natural gas projects using business models designed to output key indicators relating to project economics under certain conditions and scenarios. These models are constructed by formulating the project parameters into a mathematical system based on the data and information that are publically available, locally obtained by surveys and interviews, and/or prepared by the JICA study team. Major elements incorporated in the model are plant scale, construction time schedule, production amount and product price, feed gas requirement and price, capital expenditure, operation expenditure, tax, duty, fees and other modes of government take, subsidies, loan and interest payments, profit, government revenue, and so on. To understand the realistic financial arrangement, a loan system to finance investment requirement together with calculation of FIRR (financial internal rate of return) is prepared in the model. Sensitivity analysis is conducted to evaluate the effects of changes in key assumptions and policy selections. In addition, socio-economic impact of a project can be evaluated using the model for items such as the expected government revenue and potential amount of foreign currency savings. The models are also able to examine the impact of various policy options such as changes in taxes, subsidies and price control.

The standard model is constructed on a cash flow chart, based on technical specifications of the project and monetary relationships of elements constituting the project, covering the entire project life from the inauguration through the end of the evaluation period. Technical and economic relationships of the key elements are internally formulated, while scenarios on economic growth and price outlook and assumptions on plant size, construction cost and other key factors are given externally. In this report, project economics are calculated for a 25 year production period. For easy understanding, operation and modification, this model is developed on a Microsoft Excel spreadsheet.

To run the model, main assumptions and scenarios should be prepared at first for items such as plant size, production profile, required feed gas/material, prices of products and feed gas or feedstock material, capital investment, operation cost, and taxation system. Once these assumptions are given, the model returns output on key indicators for evaluation of project economics. Major model outputs are as follows:

Total amount of revenue, feedstock (gas or methanol), tax, profit, etc. (elements incorporated in the CFC) and Net Cash Flow

Internal Rate of Return (IRR)

Net Present Value (NPV for Project Owner and Government) at a given discount rate

Government share of profit

Financial Internal Rate of Return (FIRR)

Loan repayment schedule and interest payable

Debt/Equity Ratio

NPV for Loan Case

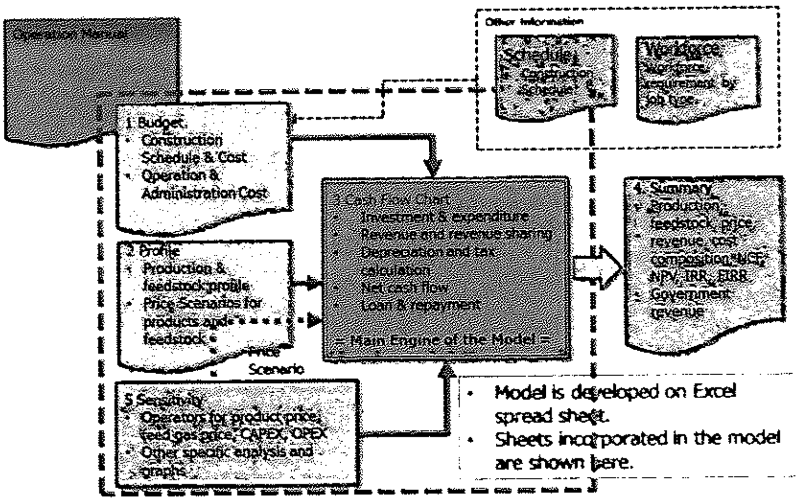


Figure 7.1-1 Model Structure

The general configuration of the model is as shown in Figure 7.1-1. For operational simplicity to treat different issues separately, the model is developed on several separate worksheets. Sheets 1to 5 are the key sheets constituting the model, while other sheets include operation manual and other important information but not directly linked in the model.

The "3 Cash Flow" sheet is the main engine of the model, where technical and economic relationships of the key elements are formulated and outputs are calculated.

Major scenarios are developed and worked out on the sub-work sheets, such as;
Construction and start-up schedule
Budget for construction and operation
Production profile based on marketing scenario
Feed gas profile based on technical relations
Price scenarios for products and feed gas

The construction and operation budgets as well as annual expenditure schedule are developed on the "1 Budget" sheet. Annual production profiles of the product and required feed gas or feedstock material are developed on the "2 Profile" sheet. Price outlook developed as annual profile are also developed on the same sheet, where various price scenarios can be selected for analysis. Assumptions developed on the sheet 1 and 2 are linked as inputs to the "3 Cash Flow" sheet.

Other assumptions are given on the"3 Cash Flow" sheet:
Tax rates: Income Tax, VAT, Excise Tax, Withholding Tax, Tax Holiday
Applicable depreciation rate
(Plant: 25% diminishing value method, Upstream: 20% straight line method)
Discount rate for calculation of NPV
Loan ratio and interest rate for FIRR analysis

The model returns all calculation results on the same sheet, and their summary is listed in the "4 Summary" sheet. The sheet "5 Sensitivity" includes the system to run sensitivity analysis altering product price, feed gas price, CAPEX (Capital Expenditure) and OPEX (Operational Expenditure). Also, other different analyses are mainly controlled by this sheet. To run multiple case studies, the model should be run for multiple times for each case, and outputs should be recorded at each run.

To consider fund requirement and more realistic economics in project investment, FIRR (Financial Internal Rate of Return) calculation incorporating loan arrangement is formulated.

1) Loan

Equity/Loan Ratio is given in the "3 Cash Flow" sheet. As the first approach, loan ratio is set at 60% in order to maintain the debt/equity ratio below 2.

2) Interest Rate

As the first approach, interest rate is set at 5%, with a slight premium on LIBOR (London Inter-Bank Offered Rate) considering procurement of institutional finance from international organizations. Realistic interest rate should be considered with in-depth study on the financial conditions available for Tanzania.

It should be noted that healthy project economics will be required to qualify for a huge amount of loan.

Policy options can be examined by altering following parameters.

1) Taxation - set on the "3 Cash Flow" sheet

Income tax, withholding tax, excise tax, and import duty

Depreciation rates for calculation of Income Tax

Tax holiday years can be selected, such as companies operating in Special Economic Zones are granted a10-year tax holiday.

Changes in taxation work to improve economics only when project economics is at a healthy level, otherwise tax would not be paid much.

2) Subsidy

Subsidy is not specifically considered in the present model. Subsidy can be considered in two ways:

Giving negative numbers for taxes

Changing price profiles giving higher product prices or lower feedstock prices in the "2 profile" sheet.

3) Revenue Sharing

Revenue sharing ratio between upstream and downstream, controlled on the "2 Profile" and "5 Sensitivity" sheets, affects economics of individual projects.

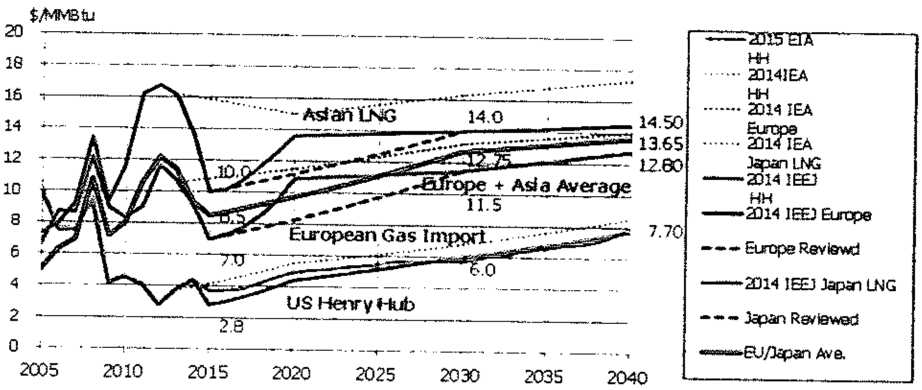
7.1.2 Price Scenarios

In conducting economic evaluation, while it is obvious that the model should accurately formulate relevant factors such as technical characteristics of the individual projects, the tax system and other socio-economic institutions applicable in the host country, the decisive factor above all is how to anticipate the prices of products and cost of raw materials. In that sense, the setting of the price scenarios is an important factor that determines the life or death of a project..

a. Natural Gas Price Outlook:

Since the summer of 2014, the plunge of crude oil and natural gas prices triggered by the Shale Revolution in the United States has proceeded with a higher pace than anticipated and, as of June 2015, the Henry Hub based natural gas price in the U.S. dropped to a level below $ 2.80/MMBtu. It is also noted that in the world LNG market, spot cargoes have showed up with prices in the $7/MMBtu range. Even the Japanese LNG import price dropped from the prolonged high level to as low as $10.26/MMBtu in April. Since this import price is an averaged figure including both long-term as well as spot contracts, the above may well be considered to indicate a significant fall in the spot cargo prices.

In the United States, with its natural gas prices in doldrums, since it is rather difficult to find a sizable outlet of natural gas until 2017, when shipments are to start from the first LNG export plant in Sabine Pass, domestic natural gas prices are anticipated to remain weak for some time to come. Furthermore, in the world LNG market, large-scale projects are expected to go online in succession during this period in Australia and elsewhere, thus the state of an oversupply of LNG is expected to last for a while.



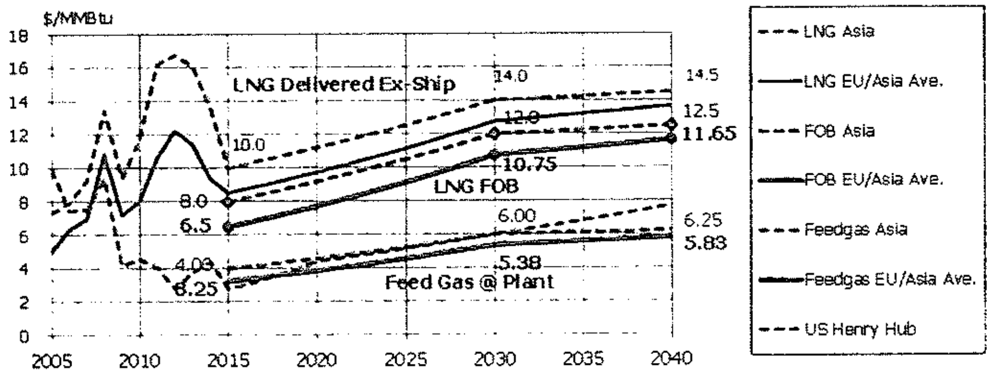
(Source) IEEJ Analysis

Figure 7.1-2 World Natural Gas Price Outlook

Meanwhile, there appears a change in China's economic situation, which so far has led the economic growth of the world and, added with factors such as the prospect of nuclear power plants in Japan gradually returning to the lineup, the demand trend in natural gas importing countries remains weak. On the supply side, in the upcoming competition with the U.S.-produced LNG in the European market, Russia will strengthen its natural gas export drive aiming at Asia, likely causing an additional supply pressure in the Asian market. Under these circumstances, slackened supply and demand situation in the world LNG market will last over a considerable period of time, and it appears the prices will not recover to the level previously anticipated until around 2030.

In the global gas market, Asia is expected to remain as the main source of new demands. While European market will be able to maintain its advantageous market conditions where it could secure import supplies from an extensive range of sources such as Russia or the U.S., the price gap between the European and the Asian markets will gradually diminish assisted by a number of new LNG projects that are being launched around the world, in particular the Pacific rim. Note that voyage time from Tanzania is shorter to destinations up to Japan than to those in Europe via Suez Canal. From that standpoint also, it seems logical to consider its main market will be in Asia, although there would be heavy influence of European market trends as far as competition in the market is concerned.

In the early stage of this Study, the economic evaluation has been carried out with a price scenario established on the basis of observations obtained by the 2014 fiscal year, whereby the world LNG price was assumed at about $12.00/MMBtu on a CIF basis, around $10.00/MMBtu on an FOB basis after adjusting for ocean freight, and the feed gas price corresponding to the above at about $6.00/MMBtu, with an assumed annual escalation rate of about 2%. However, since the downward trend of the LNG prices in the global market is even accelerating in the recent past, it is considered that this Study will have no choice but to adopt a harsher outlook for the price scenario.



(Source) IEEJ Analysis

Figure 7.1-3 LNG Price Assumptions

In consideration of the above-mentioned circumstances, this Study will from now on use a revised price scenario based on netted back market prices as described below:

The LNG prices in 2015 on a delivered basis for Asia are assumed at about $10.00/MMBtu, around $7.00/MMBtu for Europe, and averaging at about $8.50/MMBtu.

The FOB prices after adjusting for ocean freight are assumed at about $6.50/MMBtu.

The above FOB prices will gradually go up to $10.75/MMBtu by 2030, and to about $11.65/MMBtu by 2040.

For the initial approach of the economic evaluation, feed natural gas price is assumed for all projects examined at 50% of the FOB prices for the relevant LNG trade in discussion.

Table 7.1-1 Natural Gas Price Scenarios

	LNG Delivered Ex-ship			LNG Net Back FOB			Feed Gas		US Henry Hub	
	Asia	Europe	Average	Asia	Europe	Average	60%	50%	IEEJ	EIA
	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu	$/MMBtu
2015	10.00	7.00	8.50	8.00	5.00	6.50	3.90	3.25	2.83	3.69
2020	11.19	10.90	11.04	9.19	8.90	9.04	5.43	4.52	4.40	4.88
2025	12.51	11.20	11.86	10.51	9.20	9.86	5.91	4.93	5.14	5.46
2030	14.00	11.50	12.75	12.00	9.50	10.75	6.45	5.38	6.00	5.69
2035	14.25	12.13	13.19	12.25	10.13	11.19	6.71	5.60	6.80	6.60
2040	14.50	12.80	13.65	12.50	10.80	11.65	6.99	5.83	7.70	7.85
2045	14.99	13.62	14.31	12.99	11.62	12.31	7.38	6.15	8.77	
2050	15.50	14.50	15.00	13.50	12.50	13.00	7.80	6.50	10.00	

(Source) IEEJ Analysis

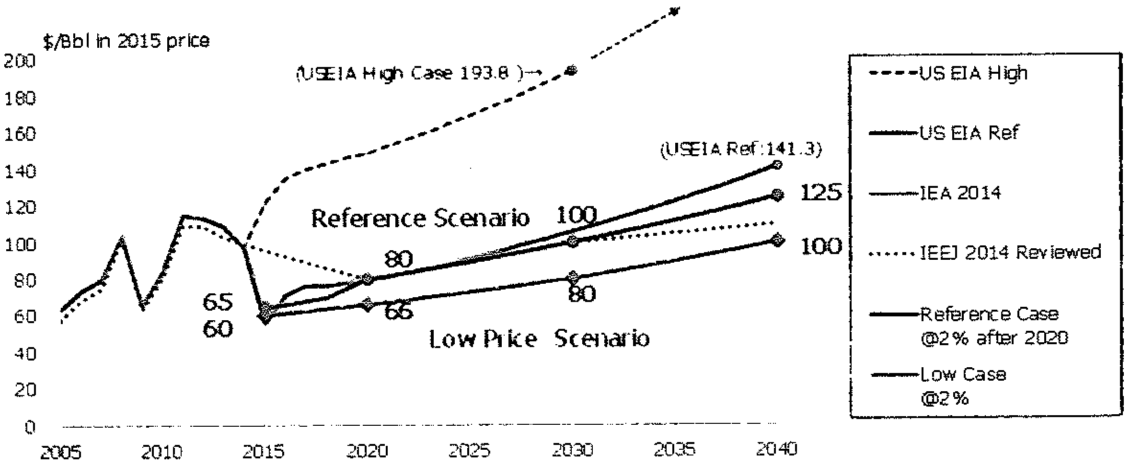
As will be discussed later, for some of the projects that the above feed gas price assumptions appear somewhat challenging. In particular, the revenue sharing percentage between the upstream and the downstream should be considered as a variable to be determined after jointly reviewing the upstream economics and the appropriate formula of the government revenues and based on a balance between the two. It should be noted that a system wherein the price of natural gas as the feed is linked to product prices (such as LNG price, etc.) so that the revenue is shared between the upstream sector and the downstream sector will have an advantage of offering less fluctuating, stable earnings in both sectors compared with a case where a fixed price system will burden either side with the entire price fluctuations in the market.

b. Crude Oil Price Outlook:

Crude oil prices have been substantially affected by the Shale Revolution in the United States and, especially after Saudi Arabia declared in autumn 2014 that it would not take measures against the weak market with production cuts, they have fallen sharply from the previous $100/Bbl levels to a level below the $50/Bbl mark. Although the prices have bounced back somewhat to about $60/Bbl in May, it again dropped to $50/Bbl in the recent past, and the pace of the recovery is still weak for the moment. Although the number of drilling rigs operating in the United States at the end of 2014 declined to nearly one-half of the peak time, it is still difficult to reduce production of tight oil as pressed by factors such as remaining drilling obligations or the fact that many wells that had been drilled are in waiting status for hydro-fracking, making the resilience in crude prices weak. It is viewed that a recovery of crude oil price could drive the tight oil production toward an increasing trend again. Such a tendency may possibly continue until the decrease in the U.S. crude oil imports due to increased tight oil production settles down at a certain level, making it difficult to hope for a significant price recovery for another year or two. However, since crude oil exports from the United States are prohibited, the direct impact of this factor on the international market is expected to weaken after a certain stage of development.

Elsewhere, oil demand generally is sluggish as can be identified by events such as a sign of shadow over China's economy that has so far played a leading role in oil imports, as well as a decline in the new car sales in Southeast Asia.

In view of the above described situation, for the purpose of the present evaluation, the Study will adopt a Reference Case, where the crude oil prices are assumed to recover from the current slump to about $80/Bbl by 2020 but thereafter go up only by 2% or so every year. Further, this Study will also consider a Low Case, where the crude oil prices are to stay in a gradual escalation trend of about 2% per annum from the present level, due to reasons such as a sluggish global economy in the background keeping the slackened state of supply and demand from improving rapidly during the study period.



(Source) IEEJ Analysis

Figure 7.1-4 Oil Price Scenarios

While the Study at this time has adopted the forecast as shown in Table 7.1-2 as the Reference Case, where the crude oil prices are assumed to recover to a $100/Bbl level by around 2030, with respect to the market trend in the cost of construction and operation of facilities related to oil and gas exploration and production, which have kept on soaring reflecting the high oil prices in the past 10 years or so, distinct signs of changes are not yet identified. However, since a fair amount of factors that may dampen the overdriven cost situation can be observed including a sharp decrease in operating rigs in the U.S., or the slowing down of deep-water development in Brazil, it would be also important to carefully watch the trends in the costing situation from now on.

Table 7.1-2 Crude Oil Price Scenarios

Source	IEA 2014	USEIA 2015			IEEJ 2014	IEEJ 2015	
Case	Ref	Ref	High	Low		Ref	Low
	$/Bbl	$/Bbl	$/Bbl	$/Bbl	$/Bbl	$/Bbl	$/Bbl
2015	106.3	55.6	121.5	51.8	95.8	65.0	60.0
2020	113.0	79.1	148.6	57.7	80.0	80.0	66.0
2025	127.0	91.1	169.3	64.2	89.4	89.4	72.7
2030	136.0	105.6	193.8	68.7	100.0	100.0	80.0
2035	145.0	122.2	176.6	72.0	104.9	111.8	89.4
2040	155.0	141.3	197.1	75.5	110.0	125.0	100.0
2045						138.0	110.4
2050						152.4	121.9

c. Petroleum Products Price Outlook

For economic evaluation of GTL, DME and MTG projects, prices of petroleum product as output are necessary. They are projected in relation to the crude oil price as follows.

For assessing grade differentials among petroleum products in the international market, Japan customs clearance data on prices of imported petroleum for the past 15 years since 2000 are used as a large and reliable statistics, results of which are given in Figure 7.1-5.

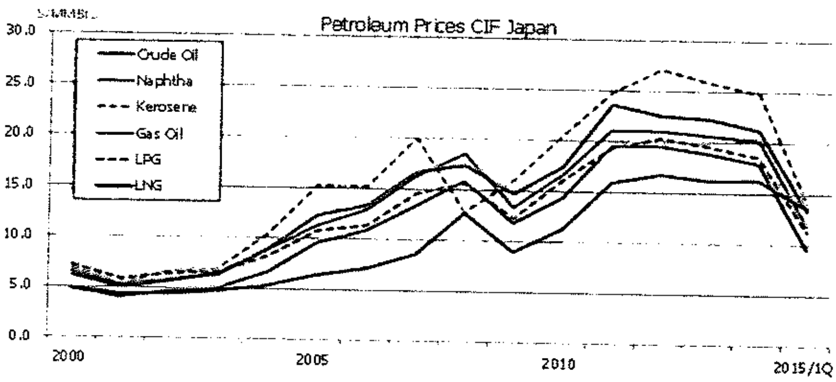


Figure 7.1-5 Grade Differentails in Petroleum Products Prices

From the average figures summarized in Table 7.1-3, value ratios of petroleum products over the crude oil are calculated. However, since motor gasoline is scarcely imported into Japan, gasoline price is derived based on market trends (i.e. the gasoline/diesel price ratio) in Tanzania, and thus assumed at 140% of crude oil in heat value equivalent. Kerosene may be used as jet fuel after some specification adjustments

Table 7.1-3 Value Ratio of Petroleum Products

	Crude Oil	Gasoline	Naphtha	Kerosene	Gas Oil	LPG	LNG
Japan Import	\$/MMBtu	\$/MMBtu	\$/MMBtu	\$/MMBtu	\$/MMBtu	\$/MMBtu	\$/MMBtu
Historical	11.7	N.A.	13.5	15.8	14.2	12.8	9.9
(2000-2015)	100.0%	N.A.	115.8%	135.4%	122.1%	109.6%	84.7%
Import Price	100%	140%	115%	130%	120%	110%	N.A.
Wholesale price (+20%)	(Pivot)	168%	138%	156%	144%	132%	N.A.

On top of the above calculated import prices linked to the changes in crude oil price, a mark-up of 20% is added as the "handling charge and fair profit" for product importers/marketers. Prices so calculated are applied in this study as the ex-refinery wholesale prices of petroleum products. As these numbers adopted here could be somewhat modest, the pricing structure of petroleum products should be looked into more carefully.

7.1.3 Taxation System:

In Tanzania, while tax systems such as the following are implemented, in the economic evaluation of gas projects under this Study, only the income tax and the withholding tax for dividend remittance will be considered:

Income tax: 30%;

Value Added Tax (VAT): 18%, not considered in the Study;

Withholding tax on dividend (=after tax profit) remittance: 10%;

Import duty: not considered in the Study;

Commodity Tax: not considered in the Study;

In Tanzania, various legal institutions such as Export Processing Zone (EPZ) or the Special Economic Zone (SEZ) are established to promote Foreign Direct Investment (FDI), along with a number of other incentive systems. In this Study, on the basis that these programs will also be applied likewise to the gas-related projects, import duties on equipment and other materials for plant construction were excluded from the economic evaluation at this time. Further, although excise taxes such as gasoline tax are levied on energy products in many countries, they are excluded from the evaluation because accurate information about the future taxation policy is not available at present. These points are to be sorted out by the government in the course of actual implementation of the project. In this respect, it can be mentioned that the challenges for the future energy policies will include a review on policy measures such as imposition of special taxes including gasoline tax to protect the related domestic projects, or introducing subsidies, which are funded by the newly set out Revenue Savings Account out of the upstream government revenue under the Oil and Gas revenues Management Act 2015 or the revenues from said special taxes, for development of gas projects and/or promotion of an expanded use of gaseous fuels.

In the current tax systems, depreciation of invested assets is regulated under the following provisions.

In the upstream sector, exploration and development expenditure before production start are booked as intangible asset and be depreciated at annual 20% on the straight line method.

In the downstream sector the diminishing value method is applied with an annual rate of 25%, while a depreciation rate of 37.5% is applied to office equipment or small vehicles and 12.5% to furniture and supplies; a uniform 25% is used in this economic evaluation as the latter are minor in values. Note that mechanisms such as the accelerated amortization depreciation, write-off of the tail-end balance after the lapse of usable life, and the deduction of the residual value (salvage value) of the equipment have not been introduced in Tanzania.

Furthermore, a ten-year tax holiday system is applied in accordance with related laws for companies located in Special Economic Zones. For gas industry projects examined in this study will require a huge amount of investment, and in view of their contribution to the development of national economy, it would be highly advisable to consider application of a similar system. This Study will deal with the use of such a system under a separate case study.

(Sections below containing confidential information are withheld)

7.2. LNG Project

7.3. Fertilizer Plant Project

7.4. Methanol Project

7.5. GTL Project

7.6. DME Project

7.7 Methanol to Gasoline (MTG)

The economic analyses provided above suggest that the huge gas reserves discovered in Tanzania will open up a brilliant future for Tanzania. We should note, however, that the fruits of the gas projects are not hanging low; they can be picked up only after enormous efforts have been paid to successfully launch and operate these projects.

Chapter 8 Upstream Model and Economics

Chapter 8 Upstream Model and Economics

This chapter contains strictly confidential information and is withheld.

Chapter 9 Promotion of Gas Utilization in Tanzania

Chapter 9 Promotion of Gas Utilization in Tanzania

9.1 Domestic Natural Gas Demand

As discussed in Chapter 5, the use of natural gas in Tanzania currently is very limited. The natural gas demand in 2012 was 0.8Mtoe (0.9bcm) and accounted for no more than 4% of the total primary energy supply. Most of the natural gas is consumed in the power generation sector (84%) and the rest in the industrial sector (16%). In the residential and commercial sector, biomass accounts for as much as 98%. Use of LPG as gas fuel has begun although its amount is still minuscule (0.037Mtoe).

However, such energy consumption structure is likely to change drastically in the future. As discussed earlier, along with the opening of large scale pipelines from existing gas fields such as Songo Songo and Mnazi Bay in the summer of 2015, it is expected that natural gas supply from deepwater gas fields in the future will contribute to increase Tanzania's domestic natural gas consumption. The forecast presented in Chapter 5 shows that natural gas will account for 25% of the total primary energy supply in 2045 for the Base Case, driven by population increase (projected to reach 85 million in 2045) and economic growth by 5% to 8% per annum.

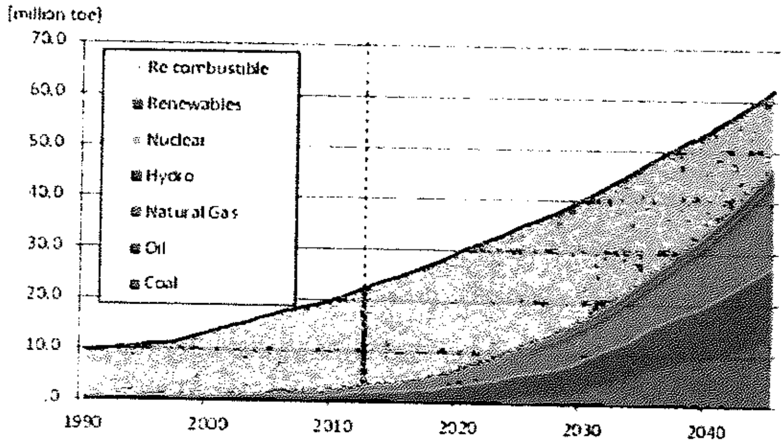
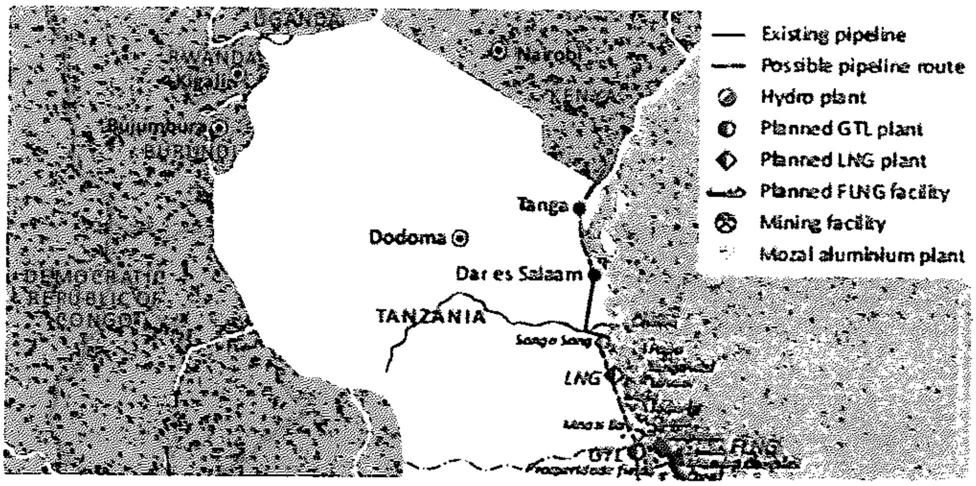


Figure 9.1-1 Primary Energy Supply: Base case

The energy outlook referenced in this Study for the Base Case assumes that the domestic natural gas demand will mainly be driven by power generation and industrial sectors, accounting for 58% and 33% respectively in the total domestic natural gas demand in 2045. Though the natural gas demand in the transport, commercial and residential sectors will be still limited in 2045, making efforts to develop the demand in these sectors is worthwhile from the viewpoint of indigenous resource utilization. In addition, while the major energy source in the commercial and residential sector is still conventional biomass such as firewood and charcoal, as emphasized in the UN Premium Development Plan, promotion of the modern gas fuel is a pressing issue in order to reduce health damage and deforestation caused by the conventional biomass use.

Use of natural gas began in the power plants and factories located along the pipeline running from Songo Songo to Dar es Salaam which was commissioned in 2004. In 2009, CNG vehicles were introduced in Dar es Salaam and currently 60 vehicles are operating. In addition, experimental natural gas supply to 70 households has started in Dar es Salaam albeit in small scale. However, natural gas is not used in other regions.



(Source) IEA, Africa Energy Outlook (2014)

Figure 9.1-2 Gas field and Pipeline in Tanzania

The government of Tanzania announced in its National Natural Gas Plan a policy that domestic use of natural gas shall take priority over export of natural gas ("The Government shall ensure that domestic market is given first priority over the export market in gas supply").[6] To expand the domestic natural gas use beyond power generation and industrial use, it is important to develop more demand in the transport, commercial and residential sectors by constructing an efficient natural gas supply system. In this regard, delivery methods other than pipelines should also be considered for regions located far away from pipelines or having a low density of natural gas demand.

[6] United Republic of Tanzania, "The National Natural Gas Policy of Tanzania – 2013", P.9

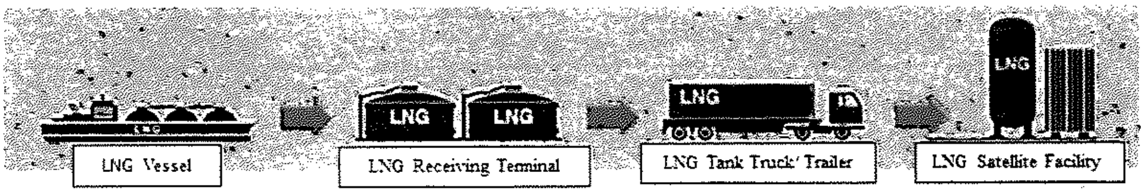
9.2 Options and Economics of Gas Transport

The main method for natural gas transportation is pipeline all over the world. However, there are some remote areas where the expensive pipeline investment is uneconomical due to the demand size and the distance to the point of consumption. As an alternative means of transportation for these areas, LNG is moved in liquid form by tank trucks to a secondary terminal called a satellite station where the LNG is regasified for supply via piping service. This section examines the economics of an LNG satellite system using tank trucks, railroad tank containers, or marine vessel operations in comparison with the pipeline transportation system.

The discussions and data in this section are mainly based on examples in Japan, where such LNG delivery systems as above have been in actual use. Note further that information contained herein is of preliminary nature and may be amended, altered or otherwise modified at a later date.

9.2.1 LNG Tank Truck Supply

Figure 9.2-1 shows an LNG tank truck supply system. LNG transported by an LNG tanker is stored in storage tanks at a receiving terminal. Subsequently, LNG is transported to remote areas by tank trucks, stored in storage tanks at an LNG satellite facility, and sent to end users after LNG is regasified.



(Source) http://www.awi.co.jp/business/energy/equipment/lngsatellite.html

Figure 9.2-1 LNG Tank Truck Supply System

9.2.2 LNG Tank Truck

Figure 9.2-2 shows an LNG tank truck with a 15.1 tonne (18,420 m3) payload. The LNG tank truck loads LNG at a special loading facility and transports its cargo to remote areas. In Japan, such a tank truck is designed, manufactured, inspected, and maintained under the provisions of the High Pressure Gas Safety Act. The LNG tank trucks are operated by qualified organizations and individuals in accordance with stringent safety rules and regulations.

(Source) http://www.tng-gas.co.jp/lng.html

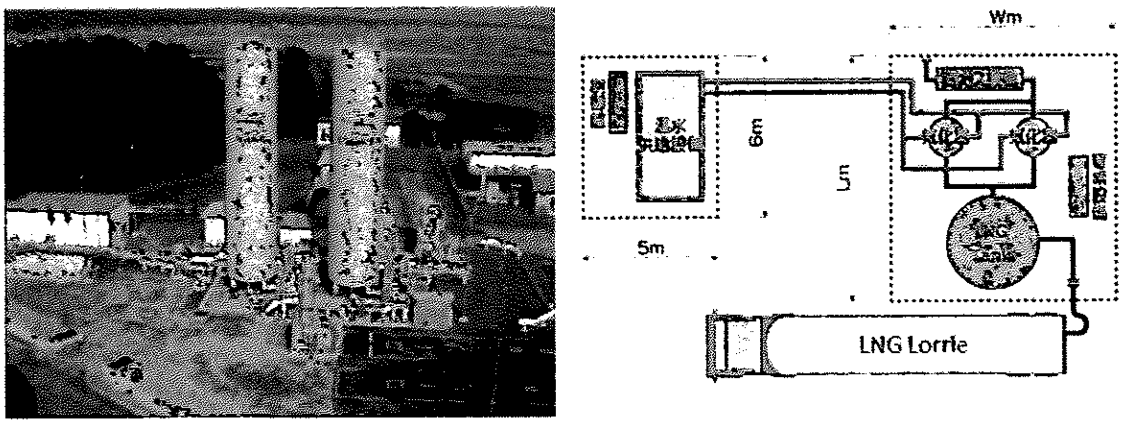
Figure 9.2-2 LNG Tank Truck (15.1 tonne)

9.2.3 LNG Satellite Facility

(1) General

Figure 9.2-3 is a general layout of an LNG satellite facility. Such a facility is developed to enable use of LNG in remote areas where pipelines are not accessible. An LNG satellite facility is a secondary LNG receiving terminal, and since a number of such terminals can be laid out around a main terminal like satellites, hence the name of the satellite facility. An LNG satellite facility consists of LNG tank(s) and vaporizer(s), with a land requirement of 400m2 which is much smaller than a main LNG terminal.

Table 9.2-3 shows specifications of LNG satellite facility. These facilities are designed for supply of 1,000 – 8,000 tonnes of LNG demand per annum, where 1,000 tonnes of LNG can serve 7,000 households in Japan for one year.



(Source) http://www.jfe-eng.co.jp/products/energy/energy_plant/ene03.html

Figure 9.2-3 Layout of LNG Satellite Facility

9.2.4 Cost Comparison between Pipelines and LNG Satellite System

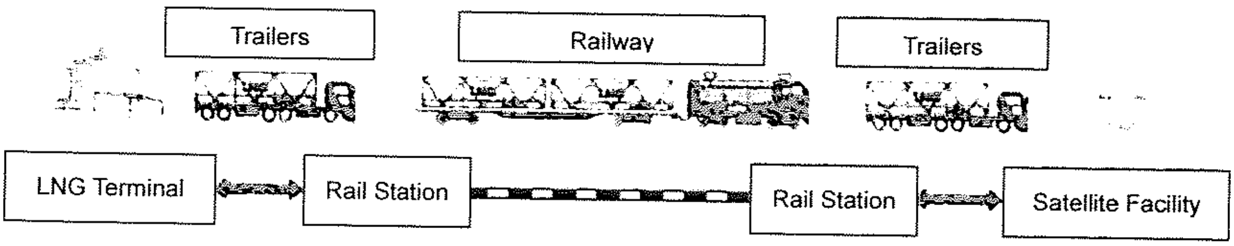
(This section is withheld as it contains confidential information.)

9.2.5 Other Transportation Mode – potential and challenges

This section considers the potential and challenges of railway and small marine vessels as alternative transportation modes of natural gas in comparison to the pipeline or the tank trucks, referring to commercialized cases in Japan.

(1) Railway

Other than pipelines and tank trucks, railways are an option to transport natural gas on land. Like LNG tankers, it is practical to transport natural gas by rail in the form of LNG rather than in gaseous state from the point of volume reduction. If the railway is in place right from a liquefaction plant to a demand site, LNG can be transported by rail for the entire transportation route. However, mismatch between the railway route and the supply/demand location is often the case. Therefore, in the case of Japan, LNG containers are transported by trailers from an LNG terminal to the originating railway station, and transferred by rail to the destination station, and again by trailers to a satellite facility near demand sites. At originating and destination stations, an LNG container is handled by elevating equipment called a trip lifter.



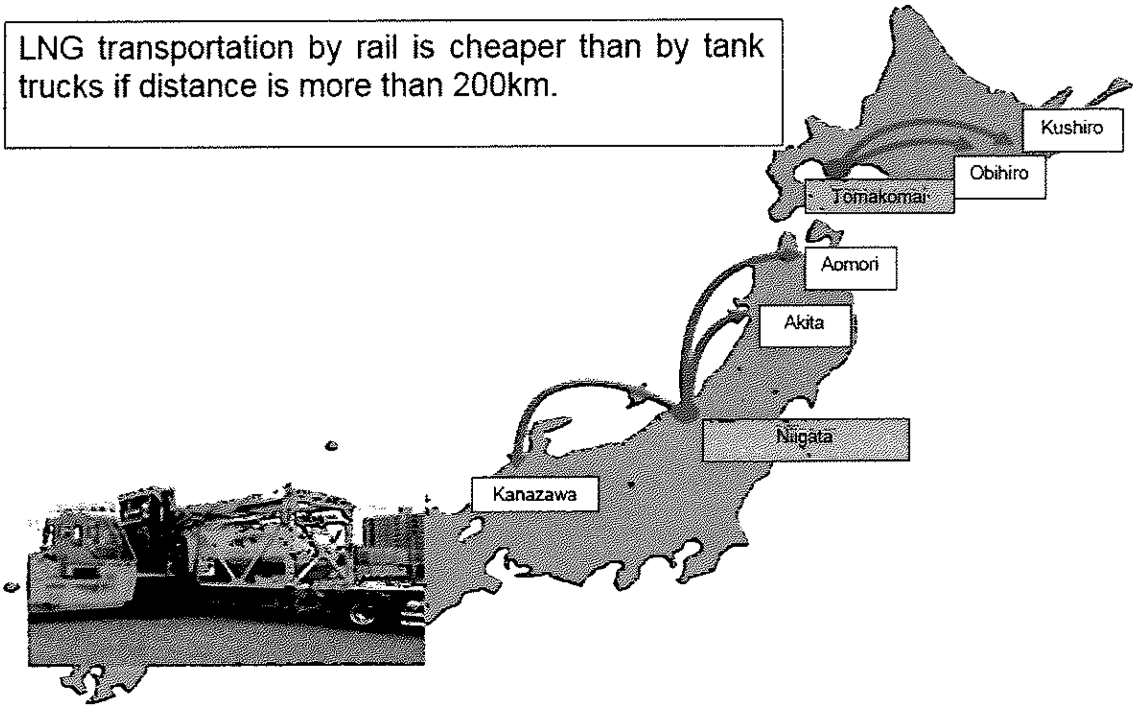
(Source) Japan Freight Railway http://www.jrfreight.co.jp/transport/service/lng.html

Figure 9.2-5 Concept of LNG rail transportation

According to Japan Petroleum Exploration Company (JAPEX), rail LNG transportation is competitive in the case of long-haul transport[7], although it is not clear at which distance railways become competitive over tank trucks. Japan Freight Railway Company states that rail LNG transportation is cheaper than via tank trucks if the distance is greater than 200km, albeit

[7] Masao Toyosaki, "LNG Satellite Supply – Introduction to onshore transportation and small scale natural gas liquefaction,
Journal of the Japanese Association for Petroleum Technology, Vol. 73, No. 2, March, 2008

without defining conditions such as quantities or frequencies. Meanwhile, Ocean Policy Research Foundation (OPRF) reports that railways can be competitive in LNG transportation if the distance exceeds 200-300km[8]. To underline this, the actual distance of rail LNG transportation routes currently in operation in Japan are all exceeding 200km, such as from Niigata to Kanazawa (340km) / Akita (270km) / Aomori (450km), or from Tomakomai to Obihiro (200km) / Kushiro (320km).



(Source) Japan Freight Railway http://www.jrfreight.co.jp/transport/service/lng.html

Figure 9.2-6 Railway LNG transportation routes in Japan

Generally speaking, in the case of onshore natural gas transportation, the longer the distance is and the more demand is in place, the more competitive pipelines become as a transportation mode. LNG tank trucks tend to be cheaper in the opposite case. The competitiveness of rail transport falls somewhere in between although detailed assessment is required concerning the route and demand size to determine the exact cost break-even point.

The JAPEX report cited above finds that the key requirements for the rail LNG transportation

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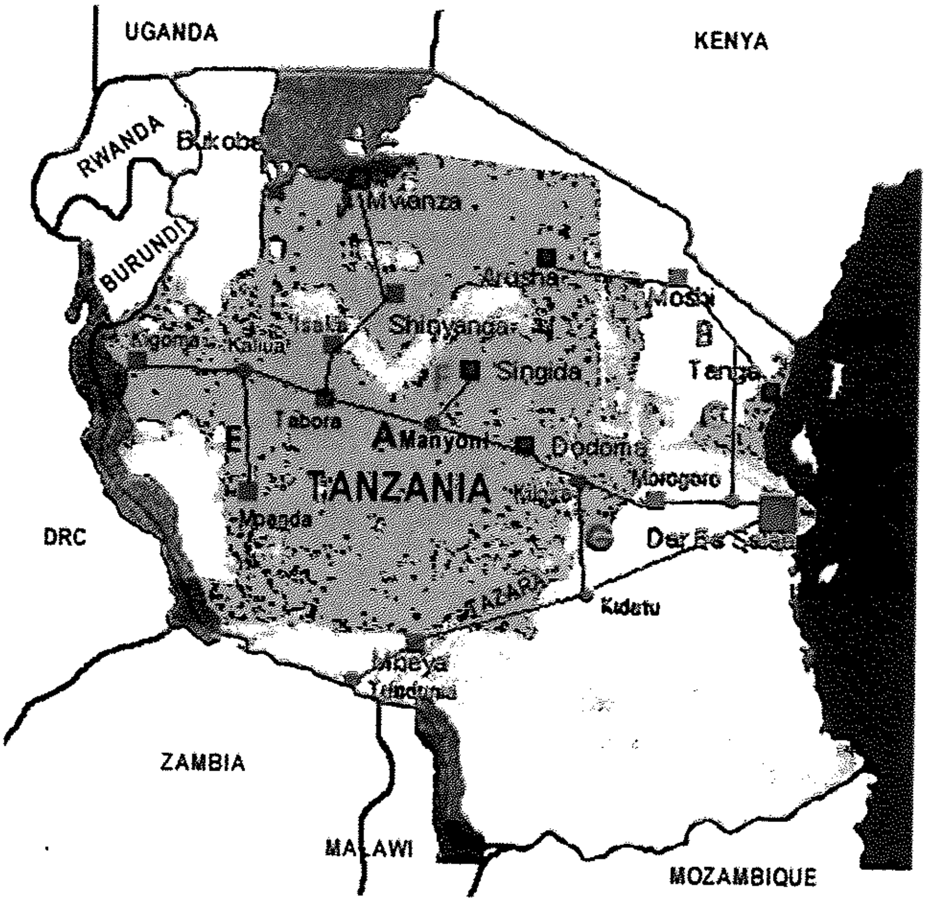
[8] Ocean Policy Research Foundation, "Study report on developing short distance natural gas transportation system, 2009, https://www.sof.or.jp/jp/report/pdf/201003_ISBN978_4_88404_240_0.pdf

are the rail service availability, loading/unloading spaces, and an adequate trip lifter deployment. Additionally, in the case of Tanzania, it is necessary to examine the extent of railway infrastructure development. Railway is not laid from/to Mtwara area where the offshore natural gas is likely to be landed calling for a study if the railway LNG transportation on existing train lines can be more practical. Meanwhile, taking underdeveloped state of Tanzanian roads into consideration, it is conceivable that existing railways if available could provide a more economical option to transport natural gas.



(Source) Tanzania Railways http://www.ntz.info/gen/b00630.html

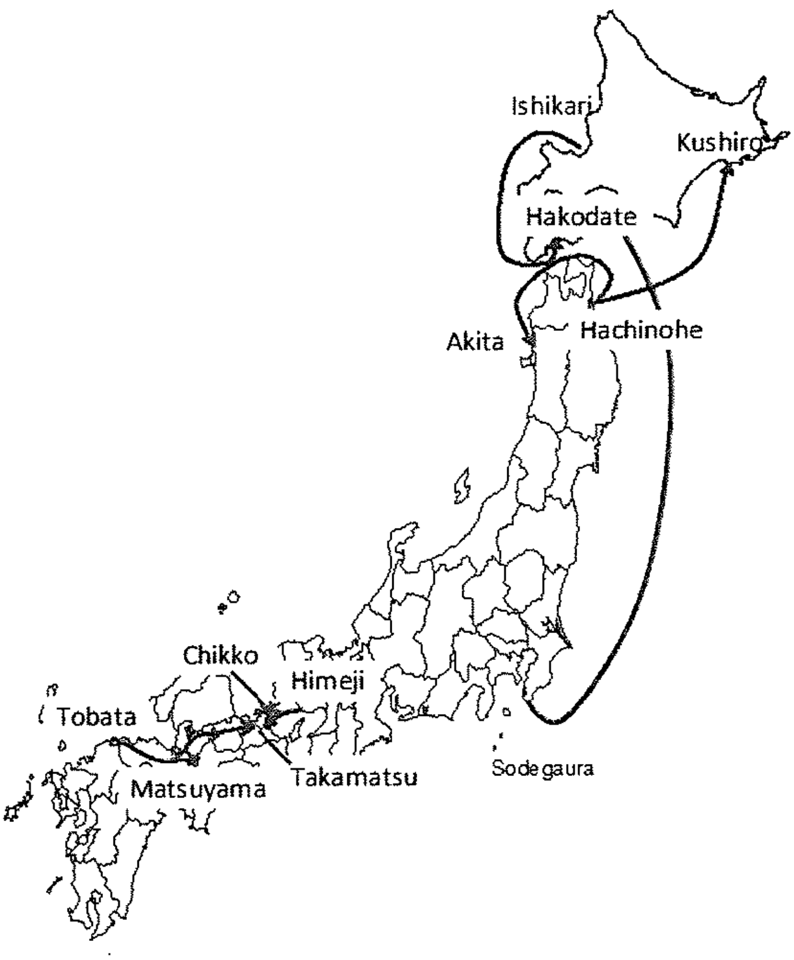
Figure 9.2-7 Railways in Tanzania

(2) Small vessel/coastal tankers

While international LNG transportation is conducted by large tankers with capacities ranging

130,000-270,000m3 (59.000-122,000 tonnes), small tankers are available to supplement the domestic LNG transportation as alternative to pipelines, tank trucks, or railways. Small scale tankers with 1,000-30,000m3 (5,000-14,000 tonnes) of capacity are utilized in Japan, China, and Baltic Sea Region.

In Japan, specially built coastal tankers have been in use to domestically transfer LNG since 2003. LNG is shipped from import terminals such as Ishikari, Hachinohe, Himeji, and Tobata to secondary terminals located in Kushiro, Akita, Chikko, Takamatsu, and Matsuyama. While transportation distance varies significantly from 50km (Himeji to Chikko) to 850km (Sodegaura to Hakodate)[9], small scale LNG tankers become competitive for a distance of 200km or longer[10].



(Source) Company websites

Figure 9.2-8 LNG shipping route in Japan

[9] However, LNG no longer is transported from Sodegaura to Hakodate.

[10] Ibid, P63

In Japan, currently six coastal tankers are operated for domestic transfer of LNG. Their capacity is in the range of 2,500-3,500m^3(1,100-1,600tonnes) as given below.

Table 9.2-9 LNG Vessels in Japan

Built	Vessel Name	Capacity (m^3)	Owner	Shipping Route
2003	Shiju Maru No.1	2,513	NS United Tanker	Tobata/Himeji <-> Chikko/Takamatsu/Matsuyama
2005	North Pioneer	2,512	Japan Liquid Gas	Ishikari <-> Hakodate
2008	Kakurei Maru	2,536	Tsurumi Sunmarine	Not specified
2008	Shiju Maru No.2	2,536	NS United Tanker	Tobata/Himeji <-> Chikko/Takamatsu/Matsuyama
2011	Akebono Maru	3,556	NS United Tanker	Not specified
2013	Kakuyu Maru	2,538	Tsurumi Sunmarine	Not specified

(Source) GIIGNL, Ocean Policy Research Foundation

In an LNG importing country like Japan, domestic sea LNG transport requires, in addition to coastal tankers, the loading arm at the LNG import terminal, and receiving terminals equipped with berth, unloading arm, LNG tank(s), and the regasification facility , as well as pipelines and/or tank trucks to deliver LNG to demand sites.

Considering a pipeline system is already in place between Mtwara and Dar es Salaam, domestic LNG transportation by coastal tankers could be feasible between Mtwara and Tanga. It is desirable to examine potential natural gas demand in Tanga area and investment required to assess the economics of the project.

9.3 Way Forward

In order to promote domestic natural gas expansion, it is necessary to develop a natural gas supply system. When natural gas is supplied to remote areas, there are several options such as pipelines, trucks, railway, or coastal tankers. If the distance is long and the demand is large, pipeline is economical. If the distance is short and the demand is small, trucks are economical. However, in case a railway network and port facilities have already been developed in the country, sometimes railway containers or coastal tankers are more economical than others.

Based on analysis in this chapter, if demand is less than 1,000 tonnes, LNG tank truck system is more economical than others. On the other hand, pipeline transport system is economical if annual LNG consumption is 80,000 tonne or more with transportation distance of 150km and annual LNG consumption is 200,000 tonne or more with transportation distance of 500km. However, to promote natural gas usage in Tanzania, not only economic aspect but also social policy such as city development plan and regional development plan shall be considered.

As shown in Chapter 5 of this report, natural gas demand in 2045 in Base Case will reach 6,628ktoe (7.4 Bcm or 5.1 million tonnes in LNG equivalent). This forecast is made by a macro-econometric approach, wherein geographical conditions, industrial structure, and infrastructures are not considered.

In Tanzania, in addition to Dar es Salaam there are 11 large cities with population of one million or more such as Shinyanga, Mwanza, Mtwara, etc. On the other hand, gas pipeline is only installed between Mtwara and Dar es Salaam at present. Trunk road among big cities is still developing. Total length of road in Tanzania reaches 12,786 km, of which 7,656 km is unpaved road.[11] In Tanzania, there are railway network among big cities. But there is no railway system reaching Lindi and Mtwara as the envisaged gas supply bases. While Tanga in the northern part of Tanzania has port facilities, it is still unclear if construction of LNG receiving terminal at Tanga is feasible or not. To promote domestic gas demand in Tanzania, it is necessary to examine optimal transportation system designed for natural gas development.

[11] Ministry of Works, "National Road Network", http://www.mow.go.tz/index.php/sectors/national-road-network

Chapter 10 Project Formation and Human Resources

Chapter 10 Project Formation and Human Resources

In order to materialize the benefits of the huge gas discovery, Tanzania needs to construct gas industries virtually from scratch. In this chapter, the Study Team will illustrate an example of how an LNG project will be formed, constructed and operated. We will also look into the matters relating to organization, workforce, and human capacity development to promote natural gas utilization.

10.1 Formation of LNG Project

10.1.1 LNG Value Chain

The main pillars of an LNG value chain are gas fields, LNG plant and customers; gas pipelines, LNG tankers and receiving terminals physically connect them. They are all necessary to materialize the benefits to be brought about by natural gas. Building such a value chain calls for sophisticated technology, huge fund, skilled workforce, world-class business management and marketing ability, and internationally acceptable laws and regulations. All of them must be developed in a coherent manner, though the world LNG market has become flexible while expansion of supply base and commoditization of LNG have progressed in recent years.

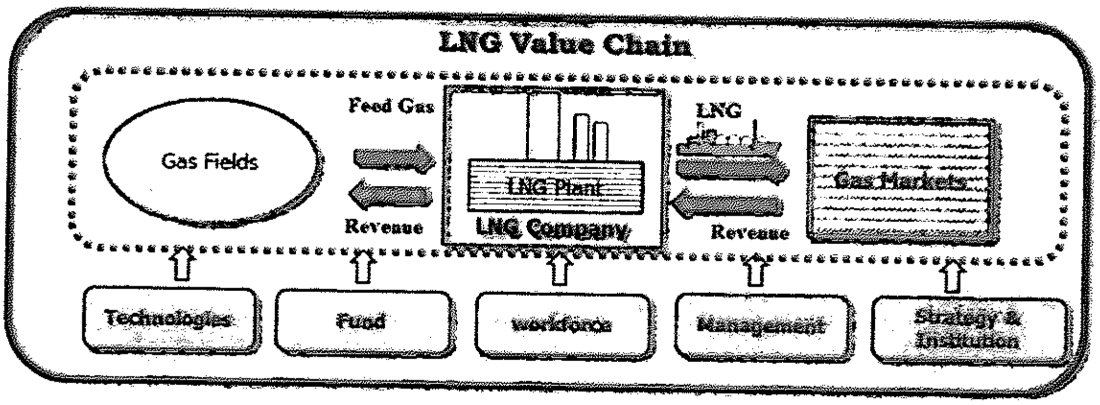


Figure 10.1-1 LNG Value Chain

Once a large-scale natural gas discovery is made and LNG is identified to be the solution to commercialize the reserves, the project structure and commercial terms for the LNG development shall be agreed among the Government and all the PSA partners ("Framework Agreement") and an implementation body of the project needs to be established based on the Framework Agreement as soon as possible. In general, it is a joint venture company of stakeholders like a "Tanzania LNG Company", which has well-defined legal status to conduct international business. There are some exceptions in the world. For example, in some cases, the entire LNG businesses among supply chain are covered by the upstream PSA including construction and operation of an LNG plant ("Integrated Model"). In some other cases, the liquefaction plant and the associated infrastructures are structured outside of the upstream PSA scope, and a separate infrastructure entity provides the services to the upstream gas owner on a tariff basis ("Tolling Model"). Under the Tolling Model, the equity positions of the LNG Plant and the associated infrastructure shall ideally be kept identical with that of the upstream consortium in order to minimize the conflicts between the entities. It should be noted that an Integrated Model, including relevant economic models, is adopted as an assumption for this study with a view to simplifying the discussion. For the avoidance of doubt, the Study Team does not have any specific intention to promote one of the structures described herein. LNG commercialization structure needs to be carefully discussed among the stakeholders to enable the Project to fly on schedule, with consideration of both financing and LNG marketing.

10.1.2 Formation of an LNG Project

An LNG project starts with a discovery of sufficiently sizable gas reserves. As discussed in Chapter 5 and 7, a standard size of LNG plant today is 5 million tonnes per annum (MTPA). A multiple train project may be favorable for stable business operation. A 5-MTPA plant consumes about 5 Tcf of natural gas over a 20 year operation. If two trains are to be built, the threshold of gas reserves for an LNG project may be 10 Tcf or more. Because LNG requires a sophisticated technology while capital intensive, not all of the upstream participants would be interested in the downstream business. Smaller companies specializing in oil exploration may prefer to farm out such discoveries. On the other hand, participation of the host government is a hard issue to accommodate. In many cases the host government is not equipped with expertise, technology and fund, while national enthusiasm to use natural gas for domestic development may become high. These issues must be solved harmoniously in the Framework Agreement.

The process of forming an LNG project is illustrated in Figure 10.1-2. Once a gas discovery is made, a feasibility study will be conducted to examine the possibility of an LNG project from the viewpoints of gas reserves and gas field development economics, candidate LNG plant site, technology selection, and the plant economics. This is followed by studies on financing and marketing. The biggest question at this stage is the project bankability and the prospect of LNG marketing; if sufficient amount of sale could be secured and if the prevailing market price would be good enough to justify the project. When the project seeks for loan, financial institutions examine if the project is bankable in terms of available gas reserves, experience and competence of the project promoters and secured long term sales. They will generally require a third party certificate of the gas reserves and the basic agreements on long term LNG sales contracts, or offtake underwritten in proportion to equity holding share of PSA contractors ("Equity Lifting Scheme").

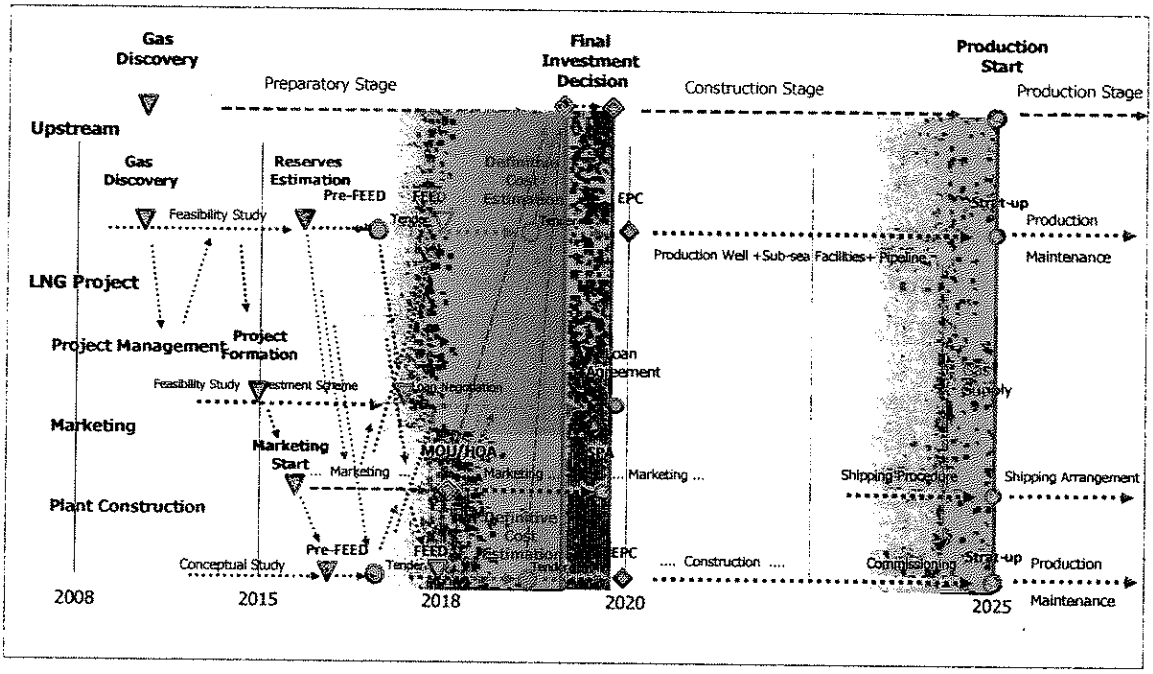


Figure 10.1-2 Process of LNG Project Formation

Marketing is a lengthy activity as LNG is often called a long negotiation game, and it is getting more competitive given that current LNG market is so called "bearish market". Generally this process takes 3-5 years pending the global market condition. There are mainly two types of marketing formation as follows:

a) Joint Marketing

Project partners organize a joint venture LNG company ("JVC"), wherein the JVC will be responsible for the marketing. Project partners may second staff and provide advice, guidance and support to the JVC. All business risks and proceeds shall be equally shared among the project partners through the activities of the JVC. This is the traditional approach, but is recently less favored by the industrial players as well as the LNG market due to its inelasticity for reaching consensus on commercial and operational decisions amongst project partners.

b) Equity Lifting

Project partners form a joint venture liquefaction company to construct and operate the liquefaction plant and the utility facilities, but the JVC will not handle the LNG marketing. Each sponsor will handle the marketing and shipping for its own entitlement of gas under the production sharing agreement. The JVC may receive a tolling fee for the transportation, processing and liquefaction of the gas.

In taking up the joint marketing formation, the JVC will endeavor to secure certain amount of long term contracts as the anchor demand for the project. To achieve this, the JVC must demonstrate its capability and establish fair reputation in the market. This process may take time and the investment decisions could be rigidly tied to the timing for execution of certain LNG contracts. In the case of the equity lifting formation, the equity portion of IOCs will be disposed of through their international networks. This process may be much faster and flexible. However, since national marketing expertise is yet to be developed, how to handle the national portion of natural gas will be an issue to be discussed among the Government and other equity partners.

At any rate, certain prospects on LNG sale and offtake must be established for confirmation of an LNG project. The reason that Equity Lifting has been prevailing in the recent market is that the investment decisions would not necessarily be influenced by progress in marketing as each equity holders provide assurance to financing lenders for the offtake commitment. Additionally, the lengthy due diligence required by Financing Institutions which normally takes more than six months will be significantly shortened in comparison with the Joint Marketing. However such benefit could only be expected by the project that has credible IOCs with track record as equity offtakers. Policy on the marketing formation must be established reviewing pros and cons of the systems discussed above.

In considering marketing, one should also take note of the immense size of the LNG business. Gas consumption by a world-class combined cycle gas turbine (CCGT) power plant with a generating capacity of 1,000 MW will amount to 1 million tonnes of LNG a year, or slightly less with the recent improvements in generation efficiency. To sell 10 million tonnes of LNG a year, therefore, the seller needs to find buyers with requirement totaling 10 of the above-mentioned power plants or an equivalent. To receive 10 million tonnes of LNG, the buyers must also make a huge investment in developing their facilities, and wait demand build-up before they reach the full capacity operation.

This, while not an easy task, requires extensive marketing efforts during the preparatory stage under Joint Marketing Scheme. The work schedule developed in Figure 10.1-2 looks very tight before some basic agreement on LNG sale, such as Memorandum of Understanding (MOU) or Heads of Agreement (HOA), is reached. The basic agreement sets forth fundamental items such as sale/purchase quantity, duration, pricing formula, flexibility, etc. After the basic agreement is set out, Sales and Purchase Agreement (SPA) should be negotiated and agreed upon concerning the detail conditions of transaction before the final investment decision. On the other hand, effectively taking advantage of offtake and market assurance by IOCs under Equity Lifting Scheme will shorten the time and lessen the effort for those pre-FID preparatory stages.

To start the preparatory work, the project framework including project structures and fiscal terms should be discussed and agreed between the Government and IOCs. It is desirable to establish an LNG project implementing body and announce it to the world at a soonest possible timing when the discovery is confirmed sizable enough. The circumstance may be very uncertain at this beginning. However, delicate issues such as site selection, marketing and financing policy must be handled firmly by a clear and responsible entity. Confidential information and strategy must also be handled under tight control.. Even if a project is yet to be confirmed, establishment of an implementing body such as a Tanzania LNG Company will enhance elements such as the following:

Market recognition that a new LNG project is coming up. Potential buyers may be interested and put the project on their suppliers list. This is the very important first step to kick-off marketing of LNG.

Readiness of financial institution to negotiate for loan arrangement. In particular, if national participation is desirable, the government should prepare the fund for investment. International financial institutions are generally in favor of promoting a good LNG project, while they request firm information and liability.

Engineering companies' listing of projects. The number of high class engineering companies in the world who are capable of constructing LNG plants as EPC contractor is limited. Their recognition of the project is important to set the construction schedule as desired.

During this period, marketing activities should be extensively promoted to secure sufficient buyers. Sales and pricing negotiation is a very important business during this stage. Extensive due diligence and negotiation on loan arrangement with Financing Institutions, if necessary, should also be made. Feasibility studies will be conducted repeatedly with input of latest information, including Pre-FEED in the later stage. Site selection and environment impact assessment (EIA) are the important procedures for confirmation of plant construction. Once certain prospects are established on the matters of gas reserves, project economics, as well as LNG marketing and financing, project partners may agree to take a step forward with the project.

The project goes into a construction phase. The front end engineering and design (FEED) will be tendered and conducted. Evaluating the definitive cost estimation by the FEED, the project partners make the final investment decision (FID). The project is actually given birth then.

Tender documents will be prepared to select an engineering, procurement and construction (EPC) contractor and bid will be invited. The tenders submitted are evaluated and the EPC contractor is selected. Now everything is all set for the construction start. This FEED/tender process usually takes two years including procedures for various governmental approvals.

As discussed in Chapter 7, construction will typically take five years from the EPC contract award to completion. In addition to plant construction, detail arrangements with buyers should be prepared during this period in relation to shipping and trading procedures.

10.2 Function and Organization of the LNG Company

To implement the tasks explained in Figure 10.1-2 in the early stage of the project, the project implementing body or the LNG Company may need to have a Steering Committee, an Implementation Team and various subcommittees responsible for technical, financing, and marketing issues, as well as the environment and social monitoring system ("EMS"). Project formation and feasibility studies, site selection, EIA, marketing and financing will be extensively worked out by them. Depending on external circumstance and the team competence, consultants and marketing agencies may be hired. In the case Equity Lifting formation is adopted, all non-government project partners may handle the national portion of natural gas being liquefied on a prorated basis, as a realistic approach.

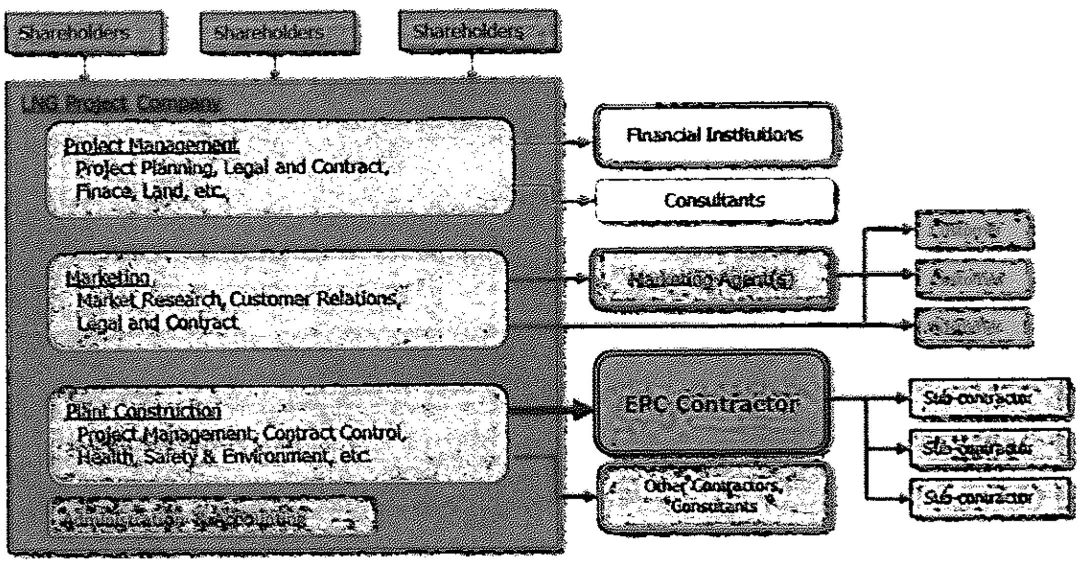


Figure 10.2-1 Organization of LNG Company: Construction Phase

Once the project implementation is confirmed, a Plant Construction Team will be added. There are two types of construction contract; i.e. Reimburse Contract and Lump-sum Turn-key Contract. In the case of the reimburse contract, the project owners' team will be a large organization and control every aspect of the construction work. In the case of the lump-sum turn-key contract, which is popular in LNG plant construction, it will be much slimmer and take a role of mainly overseeing the work progress. Conversely, reimburse contracts are popular in the upstream where work types are diverse and various risks are high.

The Plant Construction Team will look after the project from the owner's side and will work closely with the EPC contractor, who will actually build the plant. The collaboration between the project owner's team and the EPC contractor is very important for an efficient project implementation. There will be other contractors and consultants to work for the issues not covered by the EPC contractor, such as environment impact analysis (EIA).

As explained later, construction of an LNG plant needs to mobilize a considerable number of workforce directly engaged in the construction. This will accompany substantial spin-off effects on the national economy and in particular in the construction site area. Such spin-off effects are not considered yet in the economic outlook adopted in this Study or any other economic plans. Once an LNG project is confirmed, other relevant plans must be reviewed considering effects on the every corner of the economy.

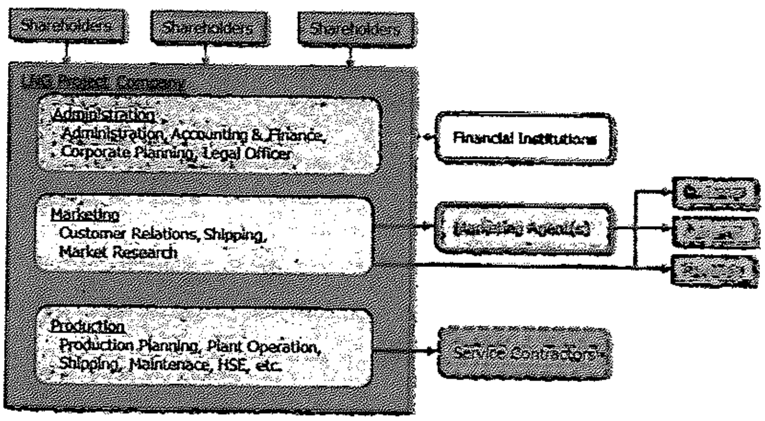


Figure 10.2-2 Organization of LNG Company: Production Phase

In the later stage of the construction period about two years prior to production start, plant operators will be employed and trained. On the marketing side, shipping and trading staff will be employed and trained. Detail shipping and transactional procedures must be worked out and agreed upon with LNG buyers during this stage.

Once the plant construction completes and production starts, the organization will become substantially slimmer as shown in Figure 10.2-2. The construction team will be replaced by the production team; their main assignments are production planning, plant operation and control, shipping operation, regular maintenance and safety, etc. Safe and stable operation of the plant is the major task of the team, while a smaller team is allocated for plant operation as modern plants are widely automated. At the time of major maintenance work including plant shut-downs, additional technical staff and services will be temporarily out-sourced. The job of the marketing team will be mainly comprising shipping procedures, regular correspondence with buyers or equity offtakers on the LNG shipping and collection, and periodical negotiations on contract volume and pricing. Job of financing may be replaced with a regular loan repayment handled by the accounting department.

10.3 LNG Plant Construction: Organization and Workforce

Construction of an LNG plant will be implemented by a joint team of the project owner and the EPC contractor, who needs to mobilize the workforce on a broad scale.. In this section, we will look into the organization and workforce requirement during the plant construction stage.

10.3.1 Execution Philosophy and Manpower Mobilization

In preparation for the LNG plant construction plan, an execution strategy should be established and optimized based on the nature and characteristics of the project such as location and plant type. The following are the key items to be considered at this stage:

Site development
Consideration of off-site fabrication activities (prefabrication and pre-assembly)
Mobilization of workforces
Handling of heavy construction equipment
Early establishment of camp infrastructure and temporary facilities
Early reflection of construction and commissioning in the design phase

LNG operators place the utmost importance on the timely and efficient completion of a reliable plant that will be operational over the planned project period. Achieving this objective, one of the key strategies is to put appropriate considerations into the construction and commissioning sequences even from the early engineering phases. When multiple trains are to be constructed, it is generally considered to be most efficient if each workforce will shift to the next train with a six month interval. If the work interval is much longer, such as examined for the 4-train case where the phase two plants will be built five years later, the job consolidation effects could not be expected much.

It is also anticipated that shortage would occur on competent construction resources, such as experienced supervisory staff, skilled labor, construction materials and equipment, risk success expertize in the projects, etc. In order to avoid risks and their adverse effects caused by such shortage, proper upfront planning is also very important.

Qualified and experienced subcontractors will be employed to perform the construction under the management and direction of the EPC contractor. The scopes and sizes of the subcontract packages should be based on a realistic analysis of the capacities of the subcontractors in order to implement such scopes in accordance with relevant plans.

10.3.2 Manpower and Construction Equipment Mobilization Plan

The following plans should be developed during the FEED stage:

Manpower mobilization plan

Construction equipment procurement plan

To develop a practical and realistic manpower mobilization plan, distribution of resources to be mobilized during the construction period must be considered by the EPC contractor. To level off the peak manpower and construction equipment required, the construction sequence and the methods must be considered.

10.3.3 Organization and Responsibility

The construction management typically consists of two phases, the construction planning organization in the Home Office and the construction execution organization on the Site.

a. Site Construction Organization

In order to make the site construction organization functional, a site manager will be elected assuming the full responsibility for the overall control of the entire team. Under the Site Manager, various divisions are normally organized, including Construction Management (Area Construction Managers and Discipline Section Managers), Health, Safety, Environmental and Security Management, SIMOPS(simultaneous operations) Coordination, Business and Administration Management, Pre-Commissioning Management, Quality Assurance/Quality Control Management, Field Engineering Management, Material Management, Construction Support Services Management, Site Project Control Management, and Subcontract Management.

Most of the site management staff will move to the site after the establishment of the execution planning and the issuance of the execution procedures.

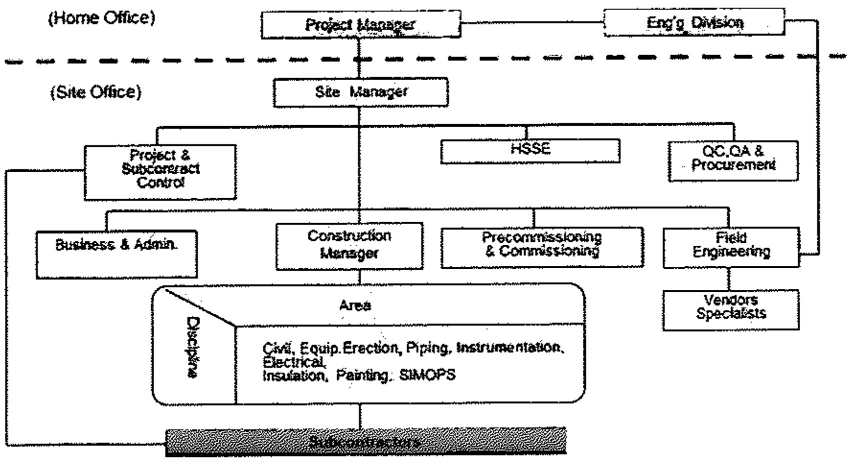


Figure 10.3-1 Plant Construction Site Organization

b. Staff Mobilization

It is necessary that competent construction staff who are able to provide professional services should be mobilized at the construction site so as to support and supervise the construction activities. In the construction planning phase, it is required to plan mobilization and demobilization to ensure that sufficient human resources are available to support the schedule requirements.

Recruitment of local human resources is one of the key factors for successful execution of the construction. If not locally available, they have to be mobilized from other parts of the country or even from abroad.

Personnel should participate in the project prior to transfer to the site to ensure familiarity with the information and requirements of the project. In particular, all key personnel need to be assigned to the project team prior to site mobilization to familiarize themselves with the following and to participate in constructability reviews:

Objectives, goals and scope of the project

Project specific drawings and procedures

Detailed schedule of construction activities

c. Subcontracting Strategy

In principle, a multiple subcontract formation is employed for execution of a project. In the planning stage, capabilities and availability of potential local construction contractors in the region should be assessed carefully. Because of quality and technical reasons, specialized contractors will be required for certain types of construction work such as special welding, hookup, measurement system, etc.

The EPC contractor selected should be fully responsible for the workforce including subcontractors in order to deliver the project successfully, working closely with the project owner's management team. As some 7,000-10,000 workforce is envisaged on site at the peak time, qualification of the EPC contractor will be one of the key factors to success in management of a technically complex project executed within budget and schedule, while satisfying international class safety and quality requirements.

d. Envisaged Staff Loading

In a large scale greenfield LNG project requiring the workforce of 7,000 – 10,000 on site at the peak time, indicative headcounts over the project period are shown for typical construction activities in the table below, which is based on the experiences of the Japanese engineering companies in planning and implementation of LNG projects of a similar size located in a remote location. Proportions of non-skilled workers are relatively high in civil, painting and insulation activities, and others require technical specialties:

Table 10.3-1 Headcounts for LNG Plant Construction

Construction Activities	Indicative Headcounts (*)
Site Preparation and marine construction	3,000 - 4,000
Civil and Building	3,500 - 5,000
Steel Structure	1,500 - 2,000
Piping and equipment erections	500 - 1,000
Electrical and Instrumentation	500 - 1,000
Painting and Insulation	1,500 - 2,000
Tankage	500 - 1,000

Note: Numbers vary significantly due to the defined scopes of activities, especially in the site preparation and marine constructions. For more detail manning plan, please refer to the economic model.

Table 10.3-2 shows the headcounts for the construction team of the project owner for the 2-train case. Those staff to be engaged in the operation may be employed in the later stage of construction and receive one year training before production starts.

Table 10.3-2 Headcounts for Project Owner

Management	2
Senior Manager	3
Manager	5
Senior Engineer	10
Engineer	50
Operation Manager	10
Senior Operator	20
Operator/Technician	300
Administration	10
Total	410

10.4 LNG Operation and Organization Philosophy

10.4.1 Organization in Production Phase

In addition to the project headquarter discussed in Section 10.2, the operation organization for the commercially operating LNG Plant is illustrated in Figure 10.4-1.

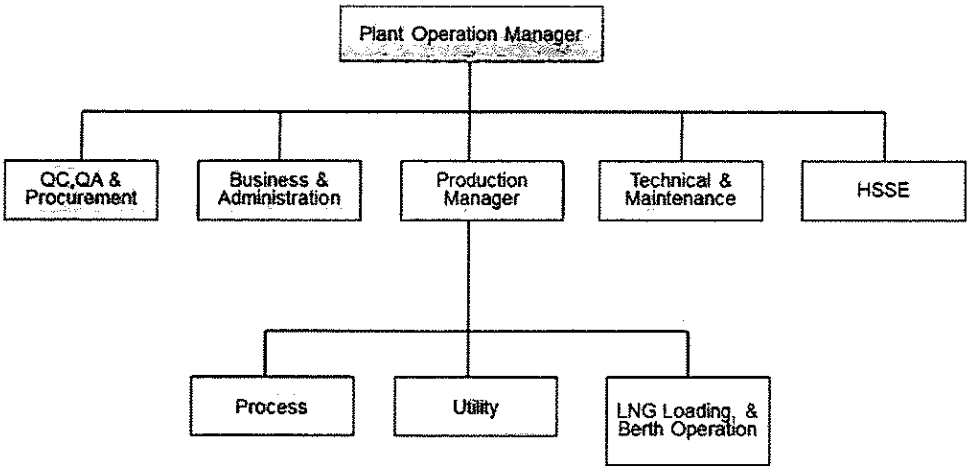


Figure 10.4-1 Plant Site Organization in the Production Phase

The organization is composed of the following functions:

a. Production

The responsibility covers both plant and maritime affairs operation. The plant operation handling group operates the process and utility plant with day-and-night shift formation, while the maritime affairs group operates tug and other function boats, and mooring equipment for LNG shipment.

b. Technical Support & Maintenance

The main task covers technical supports, routine and turnaround maintenance of the plant.

This division has special engineers for each discipline and supports plant operation and maintenance. It also has a responsibility to plan maintenance and inspection schedule for all plants in the site and to execute in accordance with these plans.

c. HSE

Under this function the main task is HSE and firefighting. HSE engineers and staffs work for the HSE affairs, and doctors and nurses work for medical treatment. The firefighting group comprises fire engines being ready for any emergency situations with day-and-night shift formation.

d. Business

Business group works for shipment planning, documentation and customs clearance procedures for LNG shipment.

e. Administration

The administration functions cover HR, Accounting and General Administration.

f. Procurement, QA/QC & Facility

Procurement procedure, QA/QC of procured materials, and equipment in all facility except in the site are controlled in this section.

10.4.2 Workforce Assignment

The plant operation will be managed by the Plant Manager, Deputy Plant Manager and several section managers with all other employees. An operational organization under the operator's management will typically require around 100 positions. In order to operate a 2 x 5 MTPA LNG Plant, 300 persons will be assigned for those positions if a 4 week-on-4 week-off and two-shift-a-day pattern is considered; this plan is assumed for a case that the LNG plant is located in a remote site where general residential circumstance is not prepared. If workers are able to commute from home, a regular three-shift system may be adopted like general chemical industries. Besides operation staff, around 40 persons from administration and other sections will work in the same shift patterns. In addition, there will be some trainees as future operating staff. During the turnaround maintenance period, headcount may become 3 to 4 times greater than the period of routine operation; technical service contractors will be engaged for such work.

Catering and cleaning/housekeeping may be outsourced to relevant service companies for accommodation and plant areas.

10.5 Recommendation on Human Resource Development

Large scale construction projects create significant employment opportunities while serious constraints are anticipated on human resources in many of developing countries where gas industries are starting from scratch.

Technical Staff

Construction involves a substantial expertise in the management of risks, materials, equipment, money and time and the coordination of activities of disparate participants who may not be directly responsible for the final product and over whom there is limited opportunity for control. Investments in manpower development in the construction industry are required to manage such issues and constraints, to acquire basic knowledge and create possibilities on human resource capability for the construction activities in host countries.

Basic education with proper content is very critical to prepare the knowledge platform. On top of this, people can enhance capabilities to harness knowledge, while investment in higher education offers the labor force opportunities for expanding the technical knowledge base. Besides teaching new and better skills, tertiary education and technical training will produce people who can monitor technological trends, access their relevant arts systematically and formulate an appropriate national technological strategy. These activities should be taken by the governmental bodies through educational programs of vocational school, college or university.

As the hydrocarbon industry is yet to emerge in Tanzania, it is not possible to provide on-the-job training in the country, which is the process to upgrade the school level knowledge and skill to real operational ones. At the outset, such training may be implemented abroad. Emergence of gas industry in Tanzania will produce opportunities to educate young engineers on the job basis at real plant

In this regard, construction of gas industry will provide good opportunities for construction engineers. Real construction activities require a broad range of management talents, skill and capacity for a continuum approach to problem solving. These skills can be acquired only through experience, while the knowledge comes from learning in real or stimulated environment on construction site. The highest level of learning by a construction professional is to be trained as an engineering or similar profession and to be performed either as a consultant or a contractor.

The Tanzania gas master plan offers a valuable opportunity to raise capabilities of engineers in various discipline fields and construction workers with appropriate knowledge for hydrocarbon construction industry.

Business Staff

In addition to the general administration and accounting job, establishing business relationship with LNG buyers is the most important capacity to secure the proceeds of the LNG business. This requires ample knowledge on the global gas business and rich experience in business trade, such as;

Business contract, trading correspondence and customer relationship

Shipping procedure (vessel scheduling, documentation, custom's procedure, etc.)

Technical knowledge on the LNG value chain

Accounting and banking procedure

Global energy trend

Basic knowledge on the global energy trend may be obtained through daily study or attending courses. However, real business knowledge on trading is not generally available from such courses or in the open market. It only comes from learning in actual business transactions in oil and gas trading and shipping, where there are many confidential issues such as pricing and transaction conditions never disclosed to outsiders. Among others, the direct acquaintance with customers is the most important platform for the marketing activity. In this sense, in the early stage of business, well experienced consultants or marketing agencies may be engaged. At the same time, capacity building may be conducted through internship to oil companies running LNG business. Finding good business partners for collaboration in capacity development is a very important issue to accumulate knowledge and experiences.

Chapter 11 Environmental and Social Considerations

Chapter 11 Environmental and Social Considerations

11.1 Brief Summary of Laws and Regulations related to Strategic Environmental and Social Considerations in the United Republic of Tanzania

1) Environmental Management Act 2004

In 2004, the Vice President's Office (VPO) enacted the Environmental Management Act 2004. The Strategic Environmental Assessment (SEA) is stipulated under Part VII of this Act. The Environmental Management Act 2004 is presented in Appendix 11-1.

2) Strategic Environmental Assessment Regulations 2008

Based on the Environmental Management Act 2004, in 2008, the VPO enacted a Strategic Environmental Assessment Regulations 2008. The Strategic Environmental Assessment Regulations 2008 is exhibited in Appendix 11-2.

3) National Guidelines for Strategic Environmental Assessment

Presently, the second Draft of the National Guidelines for Strategic Environmental Assessment dated January 2014 was drawn up and will be finalized after reflecting comments from various stakeholders. The date of enactment for the National Guidelines for Strategic Environmental Assessment is not decided because of budgeting problems. The second Draft of the National Guidelines for Strategic Environmental Assessment is presented in Appendix 11-3.

On the other hand, work on the SEA guidelines for Oil and Gas sector has not yet started.

4) Responsible Organizations for SEA Review and SEA Preparation

The Division of Environment (DOE) of the VPO is responsible for the administration of the SEA. About three years is required to prepare the Natural Gas Utilization Master Plan (NGUMP) and the MEM prepares the SEA documents in parallel with preparation of the NGUMP. The SEA documents are reviewed by the DOE of the VPO. It is needed to acquire the certificate signed by the Minister Responsible for Environment. The Institute of Resource Assessment (IRA) of the University of Dar es Salaam conducts the SEA; one of the options may be to collaborate with the University of Dar es Salaam for preparing the SEA documents.

Review of the existing SEA documents has found that there are no stylized SEA documents probably because the SEA guidelines are under preparation. Meanwhile, review of the EIA for individual project is conducted by the National Environment Management Council (NEMC) of the VPO, and a certificate signed by the Minister Responsible for Environment is required. According to the experience of the TPDC, about four months is needed for conducting an EIA survey, preparing the EIA documents and acquiring the certificate for an individual project. However, the required period can vary and on a case-by-case basis, according to the Marine Parks and Reserves Unit of the Ministry of Livestock and Fisheries Development. The implementing organization of the relevant project conducts the EIA survey and Public Consultation to prepare an EIA report. The EIA report is then submitted to the NEMC of the VPO. After receiving the EIA report, the NEMC conducts field survey and public consultations, and presents a recommendation to the Minister Responsible for Environment. The Minister Responsible for Environment makes a final judgment as to whether or not to issue the certificate.

11.2 Scope and Basic Policy for SEA Study

In this Study, the basic policy on how to conduct SEA is set forth without conducting the SEA itself because of lack of survey period.

Of the gas value chain starting from upstream to pipelines and industrial plants, five industrial plants including LNG, ammonia and fertilizer, methanol, GME and GTL are considered in this SEA study. The evaluation items of SEA for these five industrial plants are extracted and the basic policy for SEA is identified. Note here that the industrial plants are to be constructed using private investor funds and not using any of donor funding.

The contents of this study are made up by interviews and discussions with related organizations for SEA evaluation items, without conducting the baseline surveys and stakeholders meetings.

The upstream facilities are planned and constructed by MEM/TPDC in cooperation with BG and Statoil. According to MEM/TPDC, the SEA for upstream facilities has not been conducted by these organizations as yet. The pipeline has already been constructed up to Dar es Salaam.

11.3 Candidate Sites for Industrial Plants and the Surrounding Natural Environment

1) Outline of Candidate Sites for Industrial Plants

The outline of candidate sites for industrial plants is given in Table 11.3-1.

In the case when a project uses lands owned by the Tanzania Investment Center, it is only necessary to discuss and arrange for the land use with the Center, but the above does not apply to the candidate sites for the industrial plants being considered. The majority of land north of the Lindi Airport is the Corporate Land, where a farm project was planned but failed and the land is not presently in use, and the rest is the Village Land. The owner of the candidate property in Mtwara is under investigation. The seashores are owned and managed by either the national or the local governments.

The National Development Cooperation (NDC), under the Ministry of Industry and Trade, is involved with industrial development such as fertilizer and petrochemicals. The NDC has been negotiating with landowners for acquisition of a site north of Lindi Airport, but so far is unable to arrive at an agreement on the monetary front. While it is possible to expropriate a private land for a public use based on the provisions of The Land Acquisition Act 1967, the President is directing the NDC to first discuss the acquisition with the landowners.

For the land use in Village Land or Private Land, which are not owned by the Tanzania Investment Center, it is first needed to negotiate and agree with the landowner on the use. After the agreement, the transfer of ownership and so on is administered by the Ministry of Land. The form of acquisition is by lease for the period of33 years, 66 years or 99 years. The land user needs to select any of the three and obtain the approval of the Ministry of Land.

In the case of industrial estate for public use, it is conceivable that the government to acquires the land and provides the land users with the right to use under the so-called Public Private Partnership (PPP) scheme.

In the meantime, there is no involuntary resettlement caused by the construction of the industrial plants in all candidate sites.

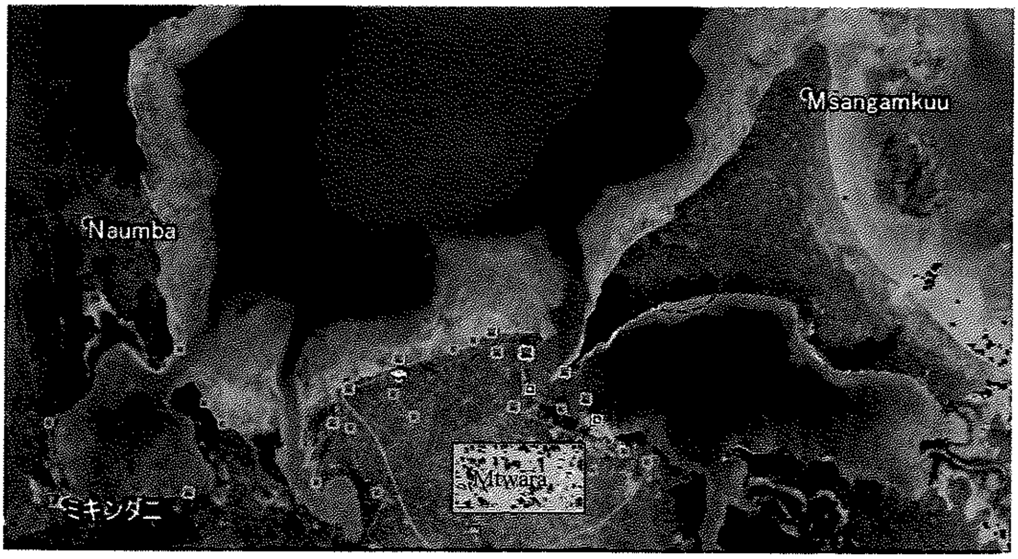
Table 11.3-1 Candidate Sites for Industrial Plants

Candidate Sites	Features	Land Owner	Industrial Plants
North of Lindi Airport:4km x 10km Planned industrial park opposite Lindi Airport:10km x 10km	Sufficient land space available	Majority: Corporate land Remainder: Village land	LNG, Methanol, DME, GTL
Mtwara: Opposite shore of Supply Base	Sufficient water depth available	Under investigation	Ammonia, fertilizer

(Source) JICA Study Team

(Source) JICA Study Team

Figure 11.3-1 Candidate Site in North of Lindi Airport

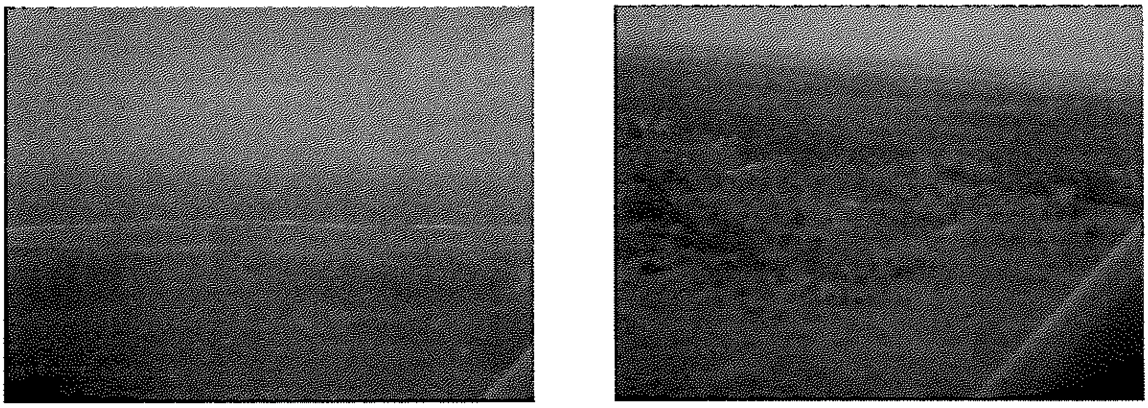


(Source) JICA Study Team

Figure 11.3-2 Candidate Site for Fertilizer Plant in Mtwara

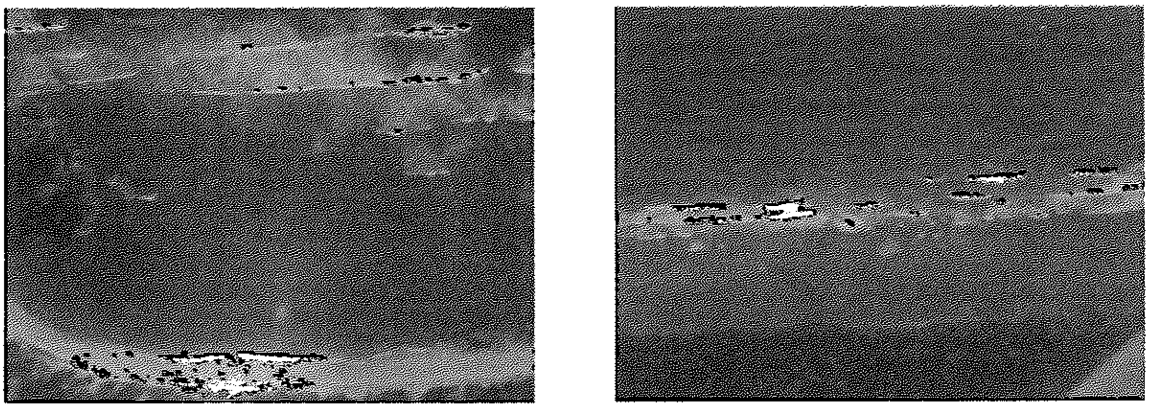
2) Surrounding Natural Environment of Candidate Sites for Industrial Plants

The aerial views of land and seashore for candidate sites of the industrial plants in the north of the Lindi Airport are shown in Figure 11.3-3 and 11.3-4. The land for the candidate plant sites is covered with flourishing forest as shown in Figure 11.3-3. The seashore for candidate sites has pristine natural environment as shown in Figure 11.3-4.



(Source) JICA Study Team

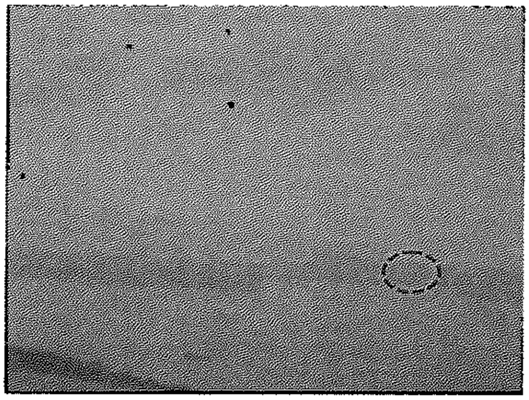
Figure 11.3-3 Northern Land of Lindi Airport



(Source) JICA Study Team

Figure 11.3-4 Northern Coast of Lindi Airport

The pictures for candidate site in Mtwara are shown in Figure 11.3-5. The red circle in the photo indicates the candidate site located on the opposite shore of the Supply Base.



(Source) JICA Study Team

Figure 11.3-5 Fertilizer Candidate site in Mtwara

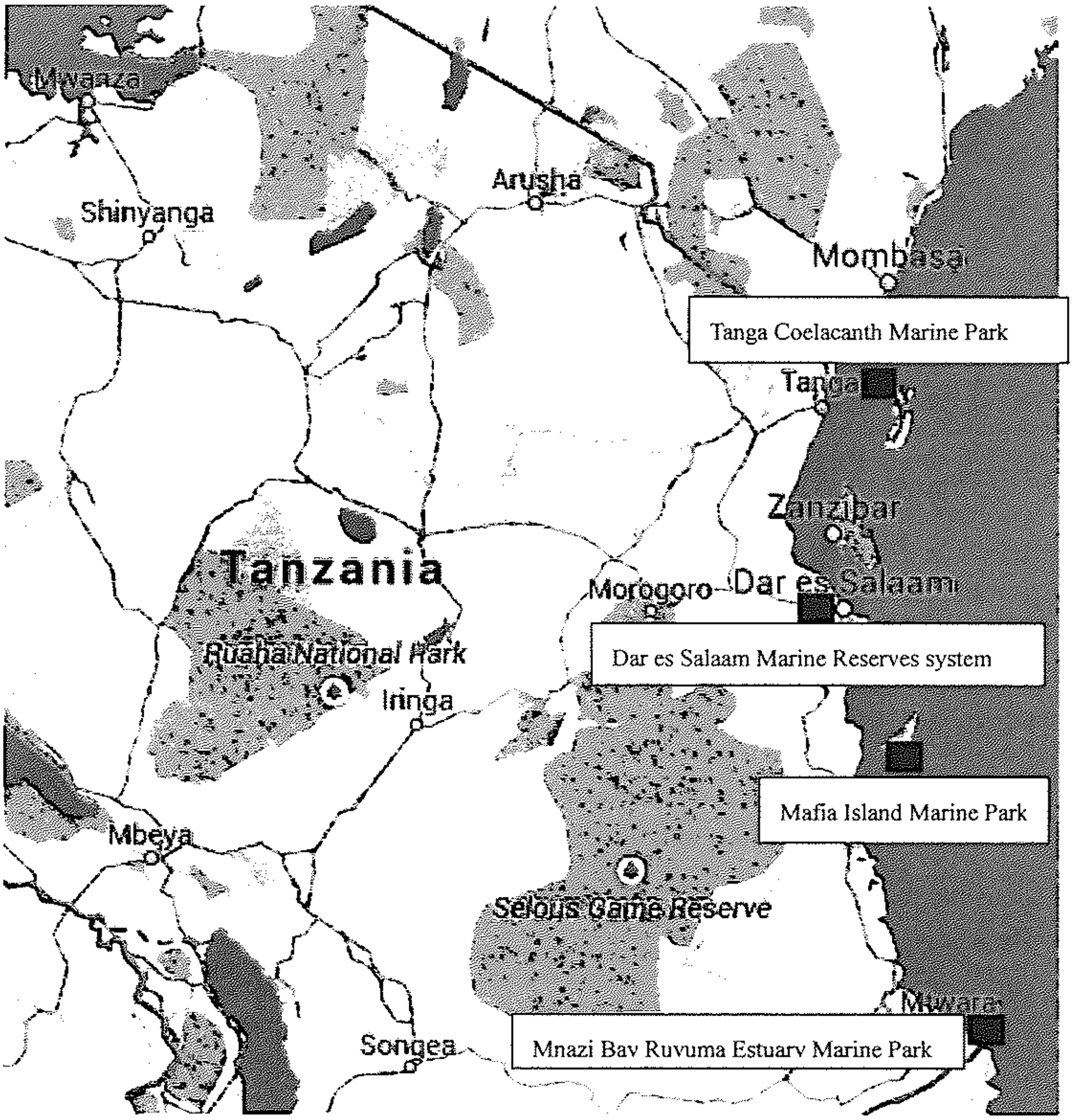
Four marine parks are located along the shore line from north to south in the United Republic of Tanzania as listed below:

Tanga Coelacanth Marine Park, 5 Marine Reserves and small inhabited islands

Dar es Salaam Marine Reserves system comprising 7small islands

Mafia Island Marine Park and 3 Marine Reserves

Mnazi Bay Ruvuma Estuary Marine Park



(Source) JICA Study Team

Figure 11.3-6 Marine Parks in the United Republic of Tanzania

The natural environment for candidate sites of industrial plants is shown in Table 11.3-2. The coral reefs and mangroves on seashore are observed in the candidate sites for the industrial plants in north of the Lindi Airport. The Ministry of Livestock and Fisheries Development expresses a considerable interest in conservation of coral reefs and mangroves.

Table 11.3-2 Surrounding Natural Environment of Candidate Sites for Industrial Plants

Candidate Site	Natural Environment	Industrial Plant
North of Lindi Airport:4km x 10km Planned industrial park opposite Lindi Airport:10km x 10km	・Forest in land area ・Coral reefs and mangroves in coastal zone	LNG, Methanol, DME and GTL
Mtwara: Opposite shore of Supply Base	・Adjacent to Msangamkuu-Mnazi Bay Marine Res. ・Annihilation of coral reefs and mangroves in Mtwara Bay	Ammonia and fertilizer

(Source) JICA Study Team

11.4 Options and Evaluation Items for SEA, and Mitigation Measures

1) Options for SEA

The available options for SEA are shown in Table 11.4-1. The Zero Option means the case for not constructing any of the industrial plants.

Table 11.4-1 Options for SEA

Category	Option
Option 1	Zero Option
Option 2	Construction of LNG, Methanol, DME and GTL plants in the north of Lindi Airport Construction of ammonia and fertilizer plant in Mtwara

(Source) JICA Study Team

2) Evaluation Items for SEA

Evaluation items for SEA are shown in Table 11.4-2. In accordance with these evaluation items, qualitative and/or quantitative evaluation is conducted and the applicability to the NGUMP is examined.

Table 11.4-2 Evaluation Items for SEA

Evaluation Items		
Engineering Evaluation Items	Consistency with upper level plans	
	Meeting with Industrial demand	
	Balance and efficiency for disposition of industrial plants	
Economic and Financial Evaluation Items	Dimensions of beneficiaries	
	Efficiency of investment	
	Contribution to expansion of production and investment	
Evaluation Items for Environmental and Social Considerations	Global Environmental Items	Degree of increase for Greenhouse gases
		Degree of increase for energy consumption
	Local Environmental Items	Impacts to air quality
		Impacts by waste
		Impacts to soil contamination
		Impacts by noise and vibration
		Impacts to protected area and biodiversity
		Impacts to living and livelihood
		Impacts to existing social infrastructures and services such as industrial water supply
		Degree of poverty reduction
		Degree of involuntary resettlement

(Source) JICA Study Team

3) Environmental and social Impacts by Industrial plants

Environmental and social impacts by industrial plants such as LNG, Ammonia and Fertilizer, Methanol, DME and GTL are summarized in Table 11.4-3.

Table 11.4-3 Environmental and social Impacts of Industrial plants

Category		LNG	Ammonia / Fertilizer	Methanol	DME	GTL
Industrial Water		27 ton/h	900 ton/h	440 ton/h	No industrial water use	180 ton/h (This can be reduced if reuse of treated waste water is carried out.)
Waste Water	Volume	32 ton/h	360 ton/h	180 ton/h	12 ton/h	Almost same as industrial water supplied
	Treatment Method	Degassing H2S in Foul Water Degasser (collecting as sulfur in Sulfur Recovery Unit) and after separating oil, treated water is discharged into the Ocean or used as irrigation water.	Recycled water of polisher, oil-separated water and cooling tower blow down are subject to treatment. Quality of effluent to be discharged is controlled in a final water-test tank by injecting caustic or acid solutions.	In addition to the treatment method of Ammonia/Fertilizer, biological treatment is carried out. (Methanol and DME are treated at one place.)	Treatment method: Regular activated sludge treatment facility is used.	—
	Substances in treated water	—	—	—	—	Oil and alcohols
Soil Contamination		Nothing in particular	Nothing in particular	Nothing in particular	Nothing in particular	Nothing in particular
Exhaust Gas		CO2: 180 ton/h NOx: 50-150 ppm Note: These figures depend on environment standards set by each country	CO2: approximately 35 ton/h NOx: follow environment standards Major sources of NOx emissions are boiler, gas-turbine and reformer. Exhaust air from urea granulation plant: Urea < $30mg/Nm^3$, NH3 < $80mg/Nm^3$ (The emissions can be lowered if acid washing is	CO2: approximately 22 ton/h NOx: follow environment standards Major sources of NOx emissions are boiler, gas-turbine and reformer.	Off gas:150 Nm^3/h After flaring, exhaust gases (CO2 and water) are generated.	Combustion exhaust gas of Reformer is 0.9 million to 1 million Nm^3/h Elements: N2, CO2 and H2O ★N2: 72%, CO2: 9%

Category	LNG	Ammonia / Fertilizer	Methanol	DME	GTL
		conducted.)			
Vibration and Noise generated during construction and operation	< Noise > Comply with levels set by local regulations or relevant regulations Between 7am and 10pm - Below 55 dBA at residential and educational sites - Below 70 dBA at commercial and industrial sites Between 10pm and 7am - Below 45 dBA at residential and educational sites - Below 70 dBA at commercial and industrial sites Note: The levels are assumed by local regulations < Vibration > Comply with local regulations	Same as regular plants	Same as regular plants	Same as regular plants	Same as regular plants
Waste generated during construction and operation	< During Construction > - Sludge: 3,500t/y - Wastes (foods, papers, plastic containers, glass containers and metal containers): 2,500t/y - Construction debris: 1,300t/y	Same as regular plants	Same as regular plants	Same as regular plants	Same as regular plants

Category	LNG	Ammonia / Fertilizer	Methanol	DME	GTL
	- Other wastes (tires, medical waste, welding rod, gas cylinder and so on) Note: 4,500 workers involved in construction. < During Operation> - Oil sludge: Depending on operations - Waste desiccant: 90t/3y - Spent carbon: 20m3/6y - Spent catalyst: 40t/3y - Activated alumina: 4t/2y - Activated carbon (oil-water treatment): 10m3/y Note: The amount of sewage sludge and wastes such as foods, papers, plastics, glasses and metals produced is proportional to the number of plant workers, especially the workers' housing is located nearby.				
Energy Consumption	Approximately 10% of Feed Gas (37,000,000 MJ/H)	Approximately 4.7Gcal per ton of urea (which is equal to approximately 20GJ, LHV standard, Natural gas as a raw material and a fuel) Natural gas as a fuel (reformer, boiler and power generation) accounts for 20% of it.	Approximately 7.8Gcal per ton of methanol (which is equal to approximately 33GJ, Natural gas as a raw material and a fuel) Natural gas as a fuel (reformer, boiler and power generation) accounts for 10% of it.	Electricity consumption: 200 kW (4,800kWh per day) Fuel gas is not used.	Natural gas as a raw material and a fuel: 10 MMBTU/bbl (55% of thermal efficiency) ★Natural gas as a fuel accounts for 5 to 10%.
Required Land Area	1,200,000m^2 is for train facility, utility, offsite facility	Approximately 350,000m^2 includes area for process	Approximately 90,000m^2 includes area for process	ISBL (for process): 2,000m^2	A scale of 15,000 BPD requires 60～80 ha

Category	LNG	Ammonia / Fertilizer	Methanol	DME	GTL
	(storage, facilities related to plant operation)	plant, utility, storage tanks, ammonia storage tank, urea warehouse, facility for bagging and so on.	plant, utility, storage tanks. (Methanol storage tank is excluded.)		(including utilities, waste water facility, ancillary equipment and fuel tank, etc.)
Remarks	<Precondition> - LNG plant of 5MTPA one train - Process cooling: Air cooling (cooling water is not used) - Heat source for process: Hot oil	<Precondition> - Ammonia: 76MTPA and urea: 132MTPA - Freshwater is used for cooling	<Precondition> - Methanol: 99 MTPA - Freshwater is used for cooling	<Precondition> DME production base: 250 KTA (approximately 760 ton/day as 330 days of plant operation)	-

(Source) JICA Study Team

4) Mitigation Measures for Negative Impacts

It is important to minimize negative environmental and social impacts by projects including development in the protected area such as marine parks. It is necessary to clearly define measures for minimization of negative environmental and social impacts. In the case of construction of port on the coast at the north of the Lindi Airport, as the sea depth is about 5m dredging will be needed and impacts will be high. In addition, it is considered that impacts of supplying industrial water to existing social infrastructures could be high.

In the case of high-negative impacts related to the evaluation items in Table 11.4-2, mitigation measures will be considered.

Chapter 12 Natural Gas Utilization Master Plan and Road Map

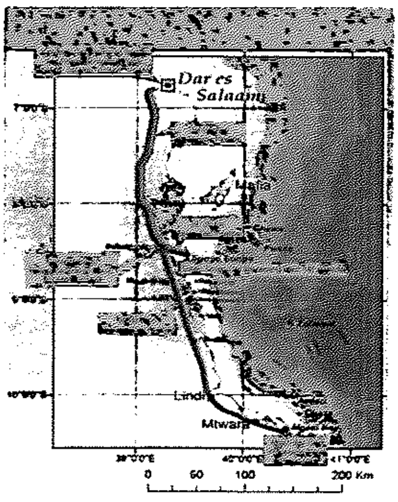
Chapter 12 Natural Gas Utilization Master Plan and Road Map

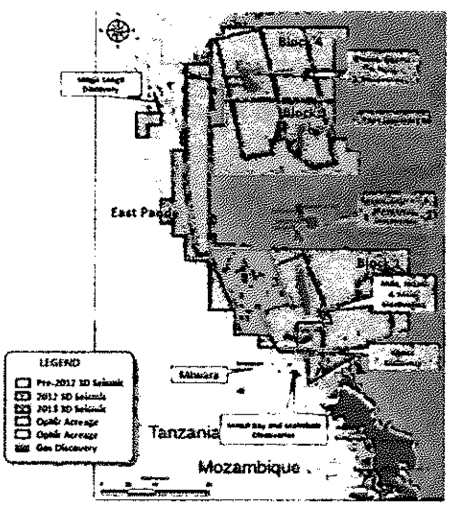
Based on the observations and analyses presented in the preceding chapters, we propose a draft Natural Gas Utilization Master Plan and Road Map as follows. In view of the present certainty level of various elements, this draft should be deemed as an indicative plan as a first approach. In particular, the recent plunge of international energy prices is a great threat for emerging energy projects such as those discussed herein. This draft, therefore, should be periodically reviewed and updated reflecting new information and developments.

12.1 Background

12.1.1 Gas Discoveries

In Tanzania, natural gas is a relatively new source of energy while a small amount is being consumed mostly in Dar es Salaam since 2004, mainly for power generation and industrial use. Natural gas is supplied from the Songo Songo and Mnazi Bay gas fields located onshore and in the shallow water along the coast. A 542 km pipeline was just completed between Mtwara and Dar es Salaam in 2015, which will significantly increase the nation's natural gas supply and is expected to open up a new natural gas era in Tanzania. The new gas-driven power plant completed at Kinyerezi receives natural gas from the new pipeline and will greatly improve and stabilize the power supply in the country.





Source: TPDC

Figure 12.1-1 Natural Gas Fields and Gas Pipeline in Tanzania

In addition to the shallow water gas fields, sizable gas discoveries have been made in the deepwater blocks since 2011. As of the middle of 2015, the total natural gas initial in place is estimated to be 57 trillion cubic feet (Tcf), of which 8 Tcf lies in the shallow water blocks and 47 Tcf in the deepwater blocks. The total recoverable reserves are expected to be about 40 Tcf; this figure is being verified by the ongoing technical study. The size of the new discoveries is truly substantial, for example, compared with the 41.3 Tcf of natural gas recoverable reserve existing in Malaysia[12], one of the LNG giants in the world. Even with an extensive gasification plan, only a portion of such gas reserves could be consumed in the next three decades. To fully realize the benefit of the giant gas discoveries of such magnitude, Tanzania needs to establish a prudent natural gas utilization plan with a long-term perspective.

12.1.2 Challenges

The extensive gas discoveries in the recent past will prove to be a great fortune for Tanzania and will fuel the socio-economic development of the country. However, natural gas lying underground is not more than a natural phenomenon. To materialize its value, we must construct a natural gas value chain fully mobilizing human wisdom and efforts. Figure 12.1-2 shows an example of an LNG value chain, where gas fields, gas processing plants and customers comprise the important pillars of the value chain. As illustrated below, a wide range of work should be implemented coherently in every sector to extract the value of natural gas.

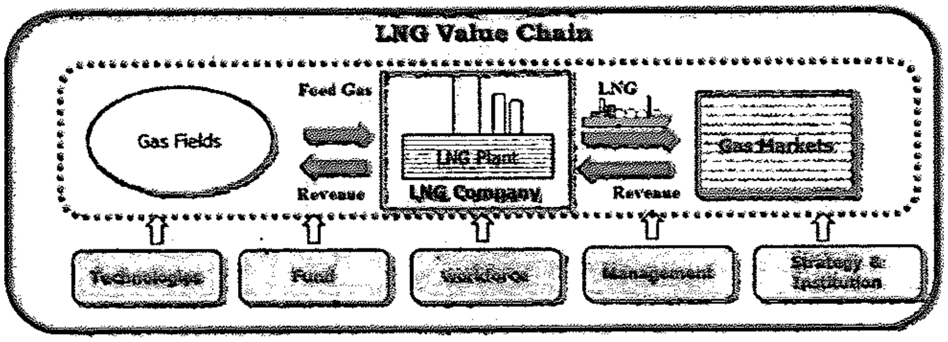


Figure 12.1-2 Natural Gas Value Chain

Major challenges anticipated in developing natural gas utilization in Tanzania will be as follows:

Most of the large-scale gas fields are located in the water of 1,000 – 2,500 m deep with harsh sea bottom conditions, potentially placing Tanzania in an inferior position vis-a-vis competitors in the international market. Most advanced technology and huge investments will be required to bring the gas to the surface. This in turn requires adequate gas outlet to assure sufficient

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revenues justifying the upstream development. Commercial viability of developing deepwater gas fields is the key for achieving the natural gas utilization.

The domestic gas demand in Tanzania, mainly for power generation as well as industrial, transport, commercial and household uses is estimated to be about 8 Tcf for the next three decades through 2045 (Low case: 6 Tcf and High case 12 Tcf as discussed later). This could not provide the necessary volume of demand to develop the deepwater gas fields.

In order to provide sufficient demand to support utilization of the discovered natural gas, Tanzania must consider developing gas industries. Such industries are to be built from scratch, while everything must be procured or created from now on such as technology, workforce, infrastructure, market, funding, and so on.

While a number of important studies are being undertaken, various elements relating to the above issues are still in a premature status with low certainty level at present. In addition, the recent plunge of the international energy prices is a great threat for any new energy projects. All in all, the discovery of the huge gas reserves is expected to open up a new era in Tanzania with promising bright future. To make such a future materialize, a big challenge must be made mobilizing every available wisdom and power of the country.

12.2 Demand Outlook and Gas Industry Options

With its ample reserves, natural gas is expected to become a major energy source for the country. Although its domestic energy demand may grow fast, it still is too small to justify the development of the huge deepwater gas fields, whilst substantial infrastructure must be developed to use natural gas nationwide.

12.2.1 Gas Demand Outlook

In Tanzania, where modernization of the society and industrialization of the economy are expected as stated in the Vision 2025, energy consumption will increase fast. At the same time, transition from traditional biomass to modern energy sources, such as from charcoal to LPG, will progress rapidly as shown in Figure 12.2-1.

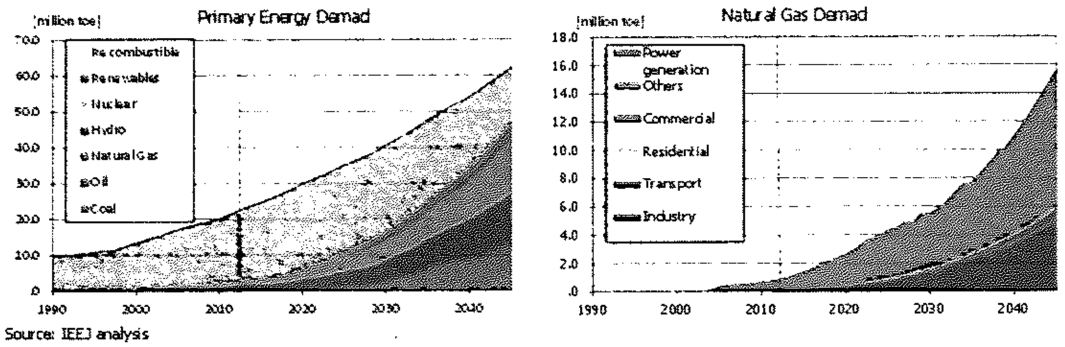
For the Base case projection assuming that the present pace of 6% per annum economic growth will be kept for the next three decades, the primary energy consumption will grow 2.8-fold from 22 million tonnes oil equivalent (toe) in 2012 to 62 million toe in 2045, while the modern energy consumption replacing the traditional renewables will increase more than 14-fold from 3.2 million toe in 2012 to 46.2 million toe in 2045.

Among the energy sources, natural gas is expected to play an important role together with coal and petroleum. Coal from the interior regions or imported will be used for power generation and industrial production of steel and cement. Oil including LPG, solely dependent on imports at present, will be used as fuel for transport as well as heating/cooling/cooking at buildings and households. Natural gas will be used mainly for power generation and industry as reliable domestic energy source. Natural gas consumption will increase 19-fold in the next three decades. However, gas consumption at household and commercial sectors will be limited due to supply constraints. To deliver natural gas to these sectors, it is necessary to construct transportation and distribution networks, which requires long lead time and huge investments.

Table 12.2-1 Energy Demand Outlook of Tanzania

	Primary Energy Demand				Composition				AAGR			
	2012	2025	2035	2045	2012	2025	2035	2045	12⇒25	25⇒35	35⇒45	12⇒45
	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Coal	49	1,626	6,754	12,943	0.2	4.6	14.2	20.8	31.0	15.3	6.7	18.4
Oil	2,215	4,412	8,344	14,768	10.0	12.6	17.5	23.7	5.4	6.6	5.9	5.9
Natural Gas	812	4,278	7,619	15,612	3.7	12.2	16.0	25.1	13.6	5.9	7.4	9.4
Hydro	143	363	1,019	1,368	0.6	1.0	2.1	2.2	7.5	10.9	3.0	7.1
Nuclear	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	
New Renewables	15	550	1,348	2,150	0.1	1.6	2.8	3.5	32.2	9.4	4.8	16.3
Combustible RE	18,938	23,917	22,566	15,395	85.5	68.1	47.4	24.7	1.8	-0.6	-3.8	-0.6
Total	22,162	35,138	47,642	62,226	100.0	100.0	100.0	100.0	3.6	3.1	2.7	3.2
Excluding RE	3,224	11,221	25,076	46,831	14.5	31.9	52.6	75.3	10.1	8.4	6.4	8.4

	Natural Gas Demand				Composition				AAGR			
	2012	2025	2035	2045	2012	2025	2035	2045	12=>25	25=>35	35=>45	12⇒45
	ktoe	ktoe	ktoe	ktoe	%	%	%	%	%	%	%	%
Industry	130	881	2,398	5,086	16.0	20.6	31.5	32.6	15.9	10.5	7.8	11.8
Transport	0	45	263	792	0.0	1.1	3.4	5.1	-	19.3	11.7	-
Household	0	27	89	185	0.0	0.6	1.2	1.2	-	12.5	7.6	-
Commercial	0	32	187	565	0.0	0.8	2.5	3.6	-	19.3	11.7	-
Agriculture & Others	0	0	0	0	0.0	0.0	0.0	0.0	-	-	-	-
Power Generation	682	3,293	4,682	8,984	84.0	77.0	61.5	57.5				8.1
Total	812	4,278	7,619	15,612	100.0	100.0	100.0	100.0	13.6	5.9	7.4	9.4



Source: IEEJ analysis

Figure 12.2-1 Energy Demand Outlook of Tanzania

Alternative cases are examined as shown in Table 12.2-2 for the High case where the GDP growth rate is set at an annual 8%, which is required to achieve the goal under the Vision 2025, and for the Low case where the GDP growth rate may be slightly lower at an annual 5% as affected by any adverse events in the global economy. If the High case economic growth is realized, natural gas consumption in 2045 will be almost double the Base case projection, while in the Low case projection it will remain at 75% of the Base case projection. The total domestic natural gas demand during the next three decades will be 8 Tcf for the Base case, 12 Tcf for the High case and 6 Tcf for the Low case, respectively.

Table 12.2-2 Natural Gas Demand Outlook

	GDP Growth	Natural Gas Consumption				
	2012-2045	2012	2025	2035	2045	2015-2045
	%	Bcf	Bcf	Bcf	Bcf	Tcf
Base Case	6.1	31.2	164.2	292.4	559.6	7.9
High Case	8.2	31.2	189.6	452.7	1,033.1	12.1
Low Case	5.1	31.2	144.5	232.1	417.6	6.3

(Source) IEEJ analysis

It should be noted that the above projections are made applying a general macro-economic method as a first approach, but not based on a detailed bottom-up study. Tanzanian economy is still modest in size. If construction of a large industrial complex becomes real, such as gas industries as discussed later, there will be a significant impact on the economy. Once construction starts, the direct investment and its associated effects will substantially push up the economy. However, because of the uncertainty about the future plans and timing, such events are not specifically programmed in the above macro-economic approach.

In this context, the above projections should from time to time be reviewed and updated with input of new information. In particular, since industrialization and urbanization are the keys for socio-economic development, industry development plans and city development plans with specific designs and lists of stakeholders will provide more precise information to be reflected in the projection. They should be backed by coherent infrastructure plans on transportation, energy, electricity, water supply, etc.

At any rate, even the Base case gas demand projection assumes an aggressive industrial development. For example, fuel for thermal power generation is assumed for all cases to be supplied at the ratio of 50:50 by coal and natural gas, excluding small diesel plants for local grids. If electricity demand goes up faster than projected, large scale coal power plants with high generating efficiency could be selected as the base load power supplier, which is not feasible for the electricity demand size presently projected. Thus, the High case projection for the future gas demand can be considered a truly ambitious one.

12.2.2 Gas Industry Options

As options to enhance natural gas demand to support the large scale gas field development, typical technologies available for commercial natural gas utilization in the world are listed below:

LNG (Liquefied Natural Gas)
Fertilizer
Methanol
GTL (Gas to Liquid)
DME (Dimethyl Ether)
MTG (Methanol to Gasoline)
CNG (Compressed Natural Gas)

Except for an on-going small pilot project on CNG vehicles, none of these industries exists in Tanzania today. As candidates for Tanzania in establishing suitable gas industries, economic feasibilities of these projects have been examined.

Features, merits and challenging issues of conceivable projects are summarized below:

1) LNG (Liquefied Natural Gas)

LNG is natural gas liquefied at -162℃. Its volume is compressed by liquefaction to 1/600 of the gaseous state, which enables long distance transport by LNG tankers or other fleets. Technology is mature and many LNG plants are operating worldwide where gas reserves are situated relatively remote from natural gas pipeline system. The global LNG market was 333 billion cubic meters or 245 million tonnes per annum in 2014 and growing fast.

Merit: Enables to acquire a big anchor demand from the established global market.

Challenges: Huge investment is required to construct an LNG plant. Extensive marketing efforts are necessary to secure sufficient customers in the case of Joint Venture Marketing. LNG price is vulnerable to changes in the world LNG market trend, which is anticipated to be stagnant for the medium term.

2) Fertilizer/Ammonia

Natural gas is processed into ammonia, and then to fertilizer, while these are partly used as petrochemical feedstock. Technology is mature and many plants are operating worldwide. Investment amount as well as gas consumption is relatively small.

Merit: Enables to replace import of fertilizer and support promotion of modern agriculture. Any surplus after satisfying the domestic demand can be exported to the international market.

Challenges: Realistic marketing plan must be established before the final project decision. Product price and feed gas price are the key factors in determining the project economics. Competition with coal based fertilizer is anticipated in the international market.

3) Methanol

Natural gas processed into methanol as chemical product. Methanol can also be used as feedstock for petrochemical industry in further downstream such as MTO (methanol to olefin) and MTP (methanol to propylene) or petroleum fuels industry to produce such as DME dimethyl ether) and MTG (methanol to gasoline). Methanol technology is mature and many plants are operating worldwide. The process needs certain amount of industrial water supply. Investment amount as well as gas consumption is relatively small.

Merit: Can be exported, or used as a feedstock for petrochemical industry or liquid petroleum product industry in the downstream.

Challenges: Development plan for methanol based chemical/fuel industry must be designed to use the products systematically. Product price and feed gas price are the key factors in determining the project economics. Competition with coal based methanol is anticipated in the market. Considering these elements, a comprehensive industry development plan needs to be established.

4) Gas to Liquid (GTL)

Natural gas processed into petroleum substitutes, such as petrol and diesel gas oil. Commercial plants are operating in gas rich countries such as Qatar and Malaysia. Feasibility of a GTL project heavily depends on the price differential between the petroleum products and the feed gas. GTL naphtha is good for petrochemical industry as feedstock, but not suitable to use as motor gasoline as its octane index is low.

Merit: Enables to replace import of petroleum products, save foreign currency reserves and enhance security of energy supply.

Challenges: Wholesale prices of petroleum products are the key in deciding the project economics. Without having domestic oil production, or any refinery processing crude oil into petroleum products, Tanzania is importing the entire oil product requirements. Realistic pricing and marketing system of petroleum products should be factored to examine the GTL project for justification.

5) Dimethyl Ether (DME)

Natural gas processed into DME via methanol, characteristics of which are similar to LPG, for easy transport and handling. DME can be blended into LPG up to 20% without modification to equipment or distribution networks according to the International DME association. DME can also be used for diesel vehicles. Coal based DME is widely used in China.

Merit: Enables to replace import of LPG and help promote domestic gasification. When used in diesel engines, exhaust gas is very clean.

Challenges: Economics of DME depends on the price differential between the feedstock methanol and the LPG price. Their pricing and marketing system should be carefully looked into for finalization of a project.

6) Methanol to Gasoline (MTG)

Natural gas processed into gasoline, via methanol. Technology is established, while heat loss in the conversion process is high.

Merit: Enables to replace import of gasoline, save foreign currency and promote domestic gas industries. Gasoline is portable to every corner of the country unlike gaseous fuel.

Challenges: Economics of MTG virtually depends on the gasoline price. Its pricing and marketing system on them should be carefully looked into for finalization of a project.

7) CNG (Compressed Natural Gas)

Natural gas compressed with high pressure to reduce volume, for transportation or portable fuel on vehicles. Technology is mature. More than 20 million CNG vehicles are operating in the world.

Merit: Enables to replace import of gasoline and diesel oil, save foreign currency and provide demand for the domestic gas supply grid. A CNG system is not expensive if natural gas delivery network is developed. Exhaust gas of CNG vehicles is cleaner than petroleum products.

Challenges: For transportation purpose, CNG is suitable only for small-medium volume and short distance movement since energy density is low. To popularize CNG vehicles, extensive gas supply network should be built to provide convenient refueling points. Traveling distance is shorter than oil-based vehicles.

12.2.3 Long Term Outlook of Total natural Gas Consumption

A long term outlook of natural gas consumption through 2045 is given in Figure 12.2-2, which combines the above domestic demand forecast (Base case projection) and gas industry build-up for the case where two LNG trains are built. Natural gas used for CNG vehicles is included in the domestic gas consumption (about 5% of the total demand in 2045: see Table 12.2-1). As a first approach, project economics are examined assuming the start-up timing of relevant gas industries as follows:

Fertilizer... 2020:1 train

Methanol...2023:1 train, 2033:1 train

DME, MTG...2023: 1 train each

LNG...2025: 2 trains (additional case...2025-6: 3 trains, 2025 and 2030: 4 trains)

GTL...2027: 1train, 2032:1train, 2037: 1 train (additional case...2025: 2 trains)

The above project size and start-up timing are hypothetical and should be reviewed and finalized taking into consideration the feasibility and strategic significance of the respective projects. The chart below shows that, natural gas consumption by an LNG project is overwhelmingly large compared with domestic gas demand and/or other gas projects.

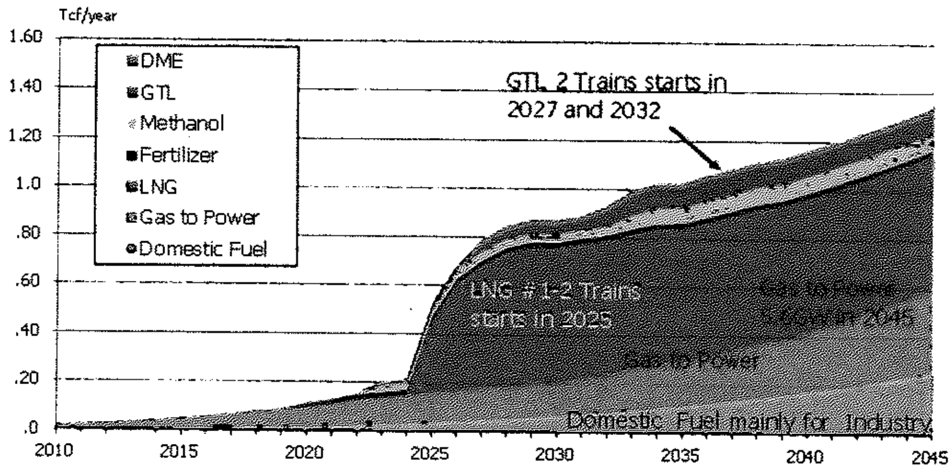


Figure 12.2-2 Combined Natural Gas Demand Outlook: LNG/2 Trains, Base Case

12.3 Economics and Other Features of Gas Projects

12.3.1 Economics of Projects

Project economics are run on the above gas projects excluding CNG vehicles.[13] These analyses were implemented using economic models developed by the Institute of Energy Economics, Japan (IEEJ) and based on the following assumptions:

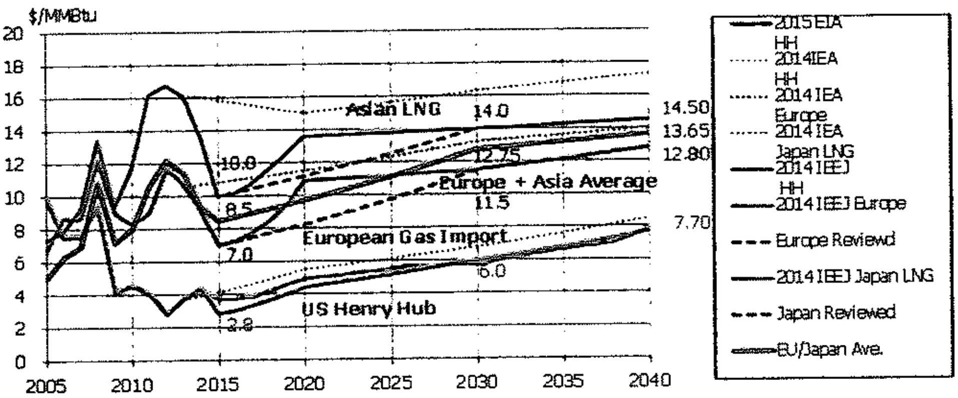
Price scenarios projected by the Study Team in view of the oil and gas prices prevailing in the international markets in the first quarter of 2015.

Project size, capital expenditure and operating expenditure estimated for each project based on the technical knowledge and experiences of Japanese engineering companies.

According to the Study Team evaluation, all of the above projects except for MTG show fair economics with the internal rate of return (IRR) above 10% (detail numbers are withheld because of confidentiality). The upstream economics for developing a model gas field cluster in the deepwater blocks also shows promising economics. Thus, they are deemed to have cleared the first screening for further examination. The economics of MTG depends heavily on the

[13] Presently a pilot project is being conducted by a party led by TPDC on CNG vehicle introduction in Dar es Salaam.

pricing of gasoline in the domestic market, which is not clarified in this study. Therefore, MTG may also be included as a candidate for the future elaborative study.



(Source) IEEJ analysis

Figure 12.3-1 World Natural Gas Price Outlook (in 2013 US Dollars)

Project economics largely depends on the product price. In this present study, an international natural gas price scenario is set as shown in Figure 12.3-1. In particular, the natural gas price in the United States is presently under severe downward pressure from the shale gas revolution. In addition, many new LNG projects are coming up in Australia, Africa and elsewhere in the world. Meanwhile, gas demands in fast-growing economies such as China and India are on a weak note, reflecting the recent economic downturn. Thus, the Study Team has adopted a scenario that the natural gas price in the international market will return to the historical trend only very slowly.

Since the third quarter of 2015, the world energy prices are sinking fast making the future price outlook quite uncertain. Product price is the biggest factor to decide the project economics and its change will in turn affect construction costs of energy related facilities. Therefore, the above price picture should be reviewed carefully while technical and other detail studies are being conducted on the practicability of these projects. In many projects, the final investment decisions (FID) are made according to the product price scenario that the project owners would adopt. In this context, this master plan and road map should be reviewed based on the revised price scenarios and the updated project feasibility closely monitoring the global market trends.

12.3.2 Economic Features of Gas Projects

a. Magnitude of Project

The gas projects examined in this study are diverse in their magnitude, their weight and position in consideration of natural gas utilization plan. Figure 12.3-2 illustrates magnitude of projects in terms of capital expenditure, gas consumption and revenue.

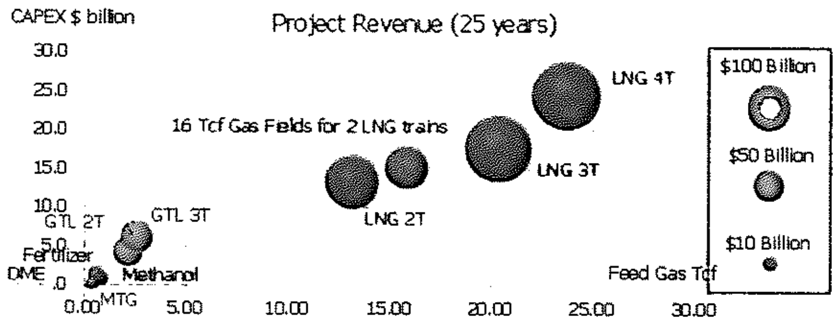


Figure 12.3-2 Magnitude of Gas Projects

Among others, LNG projects are overwhelmingly large in terms of CAPEX, feed gas requirement and expected revenues. In view of the fact that in order for the deepwater gas fields to provide bulk of the feed gas supply also requires huge amounts of investment and revenues to justify it, a successful development of an LNG project and deepwater gas fields is the key for Tanzania in establishing the platform for its gas industry development.

Fertilizer, methanol and its derivatives such as DME and MTG are much smaller in every aspect. GTL is slightly larger and more expensive. These projects may be considered separately from LNG, while they will also play important roles for industrialization and modernization of the country.

b. Government Revenues and Foreign Currency Saving

An important aspect of the gas industry development in Tanzania is that it will bring about a huge amount of government revenues.

To show a very preliminary figure, from the operation of these projects for the LNG/2 trains case from 2020 through 2045, a total of $57billion will be brought to the public purse of Tanzania and $95 billion in foreign currency outflow will be saved as shown in Table 12.3-2 and Figure 12.3-2. In the LNG/4 trains case, the government revenue will increase to $90 billion and the foreign currency saving $150 billion, respectively.

The main sources of the government revenue will be the upstream gas production and LNG. As the upfront investment cost should be recovered in early years of production, the government revenue starts to increase around 2030 to $ 3 billion a year or more. As the upstream sector supplies feed gas to the downstream sector while it does not export the produced gas, foreign currency will continue to be expended by the upstream sector for operation, maintenance and additional field development. Thus the LNG sector will be the single largest sector to earn foreign currency. Total annual saving will be more than $5 billion after 2030.

Table 12.3-1 Government Revenue and Foreign Currency Savings by Gas Projects

	LNG	Fertilizer	Methanol	GTL	DME	MTG	Gas Field	Total	
Nameplate Capacity	5.0 MTPA	4,000t/d	3,000t/d	15,000bpd	250ktpa	230ktpa	3 Gas Fields x 2	LNG 2 trains	LNG 4 trains
Trains	2	1	2	2	1	1			
Government Revenue	$ billion	$ billion	$ billion	$ billion	$ billion	$ billion	$ billion	$ billion	$ billion
Total (2015-2045)	14.2	2.6	2.0	1.4	0.6	0.8	33.7	57.3	89.6
Annual (Average:2020-2045)	0.6	0.1	0.1	0.1	0.0	0.0	1.3	2.3	3.6
Foreign Currency Saving									
Total (2015-2045)	84.7	4.1	3.0	12.5	2.7	3.5	-15.1	95.4	149.9
Annual (Average:2020-2045)	3.4	0.2	0.1	0.5	0.1	0.1	-0.6	3.8	6.0

Note: Foreign currency saving is the sum of the revenue of the project (for GTL, DME and MTG, import equivalent amount of the revenue) minus capital expenditure (foreign procurement ratio 80%), operation expenditure (50%) and transfer of dividend (100%).

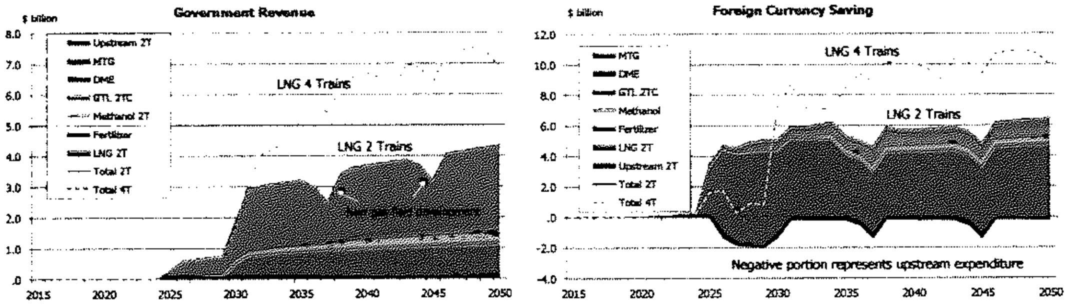


Figure 12.3-3 Government Revenue and Foreign Currency Saving

According to the World Bank, GDP of Tanzania was $49.18 billion and import of goods and services $14.70 billion in 2014. The expected government revenues and foreign currency savings will be significantly large compared with these statistics. They are the direct proceeds to be obtained from the gas projects. There will be multiplier and accelerator effects triggered by the investments and revenues involved in these projects, which are assumed to be much greater than the direct effects. Once the construction of these giant projects starts, the Tanzanian economy may take off for a higher economic growth. In this regard, economic outlook and resultant energy demand outlook should be reviewed periodically with updated information.

c. Tax Holidays

Tax holiday system is applied for investors in the Special Economic Zone in Tanzania. When the same system is applied to the gas industries, project IRRs will be improved by about 10%, thus providing good incentives except for the MTG project. Since taxes are assessed against the cooperate profit, this system is effective only when the project economics is in a healthy range. Since most of the gas industry project need a long lead time, a 10-year tax holiday from the production start year is applied in the calculation shown in Table 12.3-2. However, in case of low profitability project such as the MTG, a taxable profit occurs only in the later years of production, and therefore the exempted tax amount and its effect are limited.

Table 12.3-2 Effect of Tax Holidays on Project Economics

Tax Holidays	LNG 2T	Fertilizer	Methanol	GTL 2T Consec.	DME	MTG
	%	%	%	%	%	%
Improvement of Economics	10.5	9.9	10.3	8.1	8.6	3.7

12.3.3 Gas Field Development

Tanzania is located far away from the world gas markets. To sell natural gas beyond its domestic demand, natural gas must be processed at gas industries. In this case, natural gas supply must be controlled to assure stable operation of the gas industries. For this reason, gas fields of various sizes must be put in production in well controlled sequences as illustrated in Figure 12.3-4.

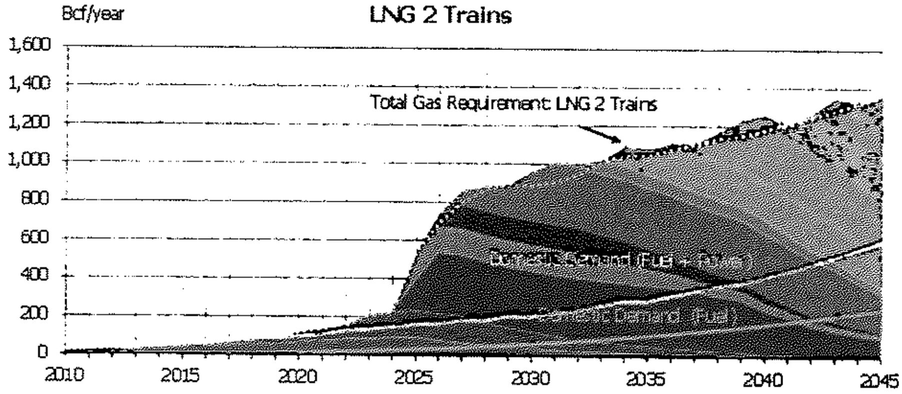


Figure 12.3-4 Gas Field Development Plan (Hypothetical)

It is important to optimize the order of the development projects, where some gas fields will be put in production only in the later years of the project period. As a result, in the hypothetical case shown here, only 70% of the gas reserves of the developed gas fields will be produced during the project period.

Another issue is that, while about 40 Tcf gas reserves are confirmed in Tanzania to date, in the LNG/2 train case, less than 60% of the present discoveries will be produced during the next three decades. Since over $ 3 billion have already been spent in the deepwater exploration activities, oil companies may want to monetize them as early as possible. Thus, because LNG is the largest gas outlet, cases of constructing three and four LNG trains are considered. In the case where four LNG trains are constructed, 80% of the presently recognized natural gas reserves will be produced by 2045, while 90% for the High demand case.

Table 12.3-3 Natural Gas Requirement in Multiple LNG Options.

	Base Case			High Case		
Scenario	2Trains	3Trains	4Trains	2Trains	3Trains	4Trains
Gas Consumption (2015-2045)	Tcf 23.0	Tcf 26.3	Tcf 31.7	Tcf 26.7	Tcf 31.9	Tcf 35.5
Against 40Tcf	57%	66%	79%	67%	80%	89%
R/P (2045)	Yrs 12.5	Yrs 8.9	Yrs 4.2	Yrs 7.1	Yrs 3.7	Yrs 1.8

From the above observation, construction of additional two LNG trains appears a promising option. However, if we apply the same gas field combination analysis illustrated in Figure 12.3-3, gas reserves exceeding the present 40 Tcf will be required to assure stable feed gas supply. Therefore, more comprehensive analysis is necessary concerning gas reserves availability and optimum field development plan to decide the construction of additional trains.

Nevertheless, we need not be overly concerned at this early stage of exploration. There are estimations that Tanzanian gas resources may exceed 100 Tcf, which could be verified through future exploration activities. If such estimation is proved to be true, any depleting gas reserves can be made up for by new discoveries. Once it is demonstrated that gas industries will start operation and provide robust outlet, as we have seen in many leading countries, oil industry will invest more in exploration to bring about additional gas discoveries. The economy will start rolling toward a higher goal. This is the first step we should take. Thereafter, to drive the economy properly forward, we should fine tune the energy plan from time to time as and when more certain information becomes available.

12.3.4 Project Timeline

A process of LNG project formation and its timeline is shown in Figure 12.3-5 targeting at LNG plant operation starting in 2025. This provides a guideline for developing a work plan to formulate an LNG project. At present, however, the certainty level of many elements is premature to lay out a firm work plan. Construction of a green-field LNG plant needs 6-7 years upon the final investment decision (FID). Important issues must be sorted out before the FID, including gas reserves evaluation, securing of LNG buyers or implementing equity offtake scheme and firming up of investment formation.

Among others, the LNG marketing is the most important issue, involving a lengthy process so that LNG is often dubbed a Long Negotiation Game. This is because of the sheer size of the LNG business. To sell 10 million tonnes of LNG, the seller should fix customers with more than 10 gigawatt of gas power generation capacity in case of a sale to power companies.[14] Power

[14] Tanzania's total electricity generation capacity in 2014 was 1.47 GW including thermal and hydro power plants

companies must make an enormous amount of investment to consume such a quantity of LNG. Accordingly very substantial decisions are required on the part of both the seller and the buyer. Generally speaking, the marketing process takes 3-5 years pending the global market condition. Even if the marketing activity is commenced immediately, the project timeline appears very tight. Alternatively, equity lifting scheme (see Section 10.1.2) shall be evaluated in order to minimize the impact from lengthy marketing processes to the project

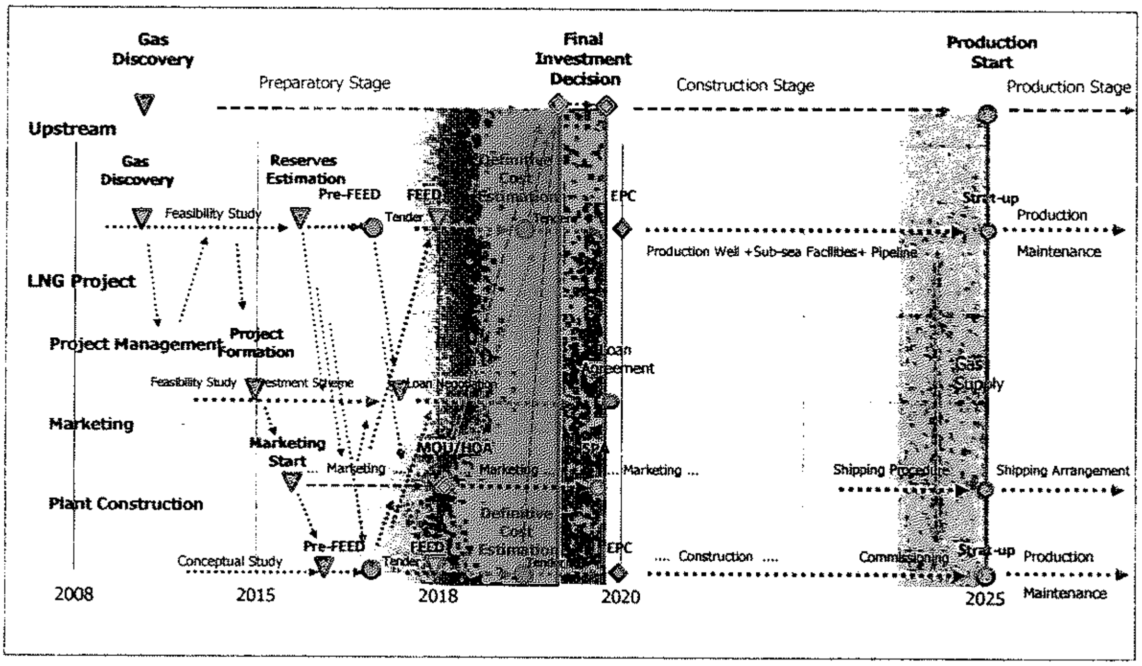


Figure 12.3-5 Process of LNG Project Formation

12.4 Principles for Master Plan

In formulating the Natural Gas Utilization Master Plan, we should consider various elements relating to; a) priority order of projects to make the plan a realistic and comprehensive one, b) reliable project implementation, and c) support for the project implementation. As a result of reviewing these issues, the principles to be incorporated in the master plan could be summarized as follows:

12.4.1 Project Priority

The priority order of projects should be laid out by evaluating the feature and role of each project concerning the following questions:

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according to TANESCO Corporate Business Plan 2014, increasing to 1.62 GW after completion of the Kinyerezi thermal power plant in 2015.

a) If the project provides a sufficient demand to justify upstream gas field development.
b) If the project is bankable to allow foreign currency investment.
c) If the project is in line with the national development policy for key industries.
d) If the project accommodates the national aspiration to improve people's quality of life.

1) Magnitude of Gas Outlet

a. A major portion of the natural gas reserves in Tanzania lies in the deepwater. To justify their costly development, large and steady demand is necessary. To provide this, LNG is the single most suitable business. Once an LNG project is confirmed which then justifies developing deepwater gas fields, other gas projects that are much smaller in gas consumption volume can source stable feed gas supply from them. In this context, deepwater gas fields and an LNG project combined constitute the platform on which the natural gas industry shall be constructed in Tanzania.
b. It is desirable to provide the stakeholders with opportunities to monetize the presently recognized gas discoveries in the next three decades, so as to enhance future exploration activities for more resources. For this purpose, construction of multiple LNG trains should be considered. To examine the optimum project size, it is also necessary to establish an optimum gas field development plan. Additional plant construction may not be justified immediately, but will be confirmed step by step as more definitive information becomes available.

2) Bankability of Project

In order to procure loans for investment, in addition to healthy economics, the project must be bankable in terms of sufficient gas reserves, competent project partners as well as secure and stable sales outlets. In particular, as such loans may well be made in foreign currency, revenues in foreign currency must be secured to assure the loan repayment.

In a country with low foreign currency reserves, financial institutions generally pay high attention if a certain portion of the products will be exported to earn a sufficient fund for loan repayment in foreign currency. In this context, product export must be considered just as seriously as the domestic consumption.

For the eyes of buyers, it is desirable that the project is bankable and assures stable supply.

3) Front Runner of Gas Based Industry

a. In Tanzania, there currently is virtually no gas industry, no supporting constructors nor technical- service providers. It is desirable to experience construction and operation of a gas industry plant as early as possible with an easier project, which will create plant construction services and workforce, and enhance knowledge and skills.

b. Fertilizer plant will be a good pilot project to spearhead the above campaign in terms of the technology maturity, handy project size and comfortable economics postulated from the prevailing international fertilizer price. A world class plant of 1.3 MTPA consumes only 0.66 Tcf of natural gas as the feedstock for a 20-year operation. This quantity of supply can be secured from the existing shallow water gas fields. So, a fertilizer plant project can be started without waiting for the decision on the deepwater gas development projects.

c. In view of handy project size and fair economics, a complex of methanol based conventional chemical plants or a co-production plant of methanol, ammonia and fertilizer will also provide a good pilot project starting with the shallow water gas reserves. These plants may be consolidated for CAPEX/OPEX efficiencies, if appropriate, which could offer a considerable advantage over the case with independent plant construction.

d. From the points of economic viability and bankability, it is advisable that a certain portion of the products from these plants be exported at first in order to acquire foreign currency for loan repayment.

e. Fertilizer demand in Tanzania was only 0.26 million tonnes in 2010, or just a half of the government target for 2015. Once the local fertilizer production starts, some amount of fertilizer naturally becomes available for the domestic market to support modernization of agriculture, which in turn will accelerate the fertilizer consumption. However, methanol and the conventional chemicals will be exported at first, and will gradually be diverted to the domestic market as national consumption begins to form. If the domestic demand grows well, additional plant constructions can be considered.

4) Industry Development Plan

a. GTL and methanol based fuel/chemical industries are much smaller in size compared with LNG, but are expected to be the core projects to create an industrial platform and quality job opportunities as well as to increase foreign currency reserves making use of indigenous natural resources. By replacing imported petroleum products, they are expected to reduce foreign currency expenditure and contribute to stabilizing foreign exchange rate.

b. These industries require sophisticated technology, skilled workforce, assured supply of feed gas, and capital expenditure. In the cases of methanol based fuel and chemical industries, it is important to design a suitable combination and sequence of various downstream fuel/chemical plants. Therefore, it is necessary to deliberate more on the specific features of these industries and products, and align their development plans in good order. In the meantime, confirmation of an LNG project will establish a solid foundation for long term feed gas supply for these projects.

c. In this context, gas based industry development plans should be defined and established using the time before confirmation of the LNG project and deepwater gas field development.

5) National Aspiration

a. Construction of a natural gas supply system to the buildings and household sectors will upgrade people's quality of life as the national aspiration under the Vision 2025. The same city gas supply system will also provide a platform to develop CNG vehicle utilization, which will contribute to cleaner environment as well as to foreign currency savings.

b. However, construction of a city gas system will be expensive and time consuming. It is necessary to establish a reasonable project design and implementation schedule which are economically feasible and socially acceptable. As a first approach, therefore, a study should be conducted in relation to how best the gas fuels can be delivered nationwide and how such a system can be developed.

12.4.2 Project Implementation

Implementing the above gas projects calls for; a) willing investors, b) sufficient fund, and c) adequate demand for the products. In addition, fair and sound rules should be established on feed gas pricing, which defines how the upstream and downstream should share the risks and proceeds.

1) Investors

a. There should be willing investors as core promotors of a project with competence to mobilize suitable technology, quality workforce and necessary fund, and among others, to find customers. IOCs have already expressed their intention to participate in the LNG projects. With respect to other projects, however, present status is not as advanced. It is a key for project formation to solicit proactive investors in these projects.

b. If the Tanzanian government desires to participate in these projects, such intention and plan should be set out firmly to reduce uncertainty in project formulation.

2) Funding and Bankability

a. As the development of gas industries progresses, a huge amount of national revenue will be raised once their production starts. Before it occurs, however, a significant amount of upfront capital investment must be made. To this end, the project must be bankable in terms of the gas reserves, competent project promoters, stable product sales and foreign currency revenues for repayment of the loan. In particular, when national participation in LNG and other gas projects is considered, the necessary fund must be procured to bear the equity liability.

b. A huge, long term fund would not be readily available in the market; they may be sought from international financial institutions. Policies for placing funding requests to relevant institutions should be prepared for early actions.

3) Market

a. Every project needs healthy and stable demand that pays reasonable price for its products. Establishing a firm prospect of marketing is one of the most important jobs in the process of project formation. In the case of gas projects that require extensive investments and long lead time, marketing prospect must be established far ahead of the actual product shipment.

b. In many LNG projects, a considerable portion of the product is sold under long term contracts, as it is necessary to secure sufficient and stable LNG buyers to justify an investment decision. As LNG is a business of immense size, this activity takes time before certain firm contracts are obtained. Under the circumstance, it is necessary to establish an LNG marketing policy, marketing formation and commence relevant activities as soon as possible. Prior to embarking on this, a marketing system must be determined as to whether the project adopts a form of a joint marketing alliance or an individual equity lifting, after considering their pros and cons with clear definition of the roles and responsibilities of stakeholders.

c. Price vulnerability is always a difficult issue for project promoters. In particular, the recent energy price plunge in the international market could seriously impact the envisioned projects. Market price trend must be closely monitored.

d. Through communication with the market and potential buyers, a realistic timeline could be drawn reflecting the market responses. As the global LNG market is anticipated to be stagnant for the medium term, marketing may take longer time to find new demands. The project timeline should be reviewed and updated incorporating the market information and responses. It is desirable to prepare a contingency plan to cope with any unwelcome development.

4) Price of Feed Gas

a. Price of feed gas defines the distribution of the overall proceeds of a downstream project between the upstream and downstream, and decides their individual economics. A set of reasonable rules should be laid out at an early timing so that stakeholders can identify their project economics

b. As commodity price fluctuate constantly in the world market, it is desirable that the both sectors share the risks and gains in a fair and flexible manner. Eventually, their relationship is like that of husband and wife; both of them ought to be healthy and happy, and collaborate for the successful future.

12.4.3 Support for Project Implementation

1) Business Environment

a. Laws and regulations relating to the gas projects implementation must be prepared in the manner accommodating international investors and transactions. In support of the construction of principal industries being considered, the adoption of established international rules and practices is the fastest and surest way to implement good projects. To ensure this, mutual trust and transparency among stakeholders are most important.

b. During the construction stage, in addition to the national workforce, a considerable number of expatriates may need to be mobilized. Equipment and materials will also be imported. Administrative systems to accommodate these provisions must be prepared.

2) Supporting Services and Infrastructure

a. An LNG plant construction alone requires as many as 10,000 directly engaged workforces, as well as high quality technical services and supports, a heavily equipped supply base and a stockyard. There could be additional need for ancillary services. Preparations for these needs are to be organized virtually from scratch.

b. Infrastructure required for the gas industry development such as port, road, industrial water supply, etc., must also be constructed from scratch in Tanzania.

c. In line with the gas industry plan mentioned above, development plans for supporting services and infrastructure should be prepared with proper priority order and budget back-up for proper implementation.

3) Human Resource Development

a. Human resource is the main engine for the intended development. Plans for developing the basic knowledge and capacity as well as applied technologies should be realigned in accordance with the requirement arising from the gas industry development.

b. Construction stage of gas industries will provide the concerned workforce with good opportunities to learn and brush up knowledge and skills.

12.5 Master Plan and Road Map

Incorporating the foregoing discussion, we submit the draft for Natural Gas Utilization Master Plan and Road Map as follows:

It should be noted that this is a preliminary guideline to show the direction and priority of work plan to pave the way for a more definitive action plan. Certainty levels of various elements are still low to make final project decisions, including gas reserves estimation, gas field development plan, LNG marketing, gas field and plant construction costs, etc. Among others, the falling energy price is a great threat at the moment. Other basic conditions for future outlook such as economic outlook and industry development plans are not very firm. Certainty levels of these elements should be improved step by step through various researches, studies and business activities.

Under the circumstance, the following master plan should be periodically revised and updated based on new information and development.

12.5.1 Natural Gas Utilization Master Plan

1) Base Gas Resources for the Master Plan

This master plan lays out a schedule to consume the natural gas presently recognized in Tanzania in the coming three decades through 2045. The recoverable reserves of natural gas are currently estimated to be about 40 Tcf, which is being verified by a technical study. On the supply side, there will be additional gas discoveries in the coming decades through future exploration activities. On the demand side, there will be new developments in consumption trend and gas industry formation. The recent energy price decline may deteriorate the commercial viability of the deepwater gas fields. By reviewing these elements, this master plan should be periodically revised and updated.

2) Gas Supply for Domestic Demand

Priority will be given to the domestic gas demand for various sectors including thermal power generation. For the medium term, the domestic demand will remain small and can be supplied with the natural gas produced from the shallow water gas fields, which are small in size and are either already in production or to be developed quickly. However, as the domestic demand grows, additional gas supply from greater reserves in the deepwater fields will become necessary by around 2025-2030.

In principle, the domestic demand may be supplied with the shallow water gas, as well as through the domestic supply obligation of international oil companies and the TPDC's share of natural gas.

3) Core Project on the Demand side

Although LNG is the core project to provide the anchor demand for developing the deepwater gas fields, and at the same time the crucial project for the supply side, it is by far an expensive one. To secure gas sources to supply for the growing domestic demand, it will become necessary to develop the deepwater gas fields in time. To this end, this master plan aims to start production of deepwater gas fields and LNG simultaneously by 2025. To materialize this, extensive marketing efforts are necessary. As time is of essence, an LNG project implementing body should be established, with a clear definition of the commercial structure and the marketing formation, to commence marketing activities as soon as possible. Rules on feed gas pricing must be set out at an early timing. Or, in case the equity lifting method is selected, shareholders and the lifting rules should be set out at an early timing. Since its outcome impacts the master plan significantly, the progress of marketing activities or contract negotiation for the equity lifting system should be closely monitored and reflected in updating the master plan.

With the presently recognized gas resources, feed gas will be safely supplied to two LNG trains of 5 million tonnes per annum each. However, in this case, more than 40% of the natural gas will be left unused even after three decades from now. Therefore, construction of additional LNG trains should be considered to start by around 2030. At the same time, an optimum gas field development plan must be established to support such gas industry development plan.

4) Front Runner

A world class fertilizer plant or co-production plant of methanol, ammonia and fertilizer shall be constructed using the shallow water natural gas irrespective of the development timing of the LNG project. This project shall become a front runner to pave the way for constructing a modern gas industry in Tanzania, by providing various opportunities to prepare technical services, enriching capacity of construction contractors, and developing knowledge and skills of workforce, and so on.

Presently, the domestic fertilizer consumption is substantially falling behind the national target. Modern agriculture development plan should be formulated to consider future fertilizer demand including supplies to neighboring countries where fertilizer is supplied by imports. As the use of fertilizer becomes popular among farmers, additional plant constructions may be considered.

5) Development of Gas Industries

Gas based chemical industries as well as fuel industries will be the future key industries based on the domestic resources. Comprehensive gas industry development plans shall be formulated with specific design of the industry complex in consideration of their merits and roles. Once the LNG project is confirmed to give the green light for deepwater gas field development, gas sources for these industries are secured. Subsequently, gas industries shall be constructed in sequence following the comprehensive industry development plan.

6) Gas Delivery to Nations

City gas supply for large industrial users, commercial and public buildings and facilities, households and CNG vehicles are all considered to upgrade the quality of energy in terms of stability, convenience, cleanness, and economics. However, developing a city gas system is an expensive and time-consuming undertaking. In the situation where users are located along the existing pipeline system with sound economics, gas supply should be started as soon as possible. For other areas and sectors, experimental projects may be developed first. At the same time, a grand design for the future gas delivery network should be drafted. These plans should be implemented step by step as circumstances allow.

12.5.2 Road Map for Utilization of Natural Gas

The conceptual road map for implementation of the Master Plan is illustrated in Figure 12.5-1. It shows major actions and decision points in the course of achieving the goals of natural gas utilization. The final investment decision on an LNG project is the first key milestone. The timeline is just indicative as various elements are still in premature status, while it appears very tight even if everything goes on very smoothly. The timeline should be reviewed periodically by closely monitoring market trends and incorporating any new development in relevant matters.

. The implementation program may be divided into three stages. Stage-1 is the preparation period to kick-off gas utilization projects, in particular LNG. Stage-2 is the implementation period of the initial projects. Stage-3 is the period for further development of natural gas utilization.

To begin with, materialization of an LNG project should be sought extensively, while technical as well as economic studies on the deepwater gas fields must be simultaneously carried out. As time is of essence, an LNG project implementing body should be established as soon as possible with clear definition on roles and responsibilities of stakeholders. Rules on feed gas pricing should also be set forth at an early timing. The FEED on the upstream gas filed development and the LNG project should be conducted at an appropriate timing. Once a certain prospect is established on the LNG marketing and project economics, the final investment decision shall be made on the LNG project and on the deepwater gas field development. This process may take longer time than illustrated hereunder.

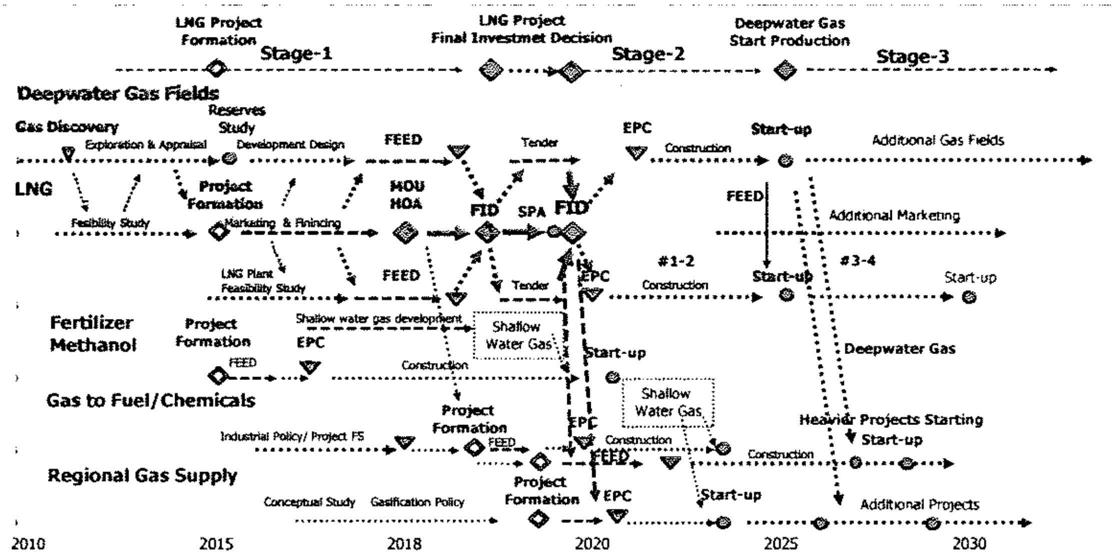

Figure 12.5-1 Road Map for Natural Gas Utilization Master Plan

Separately from the work flow on LNG and deepwater gas fields, a fertilizer project shall be started as a front runner to develop a modern chemical industry in Tanzania. Natural gas from shallow water fields will be used as feed gas for this project. To enable this, appraisal of shallow water gas prospects should be taken up immediately. Pending the decision on the deepwater gas field development, plans on other projects remain preliminary during Stage-1.

In Stage-2, the decision on the development of deepwater gas fields opens the way to use the vast gas reserves thereof and hence opportunities to pursue other gas projects. Construction of new gas projects will start and the gas based industry platform will gradually take shape. Tanzanian economy will move into a high growth era.

In Stage-3, upon production start of the deepwater gas fields, the ball starts rolling. Proceeds will start to flow to Tanzanian citizens. As natural gas supply platform is now in place, a natural gas era will flourish with expansion and/or new construction projects. While the milestone for this stage is set at 10 years from now, extensive efforts should be exerted to reach there in time in developing the industry base, supporting services, infrastructure and human resources. To implement this, Tanzanian citizens should expect a busy and exciting time ahead in next decades.

12.5.3 Way Forward

To implement the above master plan, immediate actions to be taken up should include the following:

Set up an LNG project implementing body, formulate an LNG project plan as well as marketing policy, and kick-off LNG marketing.

Compile an optimized gas field development plan incorporating all gas fields at hand. A comprehensive plan will provide a good guidance on how much natural gas will be available for future consumption.

Solicit investors for a fertilizer project and/or a co-production plant of methanol, ammonia and fertilizer, and firm up the project.

Conduct appraisal of shallow water prospects to secure feed gas for early projects.

Once certain prospects are established on the above issues, more definitive action plans should be formulated. Qualified projects shall be implemented one after another.

In the meantime, the following actions shall also be taken:

Study on a comprehensive plan for development of gas based fuel projects and chemical projects.

Study on gas delivery plans to various sectors of the economy.

Formulate infrastructure and human resource development plans to support promotion of natural gas utilization.

Since many elements are yet in premature status, this Study shows only the direction of the work plan. It is necessary to conduct more specific study on each project before the final investment decision-making. In this context, the Master Plan and Roadmap should be reviewed and updated periodically incorporating new and decisive information and related developments.

The Study Team sincerely hopes that the above draft will contribute to successful formulation of the Natural Gas Utilization Master Plan and Road Map in Tanzania.

JICA